Character Body Expression
in 3D Computer Animation:
a New Posing Approach

by

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Abstract

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Creation of 3D character animations is a complex and time-consuming process, and the character animator has to simultaneously consider a multitude of factors in order to create high quality expressive animation. The 12 Principles of Animation are traditionally considered as the main guidelines for creating high-grade character animation.

The main focus of this research is the process of animating the 3D character's body expression and the animator's practice, particularly the *Posing* phase of the animation process. Although *posing* is not one of the 12 Principles of Animation, it can be considered as the superposition of a subset of those principles that the animator has to keep in mind, while creating key-poses for any specific movement of an animated character. Additional factors that should be considered by the animator during the *Posing* stage are body language and acting, along with the technicalities of the 3D character manipulation. Hence, *Posing* is regarded as an intricate process, making it rather challenging for the animator to avoid involuntary neglect of the large number of the aforementioned characteristics. This aspect of the 3D animation process is extremely important for the final creative result of the animation, in terms of character's expression, because if the key-poses are not well defined, the computer may not be able to generate sufficiently expressive animation. This would often result in work that may be subjectively judged as lower quality animations.

This research developed the hypothesis that the key to create more expressive 3D character animation is located within *Posing*, in the Animation Blocking phase of

the process. This thesis proposes that a systematisation of the *Posing* procedure taking advantage of certain Traditional Animation, Fine Arts and Acting concepts and their underlying rationale, can greatly benefit the animator. This thesis presents a new posing approach to 3D character animation, as a conceptual guideline which promotes the arrangement of the body parts into naturalistic patterns of expression. This is achieved by combining the concepts of *Power Centre, Line of Action, Contrapposto* and *Serpentine Line* in a systematic way, around a conceptual flow of force. These comprehensible high-level concepts make *Posing* and the animation process less complicated and more accessible. This allows animators of different levels to create more believable character body expressions in an easier and less time-consuming fashion, introducing better methods of more efficient workflows resulting in improved creative results over shorter periods of time. It is also demonstrated how the aforementioned concepts can be applied to a variety of animation styles – ranging from the more realistic to the more cartoonish ones.

A prototype of a 3D Pose Tool was also developed, based on the rationale of the proposed approach, with the objective of being used as a visual guide for generation of new poses to be included in the case studies. Additionally, this tool produces visual evidence in the analysis of specific good and bad examples of character posing.

This thesis, therefore, makes the argument that the proposed solution – whether accompanied with the complementary 3D Pose Tool or not – gives the animator the possibility to work the character body expression as a whole. Thus, avoiding stiffness and ensuring that the essential steps of posing are not neglected in the process. This was demonstrated with several cases, which give evidence of the usefulness of the approach as a contribution to create more expressive character animation and to produce it in a more efficient way.

Table of Contents

List of Figures

List of Tables

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Declaration

This thesis has been created by myself and has not been submitted in any previous application for any degree. The work in this thesis has been undertaken by me, except where otherwise stated.

1   Introduction

> "You're not an animator just because you can move an object from point A to point B. (You're) someone who breathes life into a character, which is something the software and technology can't give you".
>
> **John Lasseter** (cited by Rauf and Vescia 2009, p. 24).

Animating is giving the illusion of life to something – a character or object – that has no life in reality. Therefore, the key issue of animation is in the way the animator breathes life into the character, as Lasseter put it in the quotation above.

In order to animate a believable character, the animator must consider the personality, emotions, motivations and intentions, so that he can create a particular body expression through postures, gestures and actions. The whole body must be involved because, for example, a person is not happy just in the face – the entire body conveys that state of mind. The art of character animation involves, therefore, the mastering of techniques, concepts and variables, including the technicalities of the animation software, to create expressive character animation.

Although 3D computer animation has evolved immensely, there are still challenging issues related with characters body expression which need to be overcome.

This research is, thus, motivated by some existing issues in character animation that need to abe addressed.

1.1   *Posing* issues

The process of creating the character's body expression in 3D animation for films is, essentially, achieved in the *posing* process – the creation of the key-poses, by

manipulating the character, and registering those poses using the *Key-framing* technique. To animate an action or attitude, the animator needs to imagine the corresponding movement and decompose it into its main key-poses, in order to finally create those poses, virtually, in a 3D software. Then, he sets keys in a timeline at the specific frames corresponding to the estimated time in the sequence for those poses to happen so that the software interpolates them, generating the poses that fill the in-between frames.

Although the 12 Principles of Animation (Thomas and Johnston 1995, pp. 47-69) are very important for character animation, they do not provide guidance on how to arrange the body parts into a pose. As discussed in section 2.2.1, *Posing* is not one of the 12 principles but an "uber-principle", which combines elements of those principles within it, as mentioned by Navone (2008). In fact, the *Posing* process involves a large number of variables, to be considered by the animator when animating a character: Story, Emotions, Motivations, Intentions, Actions, Line of Action, Acting, Personality, Posture, Attitudes, Power Centre, Timing, Rhythm, Weight, Asymmetry, Readability, Silhouette, Staging, Centre of Interest, Composition, etc. Having so many variables in mind is a very demanding task for the animator, as pointed out by animator Jason Ryan (cited by Beaulieu 2011, p. 42) and, thus, some of these variables may easily be neglected in the process of creating the poses, as discussed in section 2.6.1. Therefore, posing is the most critical stage of the animation process, by which the animator defines the character's behaviour and if the poses are not well defined the resulting animation generated by the computer will not be very expressive, as discussed in section 2.6.1.

There is still nowadays evidence – in movies and other media (see section 2.6.2) – of situations where the character looks stiff, mainly in the torso (and extending to the neck, in many cases), due to a deficient (or even absence of) manipulation of that part of the body. These issues have been addressed by many professional

animators, such as Bancroft (2012, p. 9), Baena (2008a), Jones and Oliff (2008), Navone (2008), Ranieri (cited by Jones and Oliff 2008, p. 158), Roberts (2007, pp. 121 and 232) and Meir (2003), as discussed in sections 2.6.1 and 2.6.2. There seems to be a tendency among animators to concentrate on animating gestures and, thus, on manipulating the limbs, as if the 3D character was a puppet or action figure, without considering the whole body when creating a pose. The stiffness issue is also linked to another recurring problem, which is the lack of expression of weight often revealed by 3D characters in the way they move (Webster 2012, p. 64; Balda 2008, p. 64), due to an incorrect weight distribution among the body parts, as discussed in section 2.6.2. Again, this has particular incidence on the torso and relates to the lack of whole body consideration, too. Paradoxically, character rigs usually have several controls for the torso, which does not help the animator to manipulate that part of the body easily and fast, thus, contributing to make the process very time-consuming and ineffective, too. In fact, the large number of controls of a 3D character rig – one for each moveable part of the body (and each control has at least nine keyable attributes) – can make the animator's task very daunting. This is especially true if he does not have a clear idea, at the beginning, of how the key-poses should look and how each body part is involved in the particular pose, i.e. how they should be manipulated in order to represent the intended expressive pose. Moreover, often the animator tends to focus more on those controls of the parts than on the body as a whole and on the intended expression to be conveyed. This kind of distraction needs to be avoided in the animation process.

The stiffness issue has been also addressed by some researchers in procedural animation, such as Huang and Pelachaud (2012), Van Welbergen et al. (2010) and Neff (2008), for example, as discussed in section 2.6.3.

One may argue that animators can avoid this stiffness issue and create expressive poses by relying on video reference alongo with classical animation principles. In

fact, the use of video reference by animators is common practice during the posing process, to help them improve the expression of the pose. However, this resource – although useful – is not always a guarantee of good results, as discussed in section 2.6.1.

The fact that these issues persist, as shown in sections 2.6.1 and 2.6.2, suggests that those solutions are not enough and might be necessary to adopt a different way of thinking the practice of posing. The results of an exploratory posing experiment (see appendix A.4.4) corroborate this need, too.

These issues affect the character's body expression, which does not look believable according to the given physical and psychological attributes of the character. Ultimately, these issues reflect a causal relationship with the arrangement of the body parts, which must be addressed when creating the poses.

1.2   Hypothesis

Considering the aformentioned issues, the following hypothesis is formulated:

Posing by using of a conceptual guideline, will help the animator to structure the pose, improving the body expression of the 3D character, and to make the animation process more efficient.

1.3   Research questions

The above stated hypothesis leads to the following questions:

- How can the Posture of the 3D character be structured in order to improve its body expression considering the concepts of *Power Centre, Line of Action*, *Contrapposto* and *Serpentine Line* in the animation process?

- Can these concepts aid bodily expression improvements in the animated character?

- How can the *Posing* process of the character in 3D computer animation be improved to make it more efficient for the animator?

- What procedures can be added to (or changed in) the *Posing* phase in order to help the animator to improve the body expression of a character in animation?

1.4 Research aim and objectives

The aim of this research is to investigate ways to improve the body expression of 3D computer animation characters and find a solution to help animators to create more expressive poses and in a more and efficient way. The focus is particularly on the *Posing* phase of the animation process, aiming to define a new approach to posing 3D characters. Additionally, it aims to design and develop a complementary pose tool – working as a plugin in an animation software – to give the animator a better and more efficient control of the *Posing* process, when animating a 3D character.

The ultimate goal is to contribute to knowledge on the process of animating the character's body expression in 3D computer animation.

To achieve this aim, the following research objectives are defined:

- To analyse and evaluate the current processes and techniques of *Posing* characters in 3D animation;

- To investigate body expression and its possible contributions to a new posing approach;

- To study and evaluate the potential contribution of some concepts related with 2D animation, fine arts and acting to improve the *Posing* task;

- To investigate new approaches or techniques to improve the *posing* process in 3D computer animation, which may allow the animator to create better body expressions of 3D characters and also make the task more efficient;

- To formulate a new posing approach and develop a tool to virtually embody the approach;

- To evaluate the results and refine the procedure and tool.

1.5   Research context and approach

Since the aim is to develop a new approach to the posing process of 3D character animation, this research focuses on the key-framing technique, which is essentially based on the pose-to-pose method of animation.

The analysis of that posing process involves the study of links between 2D animation concepts and how they can be applied to that phase of the 3D animation process and also the links between some Fine Arts and Acting concepts and how they can work, as a conceptual guide, in a new posing approach.

There are two important concepts to help the animator to define a character's posture: *Line of Action* and *Power Centre*.

Line of Action, mainly in the traditional animation context, is an imaginary line that helps to define the posture of a character's body, like a "line of force" that structures the main body to portray a particular expressive attitude. By using the *Line of Action*, an animator is able to create stronger poses.

Power Centre, which was coined by Hooks (2011), derives from acting and is relative to a character's source of energy. It can be very useful to the *posing* process of animation, by helping the animator to define which part of the character's body leads the movement or holds the pose.

This research also involves the study of other concepts related with Fine Arts, aiming to integrate and combine them with the other two, in order to develop a new approach to the *posing* process of 3D character animation. Such concepts are the *Contrapposto* and the *Serpentine line*. The first is about counterpoising the human body standing, often with the weight shifted on to one leg. The *serpentine line* is the imaginary line, usually with a shape of an "S", which is also twisted, and is used to structure the posture of a figure.

Although the focus is on the body as a whole, particular attention is paid to the axis that comprises *pelvis, shoulders* and *head*, as it influences the posture of the entire body and because it is often disregarded in 3D computer animation, which may be a reason for an eventual lack of expressiveness of some 3D animated characters.

Overall, the posing process involves not only animation specific principles and technicalities (including those related with the software and the manipulation of the character) but also intersects with body expression, which deals with other fields of knowledge, such as psychology and zoology. The animator has to consider all those variables of the pose when animating, in order to create a unique and appealing performance that reveals the character's feelings, emotions, choices and attitudes through the body expression he creates. Therefore, these are also considered in this research, being analysed from the perspective of their contribution (or possible) to a new posing process, according to the research objectives expressed in section 1.4. The researcher's experience as an animation lecturer and animator also informs this investigation, relying on the study and evaluation of practice and experience to build a critical framework. Besides the

review of the theories and techniques for the *Posing* phase of the animation process, the study also looks for objective descriptions and analysis of body expression, in a similar approach to that of Neff (2014), to see how different authors and artists consider the arrangement of the body parts to create a pose that is expressive of a particular meaning. Images of several pieces of art were analysed, with the purpose of finding out how the concepts suggested in the hypothesis can help animators to achieve a similar level of expressiveness in a 3D pose, if applied systematically during the posing process.

The research includes the formulation of a new approach to posing 3D characters and the development of a 3D Pose Tool based on it, which are evidenced through pertinent case studies and evaluated through a self reflective address of personal practice and application.

1.6   Contributions

This thesis presents a new approach to posing 3D characters, based on a systematic combination of the concepts of *Power Centre, Line of Action*, *Contrapposto* and *Serpentine Line*, to guide the animator during the process of creating the poses, allowing him to overcome the aforementioned issues.

Additionally, a prototype of a 3D Pose Tool is also presented, to provide visual guidance and feedback while giving full control to the animator over its manipulation and of the resulting pose. This way the artistic skills are not removed from the animation process, because Animation – and character expression in particular – is much more than the mechanics of motion, as pointed out by Lasseter's quotation, at the beginning of this chapter.

A demonstration of the advantages of using the proposed approach to avoid stiffness and achieve more expressive poses is also presented, as well as a suggested workflow to take full advantage of the approach.

1.7 Outline of the thesis

In chapter 2 the theoretical and practical frameworks are described, firstly in general and then specifically in the 3D arena. An extensive literature and video review is undertaken about character's body expression and the posing process, analysing the process of creating a pose in 3D animation and in other arts, such as Sculpture, Painting, Drawing, Acting and Dance. Some problems of body expression in 3D characters are analysed, as well as the research done up to now on the topic.

The research methodology is discussed in chapter 3, explaining the reasons for the chosen steps designed to accomplish the aim and prove the hypothesis.

Chapter 4 formulates a new posing approach, elaborating on the underlying rationale and concepts, explaining its virtues and discussing how it may improve the 3D character body expression. A workflow for the approach is also suggested, in order to make it more efficient.

Chapter 5 describes the development process of a 3D Pose Tool based on the proposed approach, which was integrated into a 3D animation software (Autodesk Maya), attached to the character's rig. This tool was used in the demonstration of the approach applications, and also in the approach evaluation through a posing experiment.

Chapter 6 demonstrates the application of the approach, including its complementary 3D pose tool, and discusses its usefulness, through the simulation of some famous sculptured poses as well as showing how the proposed approach can improve problematic poses, in a variety of cases.

The conclusions of this research are drawn in chapter 7, discussing lessons learned in the process, synthesizing implications and contributions, and suggesting future work.

2 Background

Body expression relates with many disciplines, such as nonverbal communication – or body language, to be more specific – in the field of psychology, and anatomy, in the field of zoology, which is a branch of biology, being investigated mainly by behavioural and neuroscience research. Its visual representation intersects with arts such as acting, dance, fine arts and character animation, being essential to the expressiveness of the animated character's performance.

Here, the challenge is to keep the scope of the body expression discussion within the perspective of computer animation, considering its contribution, as well as that of those intersecting arts, to the posing process and to the quality of characters' poses. Therefore, in this chapter, body expression and its implications to the pose are summarised in section 2.1, followed by the description of the posing process in character animation, and the discussion about the expressive qualities of a pose, in section 2.2. Section 2.3 presents the concepts that may contribute to improve the posing process in 3D computer animation, and section 2.4 extends the research to other arts where the expressiveness of the pose is preponderant, too. The importance of anatomy knowledge to the creation of expressive poses is convened in section 2.5. Section 2.6 centres the discussion about body expression and posing in the realm of 3D computer animation, describing the specifics of the posing practice, the evidence of problems affecting character's expression, and the research related with 3D character expression involving the pose.

2.1 Characters Body Expression

"Represent your figures in such action as may be fitted to express what purpose in their minds; otherwise your art will not be good."

Leonardo da Vinci (Richter 2008, p. 169)

Character animation is about representing characters – whatever their design and appearance – in such a way that they look like being alive. To achieve that, the animator must do it the similar way as Da Vinci recommended for painting, except that in this case not only for one image but for all the images needed to produce each sequence of action. Generally, any sequence of action of a character for an animated film is created with a sequence of poses describing each fraction of the movement, which is registered in a sequence of frames, at the conventional frame rate for the medium in which it is going to be exhibited.

Although many animation characters may not be humanlike – and in many cases they are not – they tend to be anthropomorphized as orthograde bipeds. As Delgaudio stated (cited by Wells 1998, p. 203) "anthropomorphic characters are a step removed from human characters and require a certain degree of imitation or impersonation of human traits in order to succeed". Stanchfield (2009, p. 206) was even more definite when he stated that "all cartoon characters, no matter how cartoony, are built on human traits or attributes". Therefore, it is very important to observe and study the movement and expression of the human body, so that it can be used as reference during the process of animating a character.

Humans express themselves using two different languages, as pointed out by Argyle and Trower (1979, p. 22): the verbal language and the body language. The first one, which can also be written, is used to communicate precise messages, for example, about facts and things. The other one "is often used quite unconsciously to express the truly human bits of ourselves – feelings, attitudes and personality"

(Argyle and Trower (1979, p. 22) and used in everyday relationships with other people.

2.1.1 Body Language

Body language is the expressive and meaningful use of facial expressions, body postures, gestures and other body motions, and its meaning can be inferred from the arrangements of the parts of the body and from its motion and direction. The expression of the body, for example the gesture, is an external response to a character's internal feelings, emotions and personality, which motivate the motion (Argyle and Trower 1979; Porter and Susman 2000; Su et al. 2005).

Research on emotion communication has been mainly focused on the face and voice, as pointed out by de Gelder (2009), "leaving the rest of the body relatively understudied" (Dael et al. 2012). However, according to many authors (Morris 2002; Coulson 2004; Mehrabian 2007; Beck 2007; Hooks 2011 and 2008) most of the non-verbal communication is conveyed through the body, not just through the face. Moreover, gestures and facial expressions are not enough, because, as stated by Aubert (2003, p. 9), "for the registration of an emotion to be complete, the body and all its members must cooperate", i.e. the body must act as a whole. This was also pointed out by Disney animators Thomas and Johnston (1995) stressing that "the expression must be captured throughout the whole body as well as in the face" (p. 443). They added that "any expression will be weakened greatly if it is limited only to the face, and it can be completely nullified if the body or shoulder attitude is in any way contradictory" (p. 444). Laban also stressed the importance of the whole body, saying that "each action of a particular part of the body has to be understood in relation to the whole which should always be affected, either by participating harmoniously or by deliberately counteracting or by pausing" (Laban and Ullmann 2011, p. 34). Even the creator of comic books Will Eisner (2008, p. 23) draws the attention to the importance of considering the whole body of a

character, stating that "confidence in the process of figurative manipulation comes from an understanding of the totality of the body, not only its individual parts". Corroborating this, Kleinsmith and Bianchi-Berthouze (2013) stated that "the body does indeed play an important role" in the expression and perception of affect, adding that "for some affective states in particular [such as afraid and angry expressions], more attention is paid to body expressions than facial expressions".

For many years it was assumed that body movement only indicates the intensity of the emotion but some studies have showed that body movement and posture also convey information that is specific to a particular emotion and is not provided by the face or the voice (Wallbott 1998; Coulson 2004; Dael et al. 2012). A bodily expression of emotion suggests a specific action associated with a particular emotion, as stated by de Gelder (2006), adding that in the case of fear the body posture provides information not just about the reaction but also about the cause of that emotion (what happened before). Moreover, "body posture is the influencing factor over the recognized emotion" (Kleinsmith and Bianchi-Berthouze 2013) when there is some incongruence between the expression displayed by both, the body and the face. This corroborates what Mehrabian (2007, p. 17) stated about the importance of posture to give consistency to the attitudes or feelings that are expressed verbally. Furthermore, according to Beck et al. (2012) "existing results on the perception of emotions have shown that it is possible to identify emotions looking at body language only".

Consequently, if an animated character has a good facial expression but the body is left stiff and poorly expressive, then the audience will probably get more of the poor expression, when watching it on the screen. As the professional animator and instructor Kelly (2013, p. 117) pointed out, people tend to see shapes first and, therefore, the body as a whole – the body language – is the first thing the audience will see. Only if they are given the chance – enough time or a close shot, for example – they will look at the details, like the elements of the face and its

expressions. Thus, since a good posture conveys emotion, the creation of the right body postures is crucial to character animation, whether for animated movies or for games, because it is very important that the character succeeds in conveying the right emotion to the viewers. Moreover, since it is the emotion that leads to the action, as stressed by Ed Hooks (2010), the expression of emotions is very important to justify the actions of a character and to achieve empathy with the audience. Although in what concerns animation for games, it should be said that most of the games production have not invested much on having characters expressing emotions. So far, they tend to insist on a dehumanization of the characters, even when in most cases they are human-like ones, making it easier for the players to deal with all the killing without regrets, as pointed out by Hooks (2013b) in his "Craft Notes".

As Walt Disney stated in a famous memo to Don Graham (reproduced in Culhane 1998, p. 124) and used to remind his animators, according to Stanchfield and Hahn (2009, p. 192), "in most instances, the driving force behind the action is the mood, the personality, the attitude of the character – or all three". The topic was addressed by Graham in his action analysis classes at Disney Studios, and continued to be discussed in those classes later by other teachers, like Walt Stanchfield, for example. The latter refers to the inner force or "the inner motivations that power a person's body to express body language" (Stanchfield and Hahn 2009, p. 385) i.e. what motivates the action in the pursuit of an objective. Understanding the objective and motivation of the character is essential for the animator to animate it in a believable way because this will determine the character action, as pointed out by Kundert-Gibbs and Kundert-Gibbs (2009, p. 152), referring to Stanislavski's acting technique. According to the transcription of one of Graham's classes (Graham 1937, p. 1), he called the attention to the fact that most animators used to animate forms instead of forces and it could be said that many animators still work that way, nowadays. In those times (using the traditional technique of drawing on paper) it could be understandable because

actually the animator had to draw the form of the character in each pose. However, in 3D computer animation the form is already there (virtually) and therefore, there is no reason for the animator to focus more on the form instead of the force. Of course, form is essential for the animation to be perceived by the audience but it must show the effect of the force acting through the body. Therefore, the animator should always conceive the animation – the poses – from the point of view of force, as stated by Graham, and the form would be dictated by that force.

The question is how shall this driving force be expressed? Force (or energy) cannot be seen, *per se,* but can be felt or visually perceived through the manifestation of its impact or effect on things. This is the case, for instance, of the force of the wind that forces the tree to bend; or the force that throws the body forward; or the force that fights the gravity and sustains the weight of the body, etc. Animation is essentially a visual art form and thus the animator must create – through poses – visual representations (more or less dynamic) of the character's force, that holds or drives the body, and/or of other forces interacting with him or affecting his performance. Thus, the arrangement of the body parts as a whole is essential to express vitality in a pose because, as Graham (1937, p. 7) stated, "it is the relationship of one force to another which gives the correlation of the whole". It produces a specific rhythm in the body shape, which is very important to express not just the motion but the personality, emotions and attitudes in a pose. Webster (2012, pp. 64-65) also refers to "energy flow" and how it is directed through the body of a figure in motion, affecting the arrangement of the body parts, in order to produce the tensions and stresses more appropriated for a specific action. According to him, the understanding of that flow of energy progressing through the body "will invariably make for more fluid motion and naturalistic animation". This concept of flow of energy is similar to that used in acting by Stanislavski or Laban, for example. Stanislavski (2008, p. 70) recommended that "at the foundation of plasticity of movement one must establish an inner flow of energy",

emphasizing its importance in producing the posture and building the character. Laban also considered flow very important to all movement expression, particularly what he called the successive flow, when one part of the body follows another (Newlove and Dalby 2004, p. 127). Therefore, when creating the pose(s) the animator must consider the above mentioned "inner motivations" or "driving force", which are distinctive of each character under a given situation, in order to determine how the flow of energy will influence the arrangement of the body parts.

There should not be two characters behaving the same way because, as with humans, "different people behave differently in the same situation" (Argyle and Trower 1979, p. 58), since their attitudes, actions or reactions depend on several factors: their personality, the situation and their mood in those circumstances. For theatrical purposes, as with animation for movies, the circumstances will involve an objective and an obstacle or conflict, which may be with other character, with his situation, or with himself (his believes, ethical values, etc.), as pointed by Hooks (2011, p. 19), and may affect his mood. The way the character will act in pursuit of his objective while overcoming (or not) the obstacle – as mentioned by Hooks (2011, p. 20) – will depend on his personality, his motivations and his ability to deal with the circumstances, i.e. his agency.

There is not just one way of giving the illusion of life, otherwise all the animated characters would have the same personality and behave the same way, as Hooks (2013a) stressed in his "Craft Notes", about the artists that make feature animation. Animators play the vital role in the making of animated films, creating unique characters' performance, which is "the heart of the matter", as stated by animator and director Brad Bird (Hooks 2011, p. xi). Shamefully, still nowadays the animated characters' credits are associated with the actors who gave them the voice instead of the artists who gave them life, as if the voice was more important than a unique illusion of life, through an appealing body expression of each

character, created by animators. This may be led by the say that "a good voice actor can create 50 percent of the animated performance" (Beiman 2010, p. 26) and some may argue that in many cases the actors are filmed while their voices are being recorded, in order to capture the facial expressions and some mannerisms that will be used as reference by the animators, later. Indeed, that may be useful for facial animation in scenes with dialogues, or may even be useless in some cases, due to poor performance, as noted by Bird (Hooks 2011, p. X). Besides, the character´s performance is not just about facial expression but about the whole body expression and in fact those actors are not really acting the character when they stand up in front of the microphone to record their voices, because they are restricting their movements so that they do not move off-mike, as pointed out by Hooks (2011, p. 55).

Rango is probably the only animated film, so far, that has appropriately shown the actors' names associated with the characters, because they did in fact act the scenes – interacting with each other and with the props – which were recorded to serve as reference for the animators to recreate the performances with the digital characters, as Johnny Depp refers in a *Making of Rango* interview (Johnny Depp: Rango […] 2011, 2:04). That kind of interaction with the other(s) is important to prompt the interpersonal attitudes (Argyle 1996, pp. 67, 178-180, 208-210), which reveal much of the character's personality and behaviour (Argyle 1996, pp. 212-213; Alberts 1997, pp. 97-100).

The expression of an animated character depends not only on the pose – the form of the body, its size and, mainly, the way the body parts are arranged – but also on the way the body moves from one pose to next one. As Arnheim (1996, p. 142) stated, the "beauty [of body expression] does not depend on shape as such but on the dynamic expression conveyed by it". For example, the "simple" expression of weight of a character is accomplished by the way the weight distribution of the body is represented in a pose and by the way it is animated along a sequence of

poses, not just in terms of form of the body (and its resulting shape) but also in terms of *timing* – duration, speed and its variation – of the movement. This *timing* principle of animation (Thomas and Johnston 1995, pp. 64-65) gives meaning to movement, as pointed out by Lasseter (1987), and helps to define the weight (whether heavy or light mass) of the character's body, by showing, kinetically, the expression of effort required to sustain and move it.

Both, the pose and the timing, are fundamental to create expressive animated characters and they must complement each other in a coherent way. The timing is only good when it is coherent with the character's poses, with his personality and with the situation he is dealing with; and the pose needs to be coherent with the timing, as well, since a good pose also suggests a certain motion and speed, when representing a dynamic action. The pose itself is also affected by the character's body, his personality and the situation. Therefore, each character should have his own postures and his own way of moving, with his own rhythm, according to his physical characteristics, psychological traits and emotional state, as pointed out by the animation director Brad Bird, when referring the need to create "specific movement" for different characters, cited and corroborated by Hayes and Webster (2013, p. 107).

2.1.2   Interpretation and visual representation of body expression

People tend to relate or identify what they see with what they know, in terms of shape and form, and to perceive the expression of the visual stimulus according to what they learned, whether from their own experience or because they believe in what they were told of, as mentioned by Berger (1972, p. 8). The influence of the past experience to the way people interpret what they see when they perceive a relation between the shape of the present object and that of the past is also referred by Arnheim (2004, p. 48). Furthermore, he states (Arnheim 2004, p. 448) that there is no "intrinsic kinship between perceived appearance and the

expression conveyed" and, therefore, "one has to learn which expression goes with which state of mind".

The perception of that kind of relation happens with any mediated image as well, like in cinema, for instance, and that is what makes people (the audience) able to recognize the expression of the feelings/emotions of the character. Furthermore, by perceiving the stimulus and projecting previously experienced feelings on to the sight, they are able to feel empathy with the character and his situation.

Getting the correct interpretation or the right meaning of a posture or gesture is not easy and requires attentive observation. Pease and Pease (2004, p. 20) establish "three rules for accurate reading" of body language, stating, in the first, that for a correct interpretation one must "read the gestures in clusters" (p. 21), considering not just one gesture but other gestures that occur at the same time. Navarro and Karlins (2008, p. 83) also refer to the need to look for "multiple tells (tell clusters) that point to the same behavioral conclusion" to make it more likely to be correct. Recent research on emotion expression, such as the one conducted by Dael et al. (2012), show that some emotions are even portrayed through several patterns of body movement, i.e. use body movements of more than one cluster, which allow emotion differentiation. Moreover, the observer must also look for congruence, by checking if the body language matches with the verbal language, and read the gestures in the context in which they occur, as stated by Pease and Pease (2004, p. 23). The context is also emphasized by others such as Argyle (1996, pp. 22 and 134) or Alberts (1997), who states that "context gives meaning to physical behavior" (p. 2), adding that "the meaning of a movement is determined by what is done, how it is done, and in what context it is done" (p. 9).

Naturally, all these considerations are also relevant for animation, and particularly the context variable is considered important to ensure that the audience makes the correct interpretation of the character's body expression, as pointed out by Buisine et al (2014). As exemplified by Thomas and Johnston (1995, p. 18), "If in

animation we are trying to show that a character is sad, we droop the shoulders, slump the body, drop the head, add a long face, and drag the feet" but the same posture may also mean that "the character is tired, or discouraged or even listless". Therefore, context must be obviously taken into account when creating the characters' body expression because it will affect the way the character behaves and will also determine the way the audience interprets his expression. The information about what happened in the previous scene and what the character intends to do next is also important for the animator to create the correct expression, as stressed by Hooks (2011, p. 24) when he says that a scene begins in the middle. For that reason Beiman (2010) stresses the importance of story context – which "can be the character's mental state, a relationship between two characters, or the interaction of a character and an object" (p. 20) – to the creation of expressive poses.

Assessing the quality of body expression is a demanding task as it includes many variables, not just in terms of body configurations but also in terms of their movements, involving force, velocity, direction, directness, among others. In affective studies, the quality of body expressions is usually assessed through the degree of "correlation between the emotion intended by the acting subjects, and the emotion perceived by the observers" (Silva and Bianchi-Barthouze 2004), with the ultimate goal to create expressive computer generated characters, procedurally synthesizing meaningful movements and attitudes. Several methods, including the Effort-Shape analysis (Chi et al. 2000) based on Laban Movement Analysis, and coding systems like BAP (Body Action and Posture) by Dael et al. (2012), have been used to accomplish the objective of building a comprehensive description of the effects of emotion on body movements, as described by Gross et al. (2010). The latter adds that such objective has been virtually impossible to accomplish because they have used different coding schemes.

Keeping that kind of correlation is also a challenge to the character animator. For instance, animation students are commonly advised not to leave the character still at any time – there must be always something moving in the character's body, even if just the movement of the eyelids or the thorax simulating the breathing, etc. – because if there is no movement the character will not look alive. However, those subtle movements are usually not enough to express emotions or mood, or to tell a story, and the whole body must be worked, portraying the body movements and gestures needed to communicate meaningfully, as discussed before. The movements and gestures must be animated to achieve a specific purpose in terms of expression, as Stanislavski (2008) warns when saying that "in acting no gesture must be made merely for the gesture's sake" (p. 45), adding that "movements must always have a purpose and be connected with the content" of the character's role. Therefore, the animator has to think about the intended expression and then create the pose with the corresponding body configuration in order that the audience can perceive and recognize that expression. By analogy with the rationale expressed by Stanchfield (Stanchfield and Hahn 2009, p. 161), creating a pose in animation is translating an action into a visual form so that an audience can retranslate the pose(s) back into an experience of that action.

The visual form of a work of art is not arbitrary, but rather indispensable for a precise interpretation of what the work is meant to express, as stated by Arnheim (2004, p. 460). Likewise, the visual form of a pose is essential to the correct representation and subsequent interpretation of the animated body expression. Moreover, the representation of the character's body – even if just the shape – is very important to help with his characterization (Hayes and Webster 2013, pp. 76-78) and is indispensable to the character's *appeal* (Thomas and Johnston 1995, pp. 68-69; Lasseter 1987). Furthermore, it is particularly critical when the character's personality, emotions and expressions are intended to be conveyed mostly through his body language and the actions carried out by his performance.

In order to communicate effectively in that way, the animation depends on those qualities of recognition of the performed body expression, on being identified by an audience as something they know (mainly from experience) and can relate to, so that they can get involved with the story. This fits mainly in the *representation* category of movement, referred by Webster (2012, p. 33), when the aim is to animate believable creatures or things, whether they exist (or no longer exist), or are the product of our imagination. That is achieved by representing movements that seem real or believed to be true, allowing the audience to be convinced by the similarity to what they know and have experienced (which applies not just to motion and dynamics but also to acting). Wells (1998, pp. 25-26) considers this correspondence to "the orthodox physical aspects of human beings and creatures in the 'real' world" as one of the "key codes" of what he designates as the "hyper-realist style" of animation. This is "the kind of animation which aspires to the creation of a realistic image system which echoes the 'realism' of live-action film" (Wells, 1998, p. 25), moving into "a realism which is simultaneously realistic but beyond the orthodoxies of realism" (p. 27). According to the same author, Disney animation, and particularly the feature films (like Bambi), are the example of hyper-realist animation because their work "is neither a completely accurate version of the real world nor a radical vindication of the [freedom of the] animated form" (Wells 1998, p. 27). Moreover, he proposes to use the Disney films as "the yardstick by which other kinds of animation may be measured for its relative degree of realism" (Wells 1998, p. 25). It should be noted that Disney's "official" position on this realism issue is that their animation is not focused on realism but on getting the "caricature of realism", as stated by Thomas and Johnston (1995, pp. 53, 62, 65-66) and echoed by many Disney animators.

Independently of any category, this relationship between the essential expressive qualities that characterize a human, an animal or a thing existing in nature and its representation through a virtual character embodiment and performance – naturalistic expression – is essential to create the correct body expression and to

ensure that the audience interprets it correctly. As Pierce and Pierce (2002, p. 121) state, "the word *natural* has come to refer often the authenticity of the relationship between this essential [quality of a person or a thing] and the "material" that embodies it". Similarly, Lecoq (2009, p. 105) says that:

> "we must never lose our grasp on the essential thing, that is to say the motors of play which arise from the natural dynamics of human relations and which audience recognise immediately. The dynamics I refer to are the shared references which are indispensable for both actors and spectators".

Furthermore, as Wells (2009) points out, people interpret body language instinctively and, therefore, "an animator must recreate the instinctive nature of the body because an audience will immediately spot if the animation does not ring true and characters seem unpersuasive" (p. 57).

Disney, of course, realised long ago that in order for the animation to be convincing it should be based on nature. The idea is clearly expressed in his memo to Don Graham, discussing a plan to train the animators:

> "The point must be made clear to the men that our study of the actual [motion] is not so that we may be able to accomplish the actual, but so that we may have a basis upon which to go into the fantastic, the unreal, the imaginative – and yet to let it have a foundation of fact, in order that it may more richly possess sincerity and contact with the public".
>
> **Walt Disney**, 1935 (Culhane 1998, p. 119).

As Williams (2001, p. 34) states "what we want to achieve isn't realism, it's *believability*", adding that in order to achieve believability in the character's expression and in his movements, the animator must depart from reality – real actions and expressions. He must work the masses of the body in a natural way to arrange the intended poses and use his imagination to further the creation of distinctive expressions and performances that are (or may go) beyond reality, like the Tex Avery cartoon animation, for example. Jones and Oliff (2008, p. 179) corroborate Williams by saying that "cartoony animation is all based on real-life

motion". Believability is indeed very important for character animation (and for all forms of storytelling), as pointed out by Hayes and Webster (2013, p. 20).

The mutability of the characters' body and of their environments, so distinctive of experimental or cartoon-like animation, as discussed by Wells (2002), with a freedom of form representation of the characters' body, as if the form of the body was free from the constrains of the skeleton – which may look more or less unnatural – may rise the question of the utility of the naturalistic aesthetics to character animation. However, even cartoon-like characters with *rubber hose* kind of limbs – loose limbs without articulations – or "'rope' designs", as mentioned by Wells (2002, p. 39), which animation is ruled by the so called "cartoon laws of motion" (O'Donnell 1980; Hayes and Webster 2013, p. 4) instead of moving according to the natural laws of physics, may be accepted and identified by the audience "as long as they possess the minimal requirements for recognition (…) [and] it provides a logic" (Hayes and Webster 2013, p. 4). In line with this, Roy (2014, pp. 244-5) considers cartoony animation as "impressionistic animation", where the animator puts the character's body behaving and resembling other visuals, "always referencing real-world things" and, therefore, he states that "cartoony animation is the result of getting the audience to see familiar dynamics within the character's performance". So, there must be a minimum reference in terms of pattern of body expression, in order for the audience to be able to recognize and establish the connection with the referent.

Bodily configurations, as arrangements of the body parts into visual patterns of expression are, therefore, important to the recognition of body expressions, as discussed by Arnheim (2004, p. 449).

The torso (or trunk), as the main part of the human body – from the pelvis up to the shoulders – is an important contributor to the general body posture, as it may keep the body upright or make it look sag or slump (Morris 2002, p. 165), for example. Michelangelo considered, according to Hugo Chapman (2010), that the

"torso was the key expressive area of the body. It was there that the movement and torsion of the figure was conveyed through the alignment of the shoulders and the hips" (p. 24). The importance of the torso to the expression of the body is also stressed by Laban (Laban and Ullmann 2011, p. 52), saying that "the trunk can follow, counteract or replace gestures of the limbs, particularly those of the arms". Furthermore, Pierce and Pierce (2002, p. 78) state that "the shoulder girdle, including arms and hands, is used for delicate and discriminating action; the pelvic girdle, including legs and feet, is used for power". In fact, the trunk movements may discriminate between positive or negative expressions of emotions, with "stretching movements predicting joy, sympathy, surprise, and interest, and bowing predicting fear, grief, shame, and anger" according to Gross et al. (2010, citing de Meijer 1989) and Aubert (2003, p. 33). There is also the leaning towards when liking (Argyle 1996, p. 209; Mehrabian 2007, p. 19), or against (in avoidance) when feeling fear or disagreeing (Navarro and Karlins 2008, pp. 31-2); the twisting or turning away for withdrawal (Mehrabian 2007, p. 19); the straight or slightly backwards for proud, confident or high status (Argyle and Trower 1979, p. 15). Bowing the torso and head may also occur when expressing low status (Argyle 1996, p. 61; Alberts 1997, p. 103), respect (Aubert 2003, p. 28), or submissive behaviour (Argyle 1996, p. 208; Morris 2002, p. 216).

In the top of the torso, the shoulders are also determinant elements in body expression. From the simple and momentary one shoulder shrug or the complex full shrug (a compound gesture, involving also the hands, the head, mouth and eyebrows (Morris 2002, p. 61)) to the raising shoulders that express tension or lack of confidence, for example (Aubert 2003, p. 38). According to Aubert (p. 7), "all expressions of intense emotion impel the raising of the shoulders". The position of the shoulders and head (and not just the face) is important to create spontaneous expressions, even when the intended ones are just smiles (Valstar 2007). A good example of the importance of those parts is given by Johnstone (1999), when he suggests: "expose the top teeth and grin, biting your bottom lip.

Now push your head forward and giggle - who is this submissive creature? (Notice how the back of the neck wants to shorten and how the shoulders want to rise.)" (p. 276). Roberts (2011, p. 100) also stresses the importance of the shoulders to character animation, saying that "much of the character and mood of a person is conveyed by the positions of the shoulders".

In summary, human body language and its interpretation and representation are essential for character animation, since characters are often anthropomorphised as orthograde bipeds. Therefore, animators need to have a deep understanding of body language and of its perception and interpretation by the audience, in order to represent well the character's body expression (his body configuration) and ensure that the audience will get the correct interpretation from every posture. Posture and pose are commonly used as synonyms of human position, meaning the mood or intention expressed through the body. Posture is an expression of the body, either interacting or not, and tends to be more spontaneous, while a pose is more driven by aesthetic purposes. Animation has this affinity with the artistic dimension associated with the creation of body expression but at the same time aims to look spontaneous, natural and believable. The pose and its creation, within the context of character animation, are discussed in the next section.

2.2   Posing a character

Posing is referred here as the process of creating poses and not as a method to animate, like the *pose-to-pose* animation principle (Thomas and Johnston 1995, pp. 56-58) – it is a phase of that method or any other method using key-poses to generate animation.

In animation for film, the creation of the character's postures or attitudes is defined by the key-poses created by the animator, unless the motion is obtained by Motion Capture systems. He has to imagine the movement of the character

that better expresses the action or attitude and then decompose that movement into the main poses that define it, in order to finally create those poses.

The pose is, therefore, the primordial element to character animation, especially the key-pose or "golden drawing", as Ollie Johnston used to call it, according to Glen Keane (Frank and Ollie 1995), which defines the posture, attitude, mood and personality of a character. It is also called the "storytelling drawing" by the animator and director Richard Williams (2001, p. 57), explaining that is "the drawing or drawings that show what's happening in a shot" – the same kind of drawing as required in a storyboard or a comic strip to illustrate what happens.

The creation of such a pose that best expresses an action is very important to any visual art and has always been a concern for the artist, as can be noticed, for example, in Leonardo da Vinci's advice (Richter 2008, p. 169) cited on page 11. In most cases, that best pose is the one representing the beginning or the end, as advised by the illustrator and art instructor Loomis (1971, p. 103) stating that "usually the action can be best expressed if you use the start or finish of the sweep". The artist and instructor Hale (2009, p. 111) corroborates that idea, by saying that the artist has to decide which phase of the motion he will seize, in order to create the best representation, adding that "an action is best drawn at its beginning or its end, not at the midpoint" (p. 120). His explanation is that "most action has a repetitive quality and there is a moment of rest at the beginning and end of the action. These moments of rest are the phases that are drawn, as they are usually most suggestive of the action" (p. 111). As an example, he refers to the woodsman raising the axe or burying it in the wood, and another example can be seen in Figure 56 – Bill throwing the knife. However, as Loomis (1971, p. 103) also noted, sometimes the pose representing the middle of the action expresses it better, like for example the diver in mid-air or a building collapsing.

Although these recommendations are made in a drawing context, the animator, as an artist, will also profit from following them. The usefulness of the representation

of those moments of rest is particularly evident when the action is very fast or involves a fast movement of one part of the body. The initial phase of preparation for the action, which in animation is called anticipation (Thomas and Johnston 1995, p. 51), and that reaches a motionless moment before releasing the force, is usually a very suggestive pose of what is about to happen. Likewise, there is no doubt that the pose representing the end moment of an action describes well what has just happened.

Ultimately, as in any creative activity, it is up to the artist to seize that fundamental pose – the golden pose – representing either a repetitive or a continuous action and, although the animator has several frames to describe a movement, there are always one or more key-poses that determine the entire sequence and must be created first.

Figure 1 shows an example of three golden poses, or key-poses, for a shot telling the story of a character walking to a board, picking a piece of chalk from the floor and then starting to write on the board.
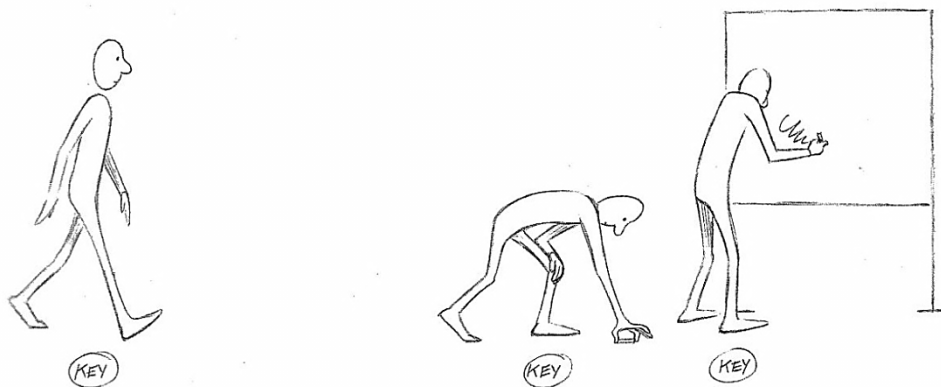
Figure 1 – Golden Poses or Key-Poses, by Williams (2001, p. 58).

Besides illustrating the action, these golden poses of this stylized character also give some hints about gender, age and mood. Probably it is an old man, since a

woman usually does not bend down like that to pick an object from the floor and a young man usually does not feel the need to use the hand on the knee to help supporting the body, when bending down. The posture of the character writing, with the head sunk on the torso and the legs bent, make it look a bit tense, like stressed or shy/insecure.

However, in order to animate that particular action, more poses must be added, as secondary poses (since they are dependent of the golden poses), usually referred to as extremes and breakdowns, as shown in Figure 2, below.
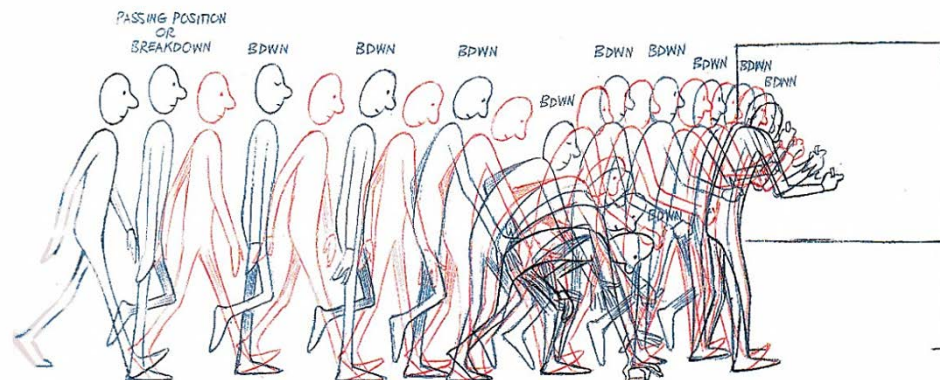
Figure 2 – Key-poses plus extremes (red) and breakdowns (blue), by Williams (2001, p. 65).

Those are all poses that must be created by the animator and registered by setting keys in a timeline at specific frames – the keyframes – corresponding to the estimated time in the sequence for those poses to appear, in order for the 3D software to generate the in-betweens and produce a specific motion.

In the language of animation, with its roots in traditional animation, the poses or drawings are commonly classified, in order of importance, as Keys, Extremes, Breakdowns (or Passing Positions) and In-betweens (Williams 2001, pp. 47-60). However, the name "Key" may be a bit confusing when discussing the computer animation workflow, since, as explained above, the process of registering a pose is done by setting a *key* on the selected control(s) attribute(s) at a specific frame in

the timeline – keyframes – which, ultimately, makes all of them being marked as *keys*. For that reason, in this thesis the poses that are considered keys are mentioned as *key-poses* or *golden poses* as opposed to *keyframes* in the animation software, to avoid any misunderstanding. The extremes are the main poses after the golden pose(s) and mark the extreme positions, or the contacts, or changes of direction in a movement; and the choice on which frame to place an extreme is determined by the estimated duration of the fragment of movement – and when exactly that pose must happen. As shown in the example above, the golden poses are also extremes but not all extremes are golden poses. The breakdown is a position between a key-pose and an extreme or between two extremes that defines the transition between them, in terms of shape and/or space variation, working as a reference to guide the creation of the in-betweens. The choice on which frame to place a breakdown is a matter of timing – of when exactly the transition between poses must happen – and, therefore, it may be closer to one extreme or the other, in terms of time (number of frames), position in space and shape variation of the pose. There may be additional breakdowns between a main breakdown and a key-pose/extreme if necessary to break the movement down into smaller bits, as recommended by Williams (2001, p. 221). The number of in-betweens depends on the number of frames between key-poses/extremes and breakdowns (how close in time they are supposed to be) but the variation of the corresponding poses, in terms of shape (more similar to the previous or to the following one) and place in space (closer to the previous or the following one), combined, are essential to determine the expression of acceleration or deceleration of the movement – Slow In and Slow Out principle (Thomas and Johnston 1995, p. 62; Lasseter 1987).

In spite of the hierarchy of dependency described above, all the poses of a movement are important, as pointed out by Chuck Jones in 1969, in an interview to Michael Barrier and Bill Spicer (cited by Furniss 2005, p. 21), stating that "great animation depends as much on the character and placement of the in-betweens as

on the primary drawings". Although the breakdown poses are dependent of the golden pose(s) and of the extremes, they have also an important contribution to the expression of the animated motion, because they help to define the characteristics of a particular movement. As Arril Johnson puts it (cited by Wells 2006, p. 93), "a breakdown often determines the flavour of the finished action more than any other drawing because […] breakdowns show how the character moves to get from one key-pose to the next". The same idea is conveyed by the animator Eric Goldberg (2008, p. 114) who says that "if the key poses are *what* the character is doing, then the breakdowns are *how* the character does it" and also that they add "juice" to the action (p. 209). Williams (2001, pp. 111-115, 218-225) also illustrates extensively the importance of the breakdown to define the action of a character, emphasizing it by saying "it's the secret of animation" (p. 218). A single breakdown can change the performance of a character (his behaviour) in an action, as Goldberg (2008) demonstrates on pages 113 to 114. In fact, sometimes a breakdown may even be a golden pose, in situations where actions are better represented by its middle moment, showing the transition between extreme poses, like the examples referred by Loomis (1971, p. 103), as discussed on page 27, or in a peculiar walk, for instance. To animate a walk, the animator needs two extreme poses (contact to the ground), one main breakdown (passing position between the extremes) and two additional breakdowns between the main one and the extremes (mainly to define the position forward of the knee and of the heel/foot going up). However, usually just one golden pose is needed to describe the walking action and the expression of the character (attitude, mood, personality), and in many cases that golden pose is a breakdown.

Although the golden poses alone are not enough to show exactly how the character moves – the acting – they may tell a lot about the personality, the mood and attitude of the character during the intended action.

2.2.1   What makes a good pose?

The expressive quality of the pose has been object of discussion by many animation practitioners. Gilbert (1999, p. 11) asks that question and gives the answer, saying that "a good pose is one that clearly describe the action and acting that you wish to convey" and "must describe the forces that have influence over the character". Goldberg (2008) considers that the right pose is the one that "communicates the idea of the character's emotions" (p. 208) in a way that is "interesting, unexpected and unique to the character". According to Maestri (2006), a good pose should have a strong silhouette and "a definite line of action" (p. 148). The silhouette is the most common and frequently used test of the readability of a pose, when animating, in order to guarantee that the audience will perceive the action, because humans perceive the shapes first and then the form and other details. Basically, the test is made by turning the camera view of the pose into a contrasting shape, produced by the outline of the character's body filled in black – the silhouette – and checking if it can be clearly understood that way. This does not mean that every pose must be subjugated to that test – the dictatorship of the silhouette – but it is important to make sure that at least the key-poses are checked.

However, a good silhouette depends not just on the perspective from where the character is seen or the way he is placed in the scene – the *staging* principle of animation (Thomas and Johnston 1995, p. 53; Lasseter 1987) – but essentially on the way the body parts are arranged into a meaningful pose. Those parts must be organized in terms of weight distribution because, as Loomis (1971, p. 38) stated, "all figure action should be based on a distribution of the weight of the body", keeping the body balanced or unbalanced, according to the intended action. The importance of balance to the animated character was already noted many years ago (1935) by Walt Disney in a memo to Don Graham (Culhane 1998, pp. 117-127), stating that "if you don't have that balance of the body, then your expressions are

wrong, insincere, unconvincing" (p. 126). The expression of weight has been focused by many animation authors and Williams (2001, pp. 256-271), for example, discusses extensively the importance of its expression at any given moment. In fact, one of the tasks of the animator is to harmonize the forces involved in a pose, according to its nature – whether a static and relaxed or a dynamic one: the force of gravity, pulling the body down; the force of the muscles, fighting against the gravity, to keep the body in a particular position and organised in a balanced or unbalanced way. Furthermore, the pose must also be organized in terms of orientation and inclination, according to the thrust that the emotions and its corresponding actions might involve, as pointed out by Hale (2009, p. 111), stressing that "A consideration of thrust must always be in the mind of the artist when he draws" (p. 112). The animator and animation teacher Walt Stanchfield (2009, pp. 79-80) also stresses the importance of expression of thrust of the action, and suggests that a good pose is the one that describes the action, establishing a clear centre of interest that features the primary action, i.e. what is important – key – in the action.

Lasseter (1987) states that "In creating an appealing pose for a character, one thing to avoid is called "twins", where both arms and both legs are in the same position" adding that each part of the body should vary in some way from its corresponding part, to make the character look more natural and more appealing. The term "twins" or "twinning" in animation was first mentioned by Thomas and Johnston (1995, p. 67) as the symmetry problem affecting the character's pose in some drawings, making it look very stiff and unnatural. Many other authors corroborate the importance of avoiding the *twinning* (Roberts 2007, pp. 195-6; Jones and Oliff 2008, pp. 301 and 304; Kelly 2009, p. 42) and Montgomery (2012, p. 361) stresses also the importance of variation in *timing*, recommending that the character should be "asymmetrically posed and timed to create more natural and fluid animation".

Beiman (2010, p. 20) says that in order to "avoid the pitfalls of clichéd poses and movements" and show particular personalities and unique performances, the animator must consider the story context and try to express the character's inner feelings, bodily, according to his own emotional interpretation.

From these examples, it seems that most of those animators are more concerned about the character's readability (silhouette) and asymmetry and not so much about the meaningful arrangement of the body parts (or, at least, it is not verbalized). The issue of focusing on animating forms instead of forces, as pointed out by Graham in 1937 (Graham 1937, p. 1) and discussed in section 2.1.1, seems to persist still nowadays. Of course, the flow of energy is implicit to the concept of *line of action* but, *per se,* this one does not define how the body parts interact with each other under a particular force, to produce a particular pose. The logical arrangement of the body parts according to a force is important to produce a pose with a shape that has a particular rhythm and that is characteristic of a specific expression.

Furthermore, the 12 Principles of Animation (Thomas and Johnston 1995, pp. 47-69), although essential for character animation, do not provide this guidance on the arrangement of the body parts of the character into a pose. As the Disney animator Ham Luske (cited by Larson 1983) clearly put it:

> "Your animation is only as good as your poses. You can have good timing, good overlapping, good follow through – but, if your poses are not strong and to the point (telling the story) you do not have good animation."

It is clear that a pose involves a number of variables and must encapsulate the expressive features that will allow the audience to perceive and recognize the intended expression of emotions, attitudes or actions, as discussed in section 2.1. Therefore, in order to create a good pose the animator needs to organize the character's body in such a way that matches the representation of physical movement with the motivation and purpose that justify it, as mentioned by Wells (2009, p. 60), while revealing the character's personality and mood.

Posing deals with many factors and concepts related to animation, body language and acting, as well as with the technicalities of the character manipulation related with the animation software, and aims to create convincing poses. In the end, the pose is better or more expressive if it is more convincing, i.e. if it conveys the intended meaning in a more effective way.

Animation is an art form that integrates many other art forms and therefore the animator can learn from those art forms, through the arts literature, following the example of Neff (2014). The following three sections of this chapter will draw a look at some concepts and knowledge – that will be later argued as pivotal to improve the posing approach – and analyse how they have been applied in other art forms.

2.3   Concepts that can make the change in *Posing*

According to the formulated hypothesis (section 1.2) and led by one of the subsequent questions (section 1.3), this research focuses particularly on two concepts that are very important in animation and can agglutinate many others involved in the definition of the character's posture: *Line of Action* and *Power Centre*. In addition to those, two other concepts, which are related to sculpture, painting and drawing, are also object of focus: *Contrapposto* and *Serpentine Line*.

2.3.1   Line of Action

The concept of *Line of Action* is an imaginary line drawn by the animator to help him structuring the body when drawing the character in any expressive posture, whether a lethargic attitude or a more dynamic action. It is strongly rooted in the context of the traditional drawing on paper animation technique and, according to Dan Gheno (2000), derives from the "action lines" coined by the American artist

Thomas Eakins when referring to the lines that describe the movement of a figure (see Figure 25). As shown in Figure 3, the *line of action* usually drives the pose, like a "line of force", from the bottom of the body to the other extremity where the force is projected. However, it is not always like that, especially if the posture does not involve a strong or dynamic action, in which cases the line may run through the entire length of the body, from feet to head.
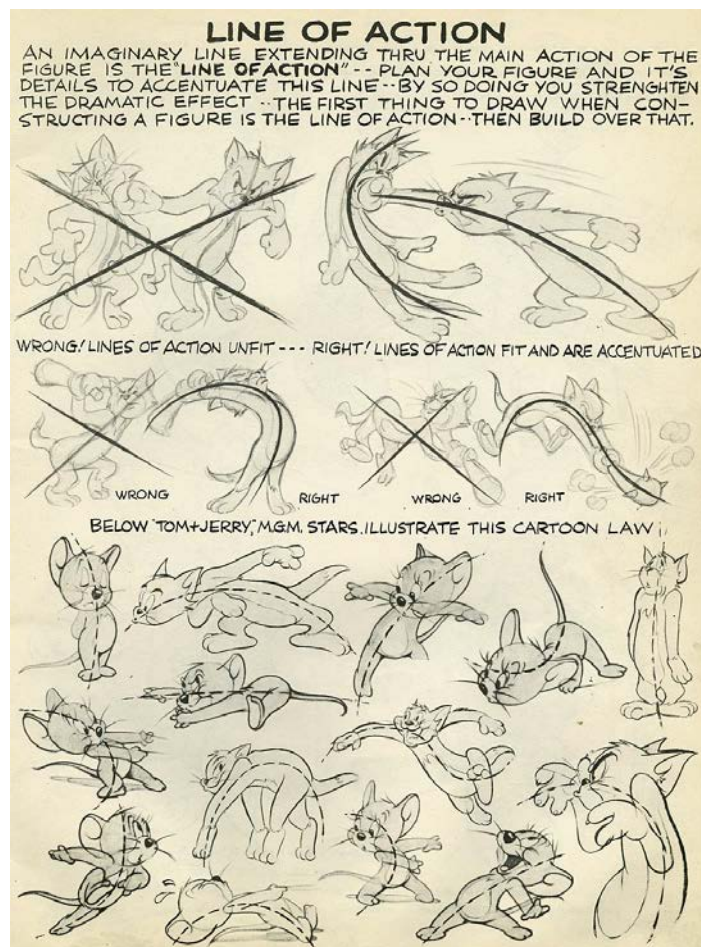
Figure 3 – Line of Action by Preston Blair (Blair 1994, p. 90-1).

In the first half of this illustration, Blair (1994) shows examples with wrong versus right comparisons, to accentuate the virtues of the *line of action* as a way to "strengthen the dramatic effect" (p. 90).

The animator Eric Goldberg (2008) also emphasizes the importance of this concept especially as a structuring element of posture, in drawing on paper animation technique, stating that it is "the first line indicated in a pose, showing the basic overall posture, prior to adding the rest of the details" (p. xix). Another animator who uses the same animation technique, Joanna Quinn, also stresses the importance of "an imaginary central line on the figure [to] draw the pathway of the moving form" (cited by Wells 2009, p. 51).

The properties of the line of action are very interestingly praised by the character designer, Deanna Marsigliese, who recommends the use of this concept when posing for animation, to get "a greater sense of direction, force and balance" and "to give your drawings fluidity and unity" (cited by Wells 2009, p. 184).

Maestri (2006, p. 148) defines it as "a strong line that you can follow from your character's feet to the tips of its fingers", which not only contributes to the creation of a more effective pose but "also adds beauty to the pose". In the same book he presents some examples of how the concept may be applied in 3D animation to create stronger poses:

> "The Line of Action affects every part of a character's body. If a character is in a tug-of-war, he'll dig his heels into the ground and arch his back, putting every muscle he can into the effort. Even simple actions should follow a definite line. If a character is proud, he'll arch his back and throw out his chest. If he's tired, he'll slump over and have a completely different arc."
>
> **Maestri** (2006, p. 149).
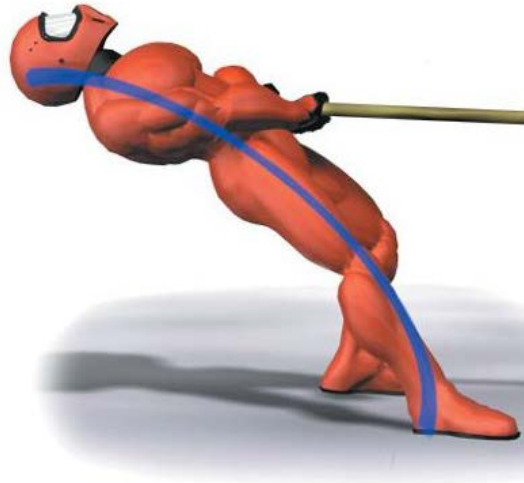
Figure 4 – Example of *Line of Action* (Maestri 2006, p. 149).

Several other animators and authors recommend the use of this concept in 3D character animation, such as Carlos Baena (2008b) , Keith Lango (2009a), Culhane 1990, pp. 160-161; Furniss 1998, pp. 76-81, 176-194; Hoshor 2004; Jones and Oliff 2008, pp. 47, 111, 119, 142, 162 and 167.

2.3.2   Power Centre

The *Power centre* concept relates to the character's source of energy and is like a magnet that leads the body or determines the posture of the character. The movement tends to be led by the part of the body that is under the influence of the *power centre* spot. The term, which was coined by Hooks (2011, p. 29) and is taught by him in his workshops for animators all over the world, has its roots in acting – is very similar to the Chekhov's *imaginary center* (Chekhov 2010, p. 47). Kundert-Gibbs and Kundert-Gibbs (2009, pp. 31-35, 159 and 163) also refer to this concept as the "centers" that lead the body, and provide several exercises for the animator to practice and internalize it.

Besides helping to determine the character's posture or the part of the body that leads the action, the *power centre* also affects the rhythm of the character, as stated by Hooks (2011, p. 29 and 56). A person with a high *power centre* tends to move at a high rhythm, like for example an anxious person – *power centre* above the shoulders – while a person with low *power centre*, like a sad person – *power centre* on the floor – tends to move very slowly (with a low rhythm).

Regarding the location of the *power centre* spot, in a normal person being under no particular circumstances, "usually it is a couple of inches below the navel, in the area that the Japanese call the hara", according to Hooks (2011, p. 29). This coincides with the centre of gravity of the human body, when standing in a normal and physically stable posture. However, the variation of place is associated with the posture that the character is portraying and the impression it gives of where the source of energy is. For example, an anxious person gives the impression of having the *power centre* above the shoulders; a ladies man (Figure 5 - b), in the groin area; and a sad person, outside of the body – on the floor.
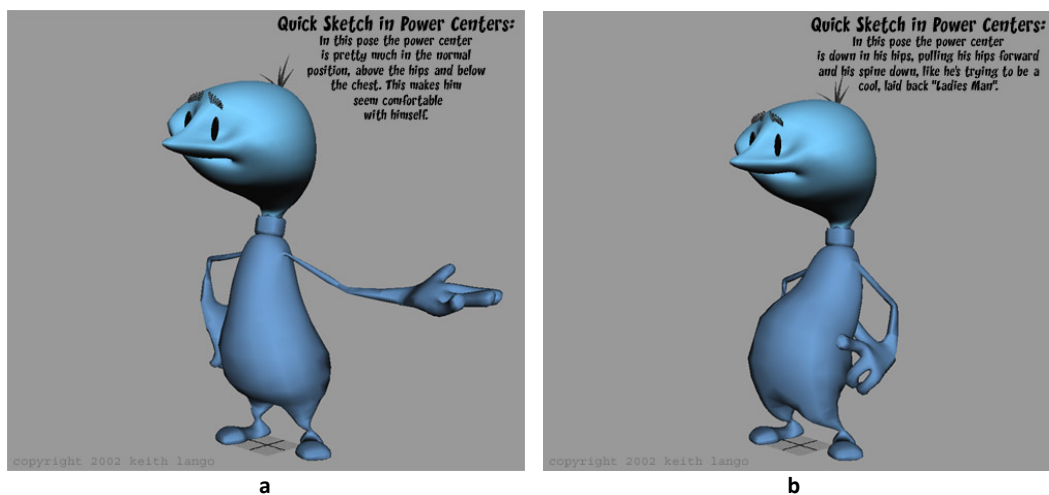
Figure 5 – 3D sketches of *Power Centre*, with examples of a normal *power centre* (a) and a "Ladies Man" *power centre* (b) (Lango 2002).

Lango (2002) describes how the *power centre* affects distinctively some animated characters, depending on where it is located:

"In the animated film **Ice Age, Sid the Sloth** has a power center that's behind his butt. When he walks he waddles with his butt cheeks squeezed together, like he has this force pushing him from right behind his bum. In **Monsters Inc.**, **Mike Wazowski's** power center seems to generally be a bit above his head, like he's being pulled along by it, making him light and flattish. By contrast **Sully's** power center is lower, around his midsection or hips."

Other examples of *power centre* places and the corresponding effects are given by Jones and Oliff (2008, p. 184), as shown below:

Table 6.1 Power Centers	
Hips	Moves like a supermodel on the catwalk or like a sexy Mick Jagger strut.
Chin	Moves like a queen, a statesman, or someone regal.
Chest	Moves like a boxer or a superhero.
Forehead	Moves like an intellectual; think Woody Allen.
Belly	Moves like a tubby person; think John Goodman or a pregnant woman.
Knees	Moves like a thug with a strut; think Rudy from *Fat Albert* or the rap star/actor Ice Cube.

Figure 6 – Table with examples of *Power Centre* places (Jones and Oliff 2008, p. 184)

This relationship between placement and the corresponding effect is not something that can be defined with mathematical precision and, therefore, it is up to the animator to decide where he imagines the power centre being located, exactly which parts of the body are affected and how much he wants to emphasize it in a pose or movement.

The *power centre* can be very useful to define either the initial characterization or the action, based on personality and other particular attributes of a character, and its place might change along the story, according to his state of mind and the circumstances influencing it, as mentioned by Chekhov (2010, pp. 80-81). As an example, the character of a chief doorman, very proud of his job at the Hotel Atlantic, interpreted by the actor Emil Jannings, in the movie "The Last lough" (Universum Film, 1924). His *power centre* is on the chest, as can be easily perceived from Figure 7-a, when he returns home, walking through the gate of the tenement slum, proudly wearing his resplandecent uniform. However, after having

been demoted, a few days later, he returns home through the same gate with a different posture – crushed – denoting a *power centre* on the ground (Figure 7-b).

a	b
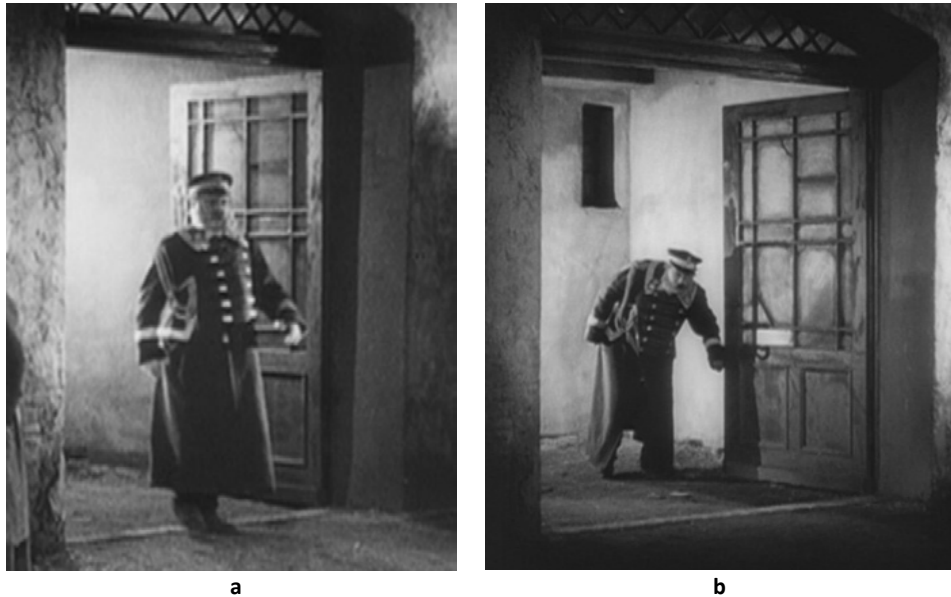
Figure 7 – A pose with the *power centre* in the chest (a) and the same character with *the power centre* on the floor (b), in the film *The Last Laugh* (1924), amended.

As pointed out by Hooks (2011, pp. 30-32), the variation in the *power centre* also intersects with the *status transaction* technique, developed by Johnstone (1999, pp. 219-262), which basically relates to the interaction between two or more characters of different status, involving a status negotiation.

2.3.3   Contrapposto

Contrapposto is another concept that the author of this research considers important to the 3D *posing* process and although not usually mentioned in the animation literature it has, however, a close relation to *weight* and *balance* concepts, which are more familiar to the animation process. According to several authors (Leftwich 1995; Meyer 1995; Ridgway 1995;.Tobin 1995; Pollitt 1999), it was first developed by the Greek sculptor Polykleitos (5th century B.C.), to give a more lively expression to the standing pose of a figure, through a crosswise counterbalancing scheme, also called *chiastic pose* (as it resembles the X shape,

which is *Chi* in Greek). Basically, it relates to the arrangement of the parts of the body in a bilateral opposition, through the weight shifting to one leg while the other stays relaxed, which causes the hips to tilt down to the side, lowering the knee and bending the leg, and the shoulders to tilt in the opposite direction, to counterbalance the body. This forces the spine to bend, producing a curvature of the torso. Furthermore, the torso is twisted by orienting the pelvis to one side, in the transverse plane (see illustration on page 328), and the shoulders to the opposite side, while the head is oriented towards the engaged leg (the one bearing the weight).

The concept can be more easily understood by observing one of the roman copies of the Doryphoros sculpture (see Figure 8) that was created by Polykleitos to illustrate the system described in his treatise – known as the *Canon* – (Tobin 1975; Pollitt 1995), being a "physical embodiment" (Hurwit 1995, p. 11) of his canon of harmonious proportions and balance of the body. The development of his canon was, according to some authors (Hurwit 1995; Pollitt 1999), influenced by the sculptural principals of the philosopher Pythagoras, adding an aesthetic dimension oriented to express perfection or beauty.
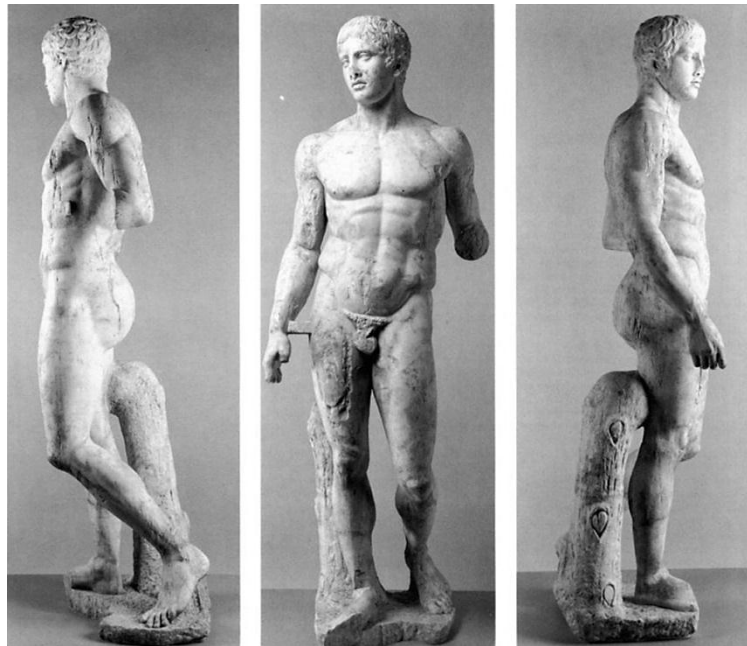
Figure 8 – Doryphoros, Roman copy (150-120 BC) of a Greek original by Polykleitos (Meyers 1995, pp. 66-67).

This statue combines properties of the body at rest and in motion, in a bilateral opposition, as if the body was divided in two, both vertically and horizontally, balancing tension and relaxation of the muscles; flexion and extension of the parts of the body. That opposition relationship is exposed more in detail in the simulation of the Doryphoros' pose presented in the documentary "How Art Made the World" (2005), as shown in Figure 9 and Figure 10.
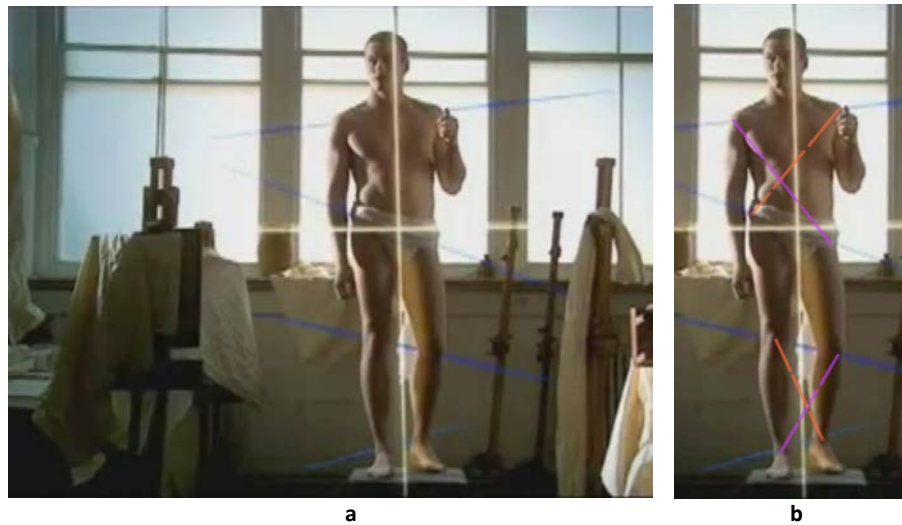
Figure 9 – Front view of the simulation of Doryphoros' pose (a) and with chiastic marks – crossed orange and purple lines (b) (amended from How Art Made the World 2005).

Figure 9 shows the representation of the main axes of the body, marked in blue, and crossed orange and purple lines were added (b), to mark the opposed ups and downs positions, in which is called a chiastic relationship.

The chiastic scheme can also be observed in the top view (transverse plane), in terms of displacement of the shoulders and hips, besides the orientation of the head, thanks to the representation of their axes, in blue (Figure 10).

Figure 10 – Top view of the simulation of Doryphoros' pose (How Art Made the World 2005).

The left leg is bent – flexed and relaxed – opposed to the right one that is in a straight position – taut and extended – causing the lateral tilt of the pelvis and also the tilt of the shoulders in the opposite direction, which produces the bending of the torso – flexed and tense in its right side and extended and relaxed in the opposite side. The orientation (in the transverse plane) of the pelvis/hips opposed to the shoulders, producing the twist of the torso. The right arm is straight – extended and relaxed – next to the flexed and tense side of the torso, while the left arm is bent – tense and flexed – next to the extended and relaxed side of the torso. The orientation (in the transverse plane) of the head is opposed to the shoulders, pointing in direction of the supporting leg. This symmetrical opposition is also visible when considering the main body divided in two halves, vertically: the lower body is relaxed on the left side and in the upper body it is the right side that is relaxed; and vice-versa to the tense parts. The alternation of tension – relaxation of the muscles, and flexion – extension of the parts, along the body produces a specific rhythm in the body shape, which representation is very important to express and justify motion in a pose (Pollitt 1999, p. 58).

The application of the *contrapposto* concept to a figure tends to produce a pose in which the whole body resembles the shape of an **S** or its reverse, in front view (coronal plane), and that is also the case of the Doryphoros, as noted by Mark (1995, p. 27). The imaginary sinuous curve going through the middle of the body, from the feet to the head, depicting that shape is called the *S-curve*. This concept of structuring a pose around that kind of line is considered a more advanced development of the *contrapposto*, as it promotes a more graceful and fluid shape of the whole body. A famous example of the *S-curve* concept applied to sculpture is the Venus de Milo.

Figure 11 – Venus de Milo, Greek sculpture (130-100 BC) (Chauvet 2010), **amended with *S-Curve* traced over it.**

The concept of *contrapposto* is not usually mentioned in animation literature, although some authors do it, implicitly, when addressing the weight distribution or the balance of the character's body, often considering just the lateral tilt. For example, the animator Richard Williams (2001, p. 146) refers to the need to counterpoise the lateral tilt of the pelvis with the opposite orientation of the shoulders in a walking character. However, he does not explain the rationale of the *contrapposto* (he does not mention it at all) and, worse than that, he gives incorrect advice on how to determine the tilt of the pelvis. He recommends that the line of the pelvis, which he refers to as "the belt line", should tilt towards the supporting leg, saying that "normally the belt line is down with the foot that is down and up with the foot that is up" (p. 147). That is not what happens in a normal walk, where the hip drops with the suspended leg of the same side, pulled down by the force of gravity. Another example is Joanna Quinn, who recommends the weight distribution and balance around the *line of action* and also stresses the frequent opposition of the shoulders in relation to the hips (Wells 2009).

Curiously, the *S-curve* derived from the *contrapposto* is sometimes mentioned as the shape to be achieved with the character's body in order to suggest the weight shift.

2.3.4   Serpentine Line

The *S-curve* was used for similar purposes to the *contrapposto* by the ancient Greek and Roman sculptors and both concepts were later rediscovered by Renaissance artists such as Donatello and Michelangelo. The latter further developed the *S-curve* concept, adding the twist in one direction, from the bottom to the top of the body, thus creating the concept that he called "Figura Serpentinata" – *Serpentine Line* (Sherman 1990, p. 81). Of course, this does not mean that there were no whole body twisted representations before Michelangelo and the sculpture of the Discus-thrower (discobolus) created by Myron, the Greek sculptor, around 460 BC, is a very good example.

Those line concepts were later revisited by Hogarth (Hogarth and Paulson 2007, pp. 41, 42, 48-59) when he introduced the concepts of "Line of Beauty" and "Line of Grace" in his aesthetics treatise "The Analysis of Beauty", referring to the "serpentine line" identified in Art by Lomazzo and which he then proposed to extend to whole nature. Hogarth was a painter and comic artist and his treatise caused controversy and was received with a lot of criticism by most of the art establishment at the time (18th century), accusing him of lack of originality and saying that his theory was unintelligible and useless. However, Paulson (Hogarth and Paulson 2007) considers that it "occupies a significant, virtually unique, theoretical and practical position in the development of english aesthetics" (p. xii). Hogarth (Hogarth and Paulson 2007) stressed the importance of the "Wave Line" to structuring the pose, as well as to the composition of the figure, and described the "Line of Beauty" like a "Wave Line" (bent in two different ways, i.e. the *S-curve*) but not every kind of "Wave Line" – the curvature must not be too bulging

nor too straighten. He also introduced the "Line of Grace" as the most expressive line, which is like a *serpentine line* but, again, not every *serpentine line* – just the one that is neither too much nor too less twisted.

Moreover, it should be noted that the application of the concept of *serpentine line*, or *figura serpentinata,* was later (in Mannerism) taken to extreme exaggeration in terms of twist, with torsions not accompanied by the corresponding effort and, therefore, lacking the suggestion of energy, as stated by Shearman (1990, p. 83). That kind of exaggeration, along with elongated proportions of the body, characteristic of that artistic style, produces artificial poses, as opposed to the naturalistic expression of the body in Renaissance, and does not serve the aim of this research. As Hogarth (Hogarth and Paulson 2007) pointed out, it must be applied with moderation, according to the intended expression.

What makes the *Serpentine line* concept more interesting and relevant to the 3D pose is that it adds the twisted condition to the *S-Curve*, taking it out of the typical bi-dimensional world where a line is expressed – and where it may bend but not twist around its axis – and, therefore, making it behave as a three-dimensional serpentine figure, that can produce a spiral form – offsetting from the central axis – in a 3D space. For instance, instead of having the pelvis and the shoulders rotating in opposite directions, along the Y axis (transverse plane), and the same kind of opposition between the head and the shoulders and the feet and the pelvis, as in *contrapposto*, with the *serpentine line* the entire body twists in one direction (to the right or to the left), gradually, from the bottom to the top, like a spiral, while keeping the *S-Curve* shape in the sagittal and coronal planes, according to the flow of energy of the movement. The head may be an exception: in some cases it may twist on the opposite direction, depending on where the character is looking at – where the centre of interest is.

The *serpentine line* concept is also not addressed in animation literature, apart from the *S-curve* quality of the body shape, in the coronal view, that some authors

recommend, as mentioned in the previous section. Recently, in one of his tutorials, Montgomery (2012, p. 366) recommends a "Spine Twist", following the *S-curve* shape that is formed "from the tip of the head to the waist" (p. 365), to make the pose look more natural. This could somehow suggest the *serpentine line* concept, but his purpose is "to create a counter weight" (p. 367) between the shoulders and the hips, in the transverse plane, which relates to the *contrapposto*. His idea is not about the gradual twist in one direction, involving the whole body (from the feet to the head or at least to the shoulders) in a winding curve.

The above discussed concepts, some of them developed many centuries ago, produce a significant impact on the representation of the posture or pose of a figure, in different pieces of art. The relation of some similarity between animation and other arts in terms of the objective of creating expressive poses is explored in this research, as a way to find a solution for a new posing approach. In the following section, some examples are analysed and discussed in the context of the pose.

2.4   The pose in other Arts

The issue of body expression of a character – and how it is highly conditioned by the way its poses are defined – is also common to other arts, where the image must communicate by itself, without text, like for instance in Sculpture, Painting, Drawing or Dance, besides the obvious Acting. The sculptor has only one piece to depict the action and to convey the expression or emotion of the character and, therefore, the artist must imagine the right posture very carefully; the same happens with painting and drawing, as pointed out by Loomis (1971, p. 103) and Hale (2009, p. 111). Obviously, the actor needs to master the body expression in order to deliver the best performance and in dance, for example, the ballet dancer also has to work the right poses to portray the best body expression all the time.

The following five sections focus on expressive poses produced by different art forms, analysing them with the objective of finding evidence of those four concepts presented in the previous section.

2.4.1 Sculpture

There is a close relation between 3D animation and sculpture because both deal with the representation of three-dimensionality. The concern about the pose in sculpture of human figure is also similar to that of 3D computer animation, as well as many of the concepts used by both art forms in the creation process. Therefore, it is important to take a look at some art works of a few artists, which are significant in terms of the pose of human body.

The sculpture of the Doryphoros (Spear bearer) is a roman copy (dating from the 1st century B.C.) of an original bronze made (between 450-440 B.C.) by the Greek sculptor Polykleitos (of Argos) and is considered one of the most copied statues of antiquity. According to Hallett (1995b, p. 132) he succeeded in combining the lifelike expression with the symbolic and monumental qualities, through the *contrapposto*, explaining that "the contrived pose seems the perfect compromise between suggested motion and a monumental inertia; and at the same time the emphatic articulation of the torso endows the human frame with a powerful and monumental structure". He also emphasizes the torso, adding that "the conspicuous pattern of tensed and relaxed muscles in the trunk enlivens the curving axis of the figure with a ripple of muscular movement, suggestive of energy and instinct with life". There are a few known copies, with some subtle differences in the pose (Hallett 1995b; Meyer 1995), and the one shown in Figure 12, which is in the Minneapolis Institute of Arts, is considered one of the best copies (Moon 1995, p. xii; Arnold-Biucchi 1995, p. 225) in terms of composition of the pose, not just due to "a more emphatic articulation of the torso" (Hallett 1995b, p. 128) but because "the statue in its entirety appears as a fluidly unified whole" (Meyer 1995,

p. 88), and also in terms of the reproduction of the hairstyle (Hallett 1995a, p. 117), although the copy that is in the Naples National Archaeological Museum is almost intact.

a   b
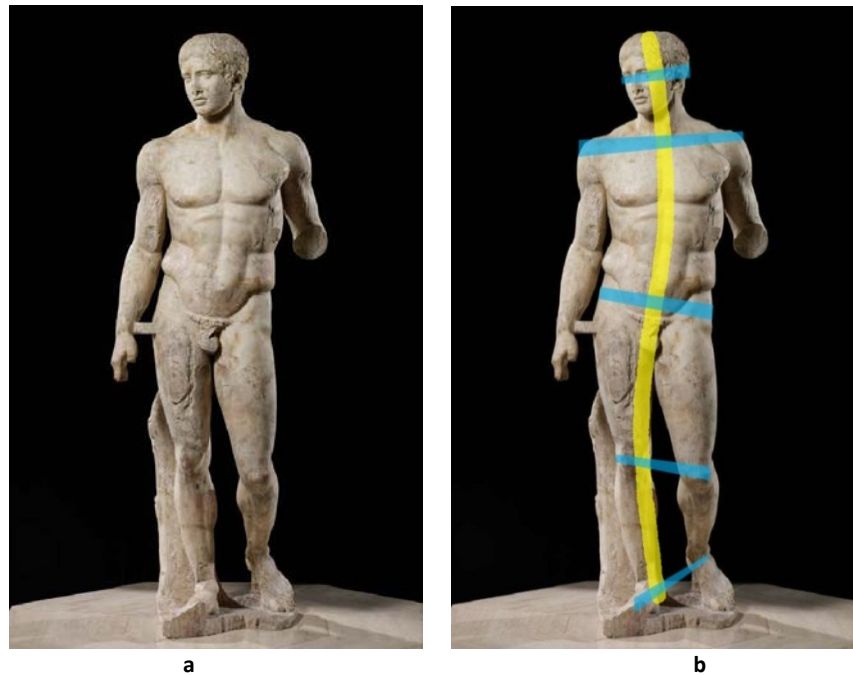
Figure 12 – Doryphoros, Roman copy (150-120 BC) of a Greek original by Polykleitos (Dennehy 2007) **(a) and amended with *contrapposto* and *S-curve* marks (b).**

There has been a lot of discussion on whether that pose represents a person in a resting position, a dynamic one or is an artificial construct created as a demonstration of his canon, that "visualizes the underlying principles necessary to any human movement through a system of binary opposition" (Leftwich 1995, p. 48) – the *contrapposto.* According to Meyers (1995) the Doryphoros' pose is a static one, corroborating the opinion of Von Steuben, but he argues that that position is not very comfortable and could be held only for a moment, before having to shift the weight. Therefore, he considers that Polykleitos captured that "ephemeral moment" (p. 87) and adds, citing Himmelmann, that the pose "contains only potential motion" (p. 87). Contrarily, Tobin (1995) says that "it depicts an upright figure in a very early stage of walking, having started from a stationary stance" (p. 55), which implies that in the initial static position the legs

would be on a stride position, with the feet placed in those same places. Therefore, in the moment allegedly represented in the sculpture the body should be leaning to its right side and also forward (although the Minneapolis copy is more balanced than the Naples one, which looks like leaning to its left side), in order to gain momentum at the beginning of the walking movement, along with the trunk twisted (in the transverse plane) toward the supporting leg, as pointed out by Leftwich (1995). He adds, among other considerations, that the "lateral rotation of the left leg and the eversion of the left foot are inconsistent with push-off in walking" (p. 47) and that "the ankle should be plantar-flexed" and not in a 90 degrees angle, as it is. Consequently, Leftwich argues that "the pose is a construct and not intended to be strictly natural for either walking or repose" (p. 47) and "does not attempt to imitate a specific action" (p. 48). That seems to be the most plausible conclusion, although one could also add that the body looks more like it is coming to a resting position, in the final stage of a movement forward. Definitely, it is not a pose belonging to a normal walking cycle, as the feet and legs displacement (see the walking representation in Figure 2) along with the pelvis and shoulders rotation (especially in the transverse plane) do not fit in any pose resulting from a decomposed walking movement.

This discussion illustrates well the problematic involving the creation of a pose, due to its complexity, and the attention and skills required to arrange the parts of the body to clearly, although implicitly, convey the expression of an intended emotion, attitude or action. It also proves that context (or the story) is very important in nonverbal communication to help getting the right meaning of a pose, as discussed in sections 2.1.2 and 2.2.

Whatever the more static or dynamic nature, and in spite of its probably illustrative function, the Doryphoros is widely considered to portray a very lively posture, in a naturalistic representation (Stewart 1995). The body clearly describes

a smooth *S-curve*, from its front view, and the *power centre* is in the chest, which is characteristic of a proud person.

Another fine example of the use of *contrapposto* and of the *S curve* is the statue of David, made by Michelangelo (finished in 1504). It is considered one of the most important sculptures of all times because the dynamic and dramatic expression in a standing posture. Contrary to the Doryphoros, the Michelangelo's David has a particular characterization and context, derived from a well-known narrative – the pose portrays David right before starting the fight with Goliath, in a latent action, and the gaze of his eyes imply the presence of Goliath and the fight that is about to take place. The body is not moving but is ready to strike – to throw a stone with the sling – since there is a sense of tension that concentrates in David's face, particularly in the eyes, as if he is giving a last gaze at the enemy before the attack (Capretti 2006).

| a | b |
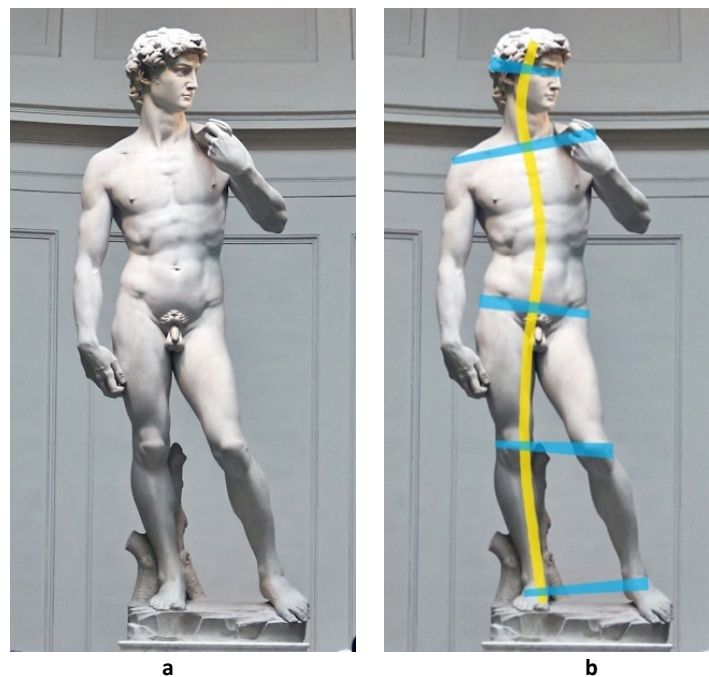
Figure 13 – David, by Michelangelo (Galleria dell'Accademia di Firenze) **(a) and amended with *contrapposto* and *S-curve* marks (b).**

The *S-curve* is clearly identifiable along the body and the *power centre* is located in the belly, as a confident person, or even in the head, due to his haughty look.

This sculpture shows the clear influence that classic antiquity art had in Michelangelo's work, which evolved later to the *serpentine line*, not just by accentuating the twisting of the torso but by extending it to the entire figure, in order to get a more dramatic expression.

The Rebellious Slave is a good example of that concept of *serpentine line* applied by Michelangelo when creating the sculpture. The body twists from the feet to the shoulders, showing great tension and expressing intense physical effort, while the head is twisting to the opposite direction, in a contrasting movement expressing his free will fighting to release his body, and adding a psychological dimension to his effort. The power centre is, therefore, in the head.

a   b

Figure 14 – The Rebellious Slave, by Michelangelo (Chipault 2010) **(a) and amended with the *serpentine line* marks (b).**

Another sculpture of the David, this one created by Bernini, shows the *serpentine line* in a more clear way (Figure 15). This dynamic pose represents the explicit

movement of anticipation that prepares the throw of the stone, by twisting and bending the body towards his right side, from the feet to the shoulders, in order to gather momentum for the pushing action on the opposite direction. The head is turned to his left side, aiming at the enemy. The *power centre* is in his hands, holding the sling (with a stone) and leading the twisting and bending of the body to his right side.

a   b
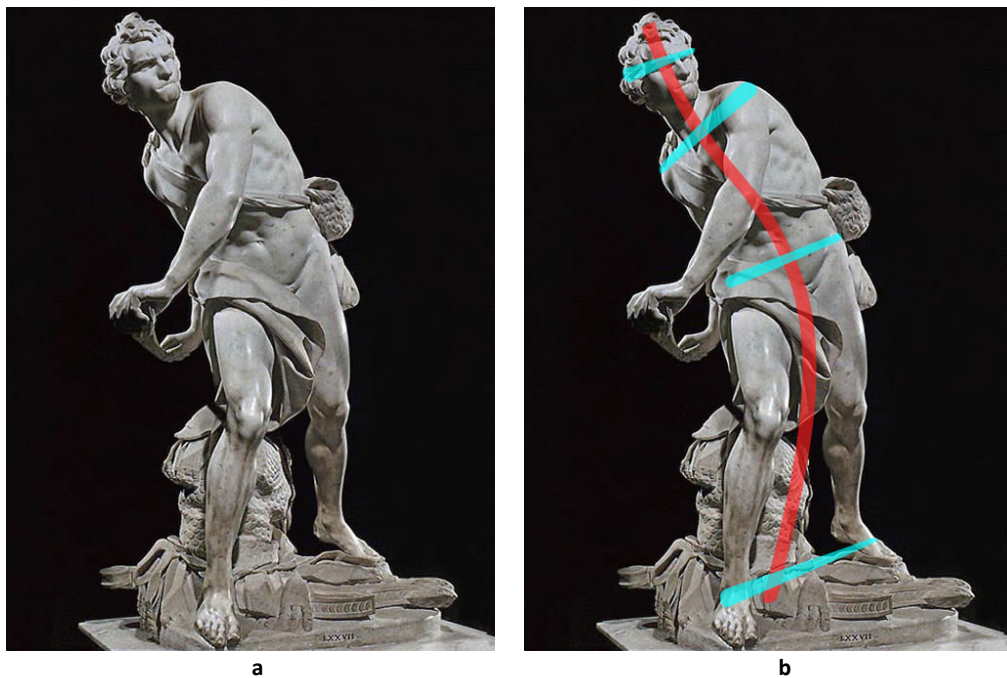
Figure 15 – David, by Bernini (The Culture Concept Circle) **(a) and amended with the** *serpentine line* **marks (b).**

Rodin was one of the greatest sculptors of the 19th century and his art was strongly influenced by the Greek and Renaissance sculpture, especially by Michelangelo. He was very attracted by those poses that express an undulation of the body, as produced through the use of the *contrapposto* and *serpentine line* concepts and, therefore, his process to create the poses for the sculptures was based on the division of the body in planes with different orientations, which was influenced by those concepts. Rilke (2011) stresses the importance of that process when he says that the use of plane is the most important element of his art.

Figure 16 – The Age of Bronze, by Rodin (Baraja) **(a) and amended with** *contrapposto* **and** *S-curve* **marks (b).**

"The Age of Bronze" (1875-76) is one of his works where the use of *contrapposto* and the *S-curve* can be identified and it caused great admiration and discussion, when it was first exhibited in Paris , due to its so lifelike posture, and Rilke (2011, p. 45) adds that it "… marks the birth of gesture in the work of Rodin".

According to Néret (2004), this sculpture was initially exhibited in Belgium, under the title of "The Vanquished" or "Wounded Soldier" (initially, the figure bore a spear in the left hand), because it seems it was intended to commemorate the French defeat by the Prussians in 1870. This may help to explain why it portrays a sense of psychological pain, like despair and frustration. The *power centre* seems to be somewhere in the back of the neck.

Another example of balance, weight shift and lively body expression in a pose is the sculpture "Little dancer aged fourteen" by Degas (1834-1917). He was known as *the painter of dancers* because of his many paintings and drawings of ballerinas, either on stage or on the backstage training rooms, but what really drawn his interest and attention was the movement of the human body and how he could

capture and depict it into a pose. Degas was also strongly influenced by the research on human actions (mainly walking and running actions) done by Etienne-Jules Marey and also by the work of Eadweard Muybridge, who, both, registered an amazing number of actions of animals and people in motion, through photographic means, and presented them in sequences of images.

| a | b |

Figure 17 – Little Dancer Aged Fourteen, by Degas (Kendall and Devonyar 2011) **(a) and amended with** *contrapposto* **and** *S-curve* **marks (b).**

To create this sculpture, Degas developed a new approach, producing a sequence of drawings made by turning around the model in order to depict her from every perspective.

The sculpture portrays a ballerina in a rest position, with the legs in a *casual fourth*, which, according to some authors (Kendall and Devonyar 2011, p.73), "was presumably chosen by Degas for its innate stability..." for it is "less extreme than the formal fourth position, which requires the feet to be turned completely outwards and the body weight to be born equally by both lower limbs". In this pose, the weight is mainly supported by her left leg, as suggested by the lateral tilt of the pelvis, and in spite of the resting characteristics, the posture is very expressive, quite provocative and sensually defiant. The anterior concave curvature of the torso is accentuated by the forward tilt of the pelvis, which makes

the buttocks and the belly more prominent, and by the position of the shoulders, produced by the hands positioned in the back.

The *S-curve* and the *contrapposto* can easily be identified in this posture, especially in his naked version, and the *power centre* is clearly in the belly.

2.4.2 Painting

There are probably thousands of paintings portraying the human figure, where there is clear evidence of *contrapposto* and *S-curve* or *serpentine line* concepts. Those shown below are just some significant examples of that evidence, covering several periods of painting history.

The "Leda and the Swan" (Figure 18) c.1515, which was painted by Cesare Sesto after a lost painting by Leonardo Da Vinci, is a very good example of the *contrapposto* and the *S-curve,* with the tilt and the twist of the pelvis and shoulders in opposite directions.

a   b
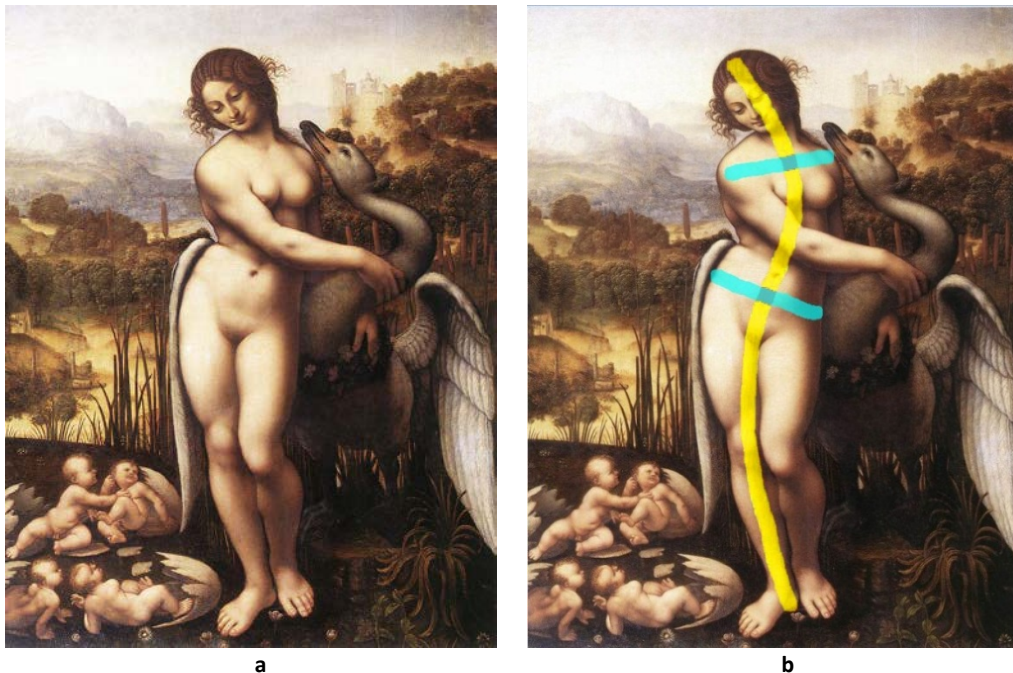
Figure 18 – Leda and the Swan, painted by Cesare Sesto after a lost painting by Leonardo Da Vinci (Wikimedia Commons) **(a) and amended with *contrapposto* and *S-curve* marks (b).**

The *power centre* seems to be in her head.

The panel of "The Creation of Adam", painted in the fresco technique on the ceiling of the Sistine chapel, by Michelangelo, between 1508 and 1512, shows two main figures in quite different poses. Adam (Figure 19) is in a quite passive pose, lying on the ground, although his torso is bent and supported by the right arm, producing the characteristic tilt and twist of the *contrapposto*, while the main body describes a *C-curve* shape. He looks as if he has just been awakened from an inanimate state and pulled up towards God, and that expression is emphasized by his left hand hanging from the wrist, which gives the impression of being pulled up by an imaginary string, like a powerless puppet, yet. The *power centre* seems to be in the tip of Adam's left index finger, which rises towards God's index, as if attracted by a magnetic force that is insufflating life into the inanimate body.
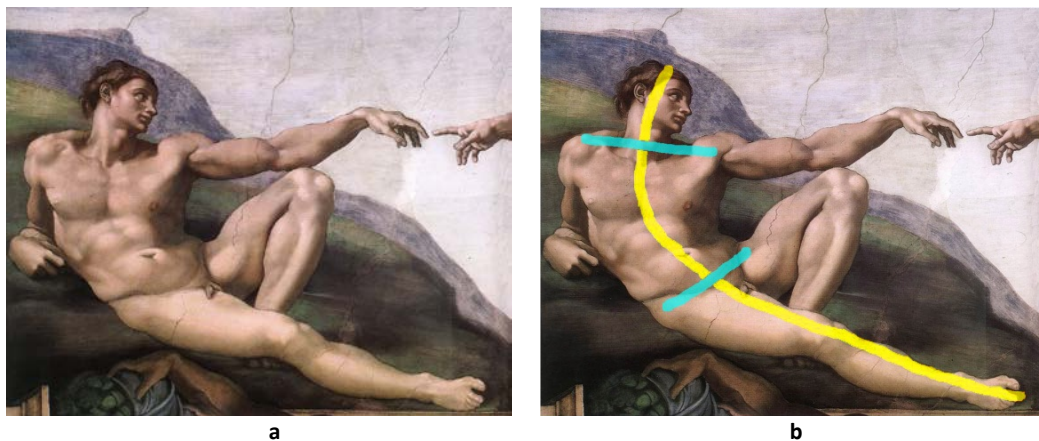
Figure 19 – The Creation of Adam (detail of Adam from the ceiling of the Sistine chapel, Vatican), by Michelangelo (Vatican) **(a) and amended with the *C-curve* marks (b).**

On the other side, God has a more dynamic and active pose, portraying a quite energetic posture although he is being carried by a group of angels (Figure 20). Despite his main body shape is in a diagonal position a bit similar to the one of Adam, he is leaning towards Adam, with the whole body twisted in a serpentine effect and his right arm is extended, aiming and projecting the flow of energy, in a

clear intention to reach Adam's finger and give him life and soul. The *power centre* is in the head, particularly in the eyes, which leads the movement of the body.

Figure 20 – The Creation of Adam (detail of God from the ceiling of the Sistine chapel, Vatican), by Michelangelo (Vatican) **(a) and amended with the *serpentine line* marks (b).**

The "Rape of the Daughters of Leucippus" (Figure 21), c. 1608, painted by Peter Paul Rubens, shows a very dramatic scene of Greek mythology, where the *serpentine line* can be clearly identified, especially in the women's body, as they struggle to release themselves.
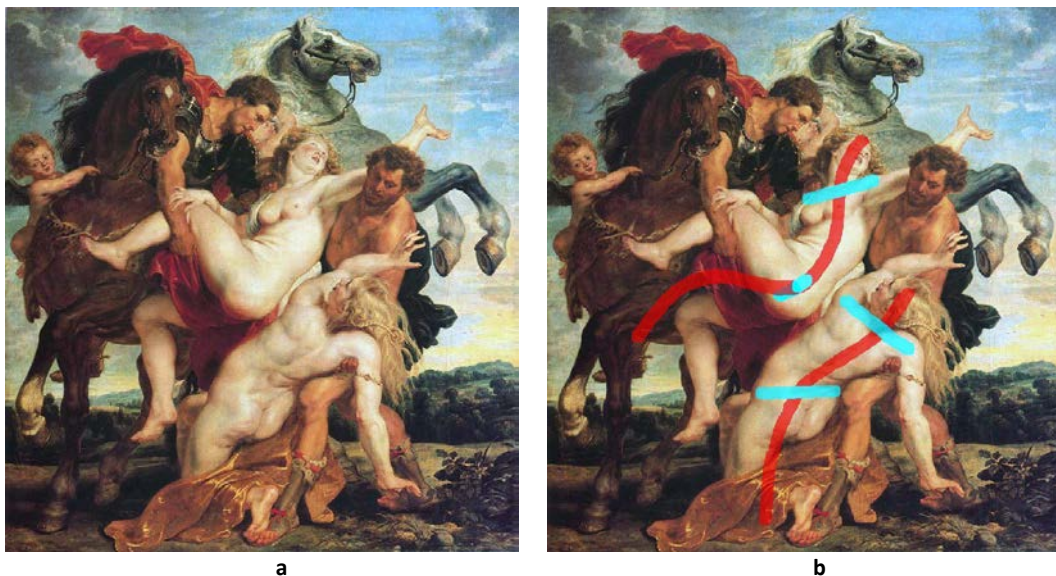
Figure 21 – Rape of the Daughters of Leucippus, by Peter Paul Rubens (Alte Pinakothek) **(a) and amended with the *serpentine line* marks (b).**

The *power centre* seems to be in the left hand of the upper woman and in the back of the neck of the one in the lower position.

Even the painter Lucian Freud (1922-2011), very famous for his portraits and figure paintings with laying foreshortened and contorted body poses, portrays a pose with a clear *S-curve* when painting a standing woman – "Naked Portrait Standing ", 1999-2000 (Figure 22).

<div align="center">a   b</div>
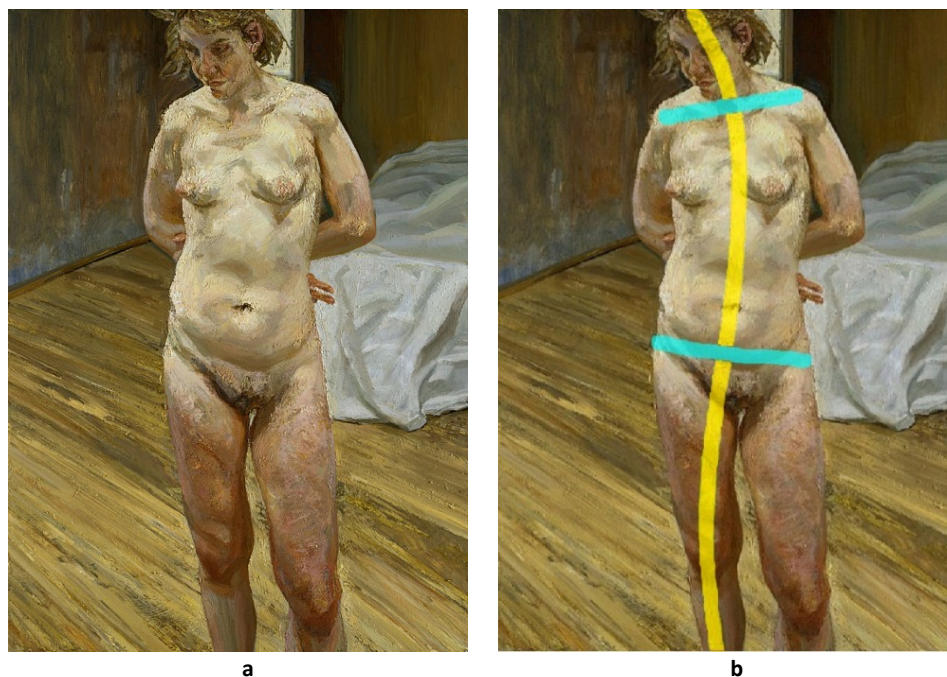
Figure 22 – Naked Portrait Standing, by Lucian Freud (Feaver 2011, p. 403) **(a) and amended with the *S-curve* marks (b).**

The *power centre* seems to be in front of the belly.

2.4.3   Drawing

Most of the visual arts works and everything which involves design are initially developed and created from sketches, i.e. with the assistance of Drawing. When capturing (often momentary) body expressions or creating the pose of a figure, *gesture drawing* is fundamental because it allows to register or plan the essentials of the gesture or posture, at an initial stage, before focusing on the anatomy and

the mechanics of the body. For this reason, it is recommended as a solution to fight the initial tendency of art students in a drawing class, of caring more about representing the anatomy or the costume of the model than the expression of the body. As stated by Hampton (2009, p. 3) "a 'gesture drawing' is considered the framework for everything you plan to accomplish" and he recommends it to distil "everything seen into only the essential qualities of the figure/character in front of you (or in your imagination)".

Naturally, drawings also exist as finished art works and the concept of *line of action*, as a structuring element, can be found in many figure drawings. As an example, the drawing *Standing Nude* (Figure 23) made between 1785-90 by Pierre-Paul Prud'hon, a fine painter and draftsman who explored the language and appeal of the human body. The *S-curve* is evident and the *power centre* seems to be in the right side of her pelvis.

<div align="center">a   b</div>
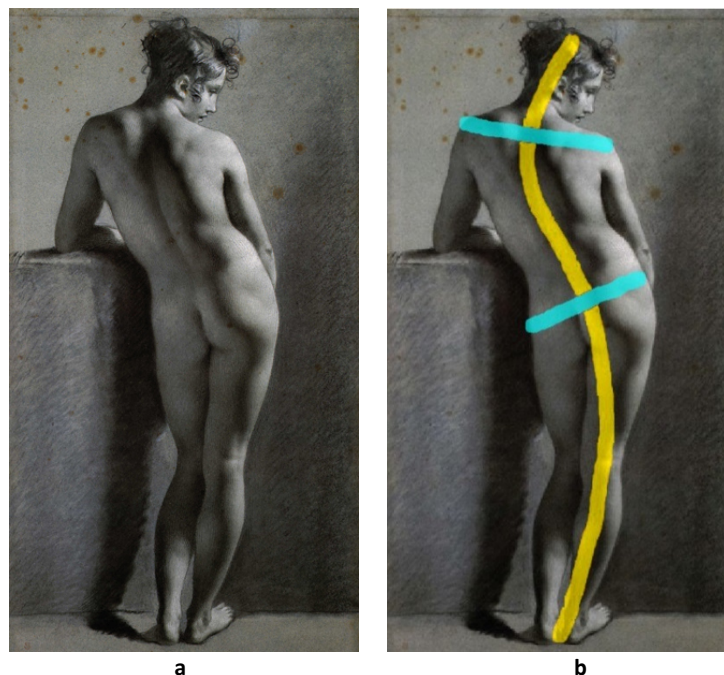
Figure 23 – Standing Nude, by Pierre-Paul Prud'hon (Rubenstein 2007) **(a) and amended with the *S-curve* marks (b).**

The importance of the *line of action* in figure drawing is also emphasized by the American artist, Jon deMartin, who refers in an article published in the Artist Daily.com (deMartin 2010) that it "can rhythmically link multiple parts of a complex structure" (p. 38). He explains, paraphrasing the artist and teacher Dean Keller, that the *line of action* helps to connect "the parts of the drawing together into one whole" (deMartin 2010, p. 41) like the string of a pearl necklace, for example. Such a line "often coincides with the inner axis that runs through the middle of" a body – from the head to the pelvis, in the case of the human – comparing it to the armature the sculptors use to structure the pose of a figure (deMartin 2010, p. 38).
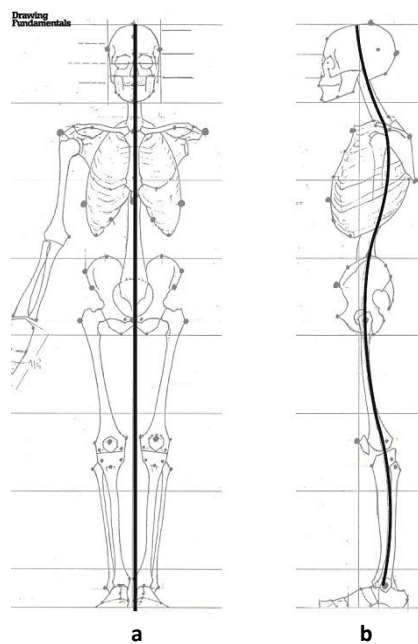
Figure 24 – Inner Axis, front (a) and side (b) views (deMartin 2010, p. 41).

This inner axis, as presented by the artist (see Figure 24), follows the human skeleton from the head to the feet, in a straight line, if seen in front or back view, but, if seen from side view, it describes a serpentine kind of line, following the spine curvature down through the bones of the legs, inspired in drawings by Thomas Eakins, in the 19th century.
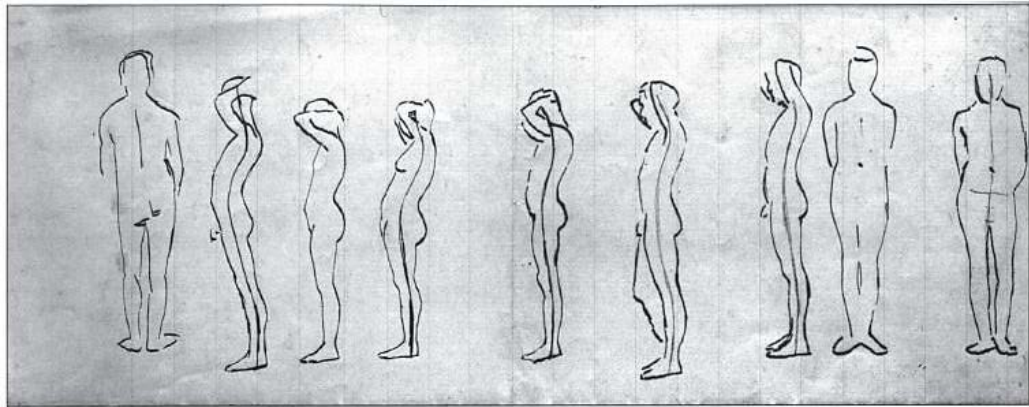
Figure 25 – Nine Studies of Figures, by Thomas Eakins, ca.1883 (deMartin 2010, p. 42).

The creation of the pose is also very important in any drawing intended to illustrate a sense of drama or body expression, like in the comics' world (see Figure 26). Therefore, the concept of *line of action*, as a guide to draw the figure, is also discussed among the comics creators, as stated by Lee and Buscema (1986, p. 62) "Pay particular attention to the *center line* drawn through the figure from top to bottom. This line is always drawn first; it gives you the curve, or the swing, that you want your figure to have".

Figure 26 – Sketch (Lee and Buscema 1986, p. 62).

Fashion Design is another area of drawing where the creation of the pose of the human body, from the proportions to the body expression is taken very seriously. As we can see in Figure 27, there is a clear *S-curve* line that gives structure and

rhythm to the pose since the beginning of the sketch. Drudi (2001, p. 88) calls it the "key line" and she shows its importance as she recommends: "First and foremost you should sketch a line in the upper body, passing through the hollow of the neck, the sternum, the navel and the pubic region, which then descends to the ground following the leg, which functions as a support for the body."
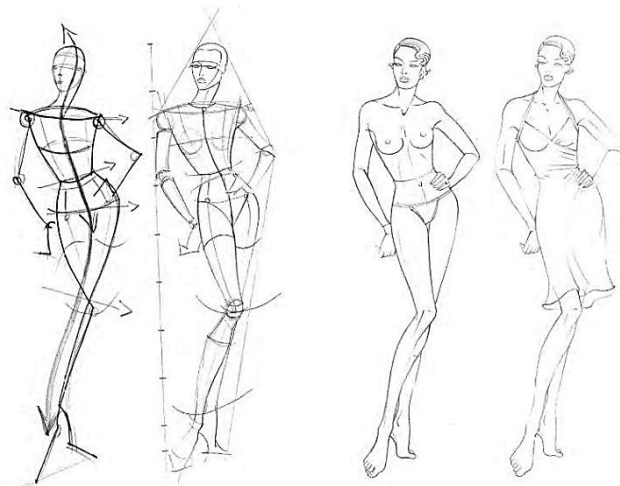
Figure 27 – Phases of drawing a fashion figure (Drudi 2001, p. 89).

2.4.4   Acting

Acting, as the art of portraying a character, relates to different art forms, such as pantomime, theatre, cinema or ballet. Using the body to express emotions or attitudes is the main goal of an actor, as well as of the animated character and, in that way, the animator must be aware of the acting issues, as pointed out by Roberts (2007, p. 182).

In the first four decades of cinema – the era of silent movies – the cinema actors could only count on their body to tell the story and, thus, they had to be very explicit and accurate with their gestures, acting as if they were mimes, in order to convey the right expression.

Pantomime may be useful to help defining some particular pose and it is recommended by some animators, such as Eric Goldberg (2008, p. 23), who

suggests the animators to "think in pantomime" as a way to get "strong attitude poses" and to work the change of attitude. The mime has to master the counterpoise of the body, in order to simulate the action and/or the interaction with the props that are not there, like for instance leaning against an imaginary wall or simulating the weight of an object he is pretending to hold. Roberts (2007, p. 64) draws a parallel between the challenges faced by the mime and those faced by the animator because although the objects are visually represented in an animation scene they lack the physical properties and thus the animator has to imagine how to pose the character's body in a way that looks convincing of such an interaction. Therefore, that author recommends the animator to study the performance of mime artists, in order to learn how they express those imaginary interactions. Figure 28 (a) shows Marcel Marceau (who was a very famous mime) shifting the weight of his body to balance it according to the action he is representing, and an *S-curve* can be clearly identified in that pose (b).

| a | b |
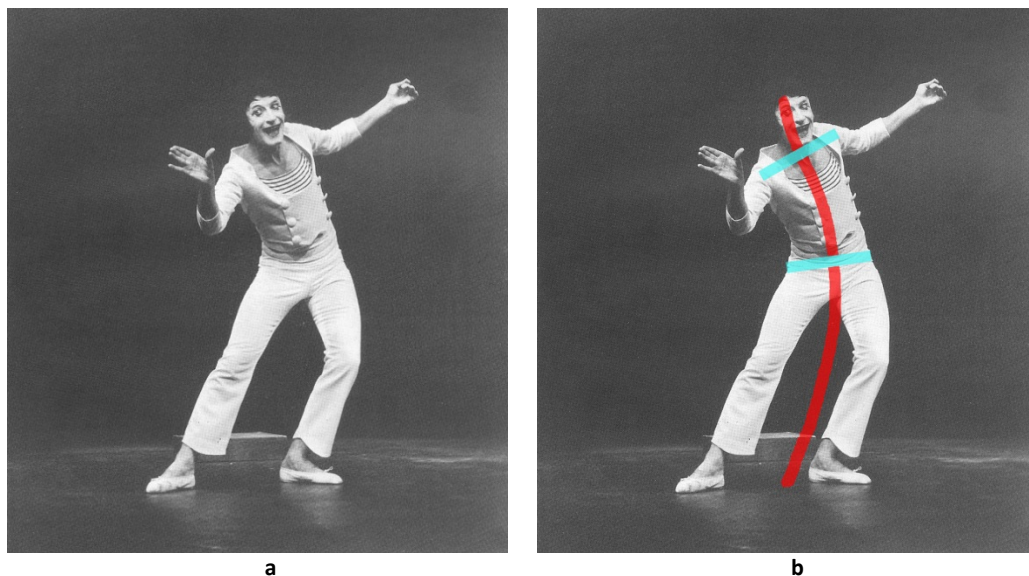
Figure 28 – Marcel Marceau in *The Public Garden* (Lust 2003) **(a) and amended with the *serpentine line* marks (b).**

Therefore, character animation may benefit from the experience and advice of mimes, like for instance Aubert (2003), who discusses posture and gesture, providing not only descriptions but also graphic representations of several

postures, which can be used by the animator as a base to start with when creating the character's poses. However, using pantomime performance footage as reference may be misleading and the animator should be careful not to follow pantomime systematically in the posing process, to create the poses of an entire action (or movement), because the resulting animation tends to be over-gesticulated, especially when animated to a pre-recorded voice track, as Hooks (2011, pp. 59-61) points out. The reason is that pantomime is a storytelling art using only the body and no voice is allowed and, therefore, the mime tends to over-gesture the performance to illustrate the words he cannot speak, in order to clearly communicate the message to the audience. As Lust (2003, p. 8) put it, "the pantomimist, with stylized, conventional movements, creates a specific illusion of objects and portrays a precise idea or emotion", which is quite different from the actor who speaks, interacts with real objects and uses non-stylized movements. Similarly to the actor, the animated character is usually supposed to interact with the props and other characters, too.

The need of mastering the body expression, by the actor, has continued even after the advent of sound in cinema, leading to the development of different acting theories and techniques, aiming at a deeper expression of the character, his soul and emotional subtleties.

Although actors are not ruled by the *line of action* or the *serpentine line* to create the postures, those concepts can be clearly identified in the characters' performance, in different movies. Charlie Chaplin, for example, who was one of the most famous actors of the silent period, usually shows this kind of lines very clearly (Figure 29). There is some exaggeration in the body expression, which was typical in silent movies, as the character is dancing in that shot (a peculiar and funny reaction to the situation of confrontation, like trying to tease the opponent). In that scene the character seems to have the *power centre* is in the head/above

the shoulders, as an anxious person, although trying to act confidently to elude the manager.
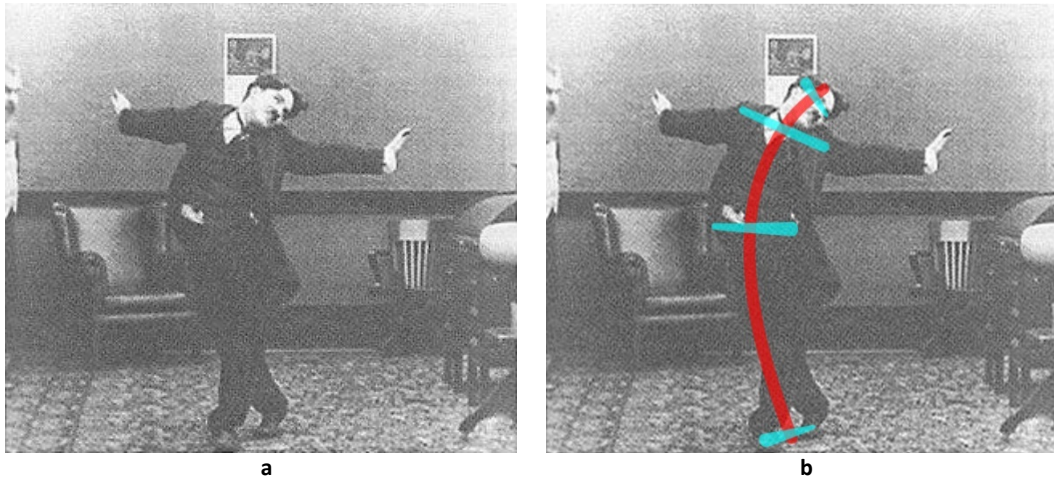
Figure 29 – Charlie Chaplin, in *The Floorwalker* (1916) (a) and amended with the *serpentine line* marks (b).

There is also a clear evidence of the *serpentine line* in the twisting of the body, from the feet to the head.

This serpentine effect in the body expression is very common in dynamic poses and, therefore, can be often seen in dynamic scenes acted in cinema or theatre. For example, the character Bill, the Butcher, acted by Daniel Day-Lewis, in the film "Gangs of New York", in a scene where the character has just thrown a knife, being evident the twist of his whole body, while bending forward to project the force into his right hand – where the *power centre* is during that action.

Figure 30 – Daniel Day-Lewis in *Gangs of New York* (2002), amended (a), and a detail with the *serpentine line* marks (b).

Since this image shows the final moment of the throw, the left foot is in the process of taking over the majority of the weight of the body and the *power centre* will move to the chest, leading a proud posture.

There are several theories on acting – systems, techniques, methods – that teach how to become a good or better actor. Teaching to prepare and build the character will ultimately lead the actor to reach particular postures and, in this way, those acting theories may help the animator to create the character's poses, too. As Thomas and Johnston (1995) stated, "the acting possibilities […] enable the animator to go beyond a mechanical performance" (p. 359) and there are some acting concepts which are usually recommended to animators to help them finding the character's expression.

One of the concepts is the Chekhov's *psychological gesture*. Based on the fact that body and psychology influence each other and considering that the body is an instrument for the actor to express his creative ideas on stage, Chekhov (2010, pp. 63-76) says that the actor must try to achieve the complete harmony between body and psychology. Thus, he developed the concept of psychological gesture, "as an archetype that takes possession of [the whole body]" (p. 70) to help the actor to provoke or attract the right feelings for producing a particular expression

for the role as a whole or for one of its moments (p. 188). In order to search for the psychological gesture, the actor shall start by making a strong, intense, gesture that defines the character, and then experiencing it several times while trying to refine it by following his intuition and sensibility, until it "grow[s] and develop[s] like [a] living, animate being" (p. 190). The movement (gestures and actions) practiced several times will influence the feelings and wish (or desire), strengthening what Chekhov calls the "will power", which then influence the expression of the body. In order to express the essence and particularities of a character, the psychological gesture "should be as *simple* as possible" (p. 70), with "a very clear and definite *form" (p. 71)* and having a specific *tempo*.

The expressive result can be amplified if the actor adds the concepts of *imaginary body for the character* and *imaginary center*, together or one at a time. The first one is not important to the posing phase of the 3D animation process, because the character is already there and, therefore, the animator does not need to imagine how it looks like. However, it is important to consider how the character's physicality will influence its movements and thus the concept of *imaginary center* can be very useful.

Imaginary center is similar to the *power centre* concept disseminated in the animation arena by Ed Hooks (the latter is probably inspired by the *imaginary center*) and Chekhov (2010) defines it this way: "Think of this *imaginary center* as a source of inner activity and power within your body." (p. 47) that "... coordinate[s] all your movements, influence[s] the entire bodily attitude, motivate[s] your behaviour, action and speech..." (p. 80). It can be placed anywhere in the body or outside the body and its quality can be changed according to the character we want to create. He gives several examples, such as: "For a wise man ... imagine the center in your head as big, shining and radiating..." or "Place a tiny, hard center on the tip of your nose and you will become curious, inquisitive, prying and even meddlesome" (p. 81). Chekhov adds that it can even be movable, for instance,

swaying in front of the head and circling it from time to time, for the effect of a bewildered person.

This *imaginary center* concept was also adopted by Johnstone (1999), who acknowledges Chekhov's concept when discussing the changing of a character's body image and adds, as an example: "Imagining the mind as a 'silver ball' in your chest that radiates a wonderful light into the universe can turn you into a Seigfried-type hero" (p. 276). Johnston also invented the concept of *status transaction* (p. 219) to define the manipulation of the character's level of dominance or submission. In this case, status does not mean social position but is about how the character's behaviour signals, consciously, his importance or lack of it when interacting with others, lowering or raising his status through body language.

While Chekhov's *psychological gesture* works externally to internally, allowing the physical aspects to influence the emotional life of the character, the Stanislavski's system or "the method", as it is often called, works from internal to external. The central concept is the *Emotional Recall*, meaning that the actor must recall from memory an emotional situation that he had experienced before, in order to stimulate the emotions to be applied in a scene. This way the actor can create specific and unique expressions instead of generalized ones.

In terms of plasticity of motion of the body, Stanislavski (2008) states that the beauty of movement can only be achieved if the actor feels the *inner line of movement* (as opposed to the external line of mechanical movements of the body, like gymnastics), which "comes from the deepest recesses of our being, [and] the energy it engenders is saturated with stimuli of emotions, will and intellect" (p. 67). According to him (p. 70), that inner line represents the flow of energy going through the body and must be fluid and unbroken in order to add beauty to the movement.

Laban is probably better known for his notation system for dance – *Labanotation* – to describe movement but he also developed a very important movement theory – Laban Movement Theory – for actors, which can be very useful to animators, too. In fact, several authors (Neff and Fiume 2004; Roberts 2007, pp. 182-184; Kundert-Gibbs and Kundert-Gibbs 2009, pp. 203-236; Neff 2014,) recommend it as a useful approach to improve the body expression, especially to define the dynamic position/orientation of the body in action and the intensity, control and speed of the movement. The Effort category can be particularly helpful to define the attitude of the pose as well as to work the *timing* of the movements (the variation of time between poses) and define the rhythm of the animation of a character, later in the animation process. It is based in four motion factors or qualities – space, time, dynamic (weight) and flow. *Space* as an imaginary Globe-shaped space (that he called *Kinesphere*) where the actor/character moves; *time* as the speed at which the character moves in the scene; *dynamic* as the energy that defines the way the character moves and acts; *flow* as the way the character uses space, time and dynamic combined to create an action. For each motion factor there are two elements: space can be direct or indirect, time can be fast or slow, dynamic (weight) can be heavy or light. The use of these different combinations allows the actor/animator to define any kind of emotional expression (like for example: direct, slow, heavy; or indirect, fast, light; etc.).

Having this kind of label "attached" to the character may help the animator to define the pose, especially if he combines *effort* – intention or inner attitude – which can be passive or active, toward each of those factors.

Bishko (2007) adds that there are also correlations of Laban Movement Analysis (LMA) with the *twelve principles of animation* created by Disney and states that LMA "addresses the relationship of intent to action, an innovative feature that aids us in the observation of authenticity which the Animation Principles lack".

2.4.5 Dance

As Judith Mottram (Smith and Dean 2010, p. 29) says, "contemporary dance declares thoughts and ideas not in words but expressed kinaesthetically and emotionally through movement". Dance can be "an interesting source of information for study of affective gestures" but "it exploits gestures that may be exaggerated and not naturally performed in everyday life", as stated by Silva and Bianchi-Berthouze (2004). Stanislavski (2008, pp. 44-45) also draws the attention to the exaggerated movements of dance and ballet, which try to "achieve more beauty, more pomp, than is necessary".

In ballet, the body expression results not just from the movement of the body synchronized with rhythm of the music – as in dance in general – but obeys to a specific choreography to achieve a very precise aesthetic composition of the body (or bodies) on stage. The same happens with modern dance, although this one has more freedom of movements and is considered more *earthy* than ballet, because the dancers are more in touch with the floor, for example, they can walk putting the heel on the floor while in ballet the dancer normally walks on the toes – which make it more ethereal. Being a highly technical form of dance with a very specific vocabulary, ruled mainly by aesthetic purposes and subjugated to the elegance and the fluidity of body movement, besides the rhythm of the music, makes ballet a very distinctive art form, in terms of body expression.

Figure 31 – (a) Nefes, by Pina Bausch (Bertrand Guay 2003)**, amended, and a detail with the** *serpentine line* **marks (b).**

Ballet is not about logic, as Jacobs (2009) says, because there is no logic in many of its poses, which carry a strong poetic significance rather than just the expression of a particular emotion or action. The legs have not just a locomotion function or that of supporting or balancing the body in any other kind of action but are also an important element to draw motion in space, using a specific vocabulary.

Therefore, the ballet pose cannot be created using the same rationale as for the creation of poses of a normal action. The concepts of *contrapposto* and *serpentine line* can be identified in ballet when the body has both feet on the floor, which doesn't happen in many moments during a ballet performance and in most of the cases the dancers walk or stand up on their toes – *pointe work*.

When one of the legs is just supporting the body and the other one is leading the movement or complementing the pose – not just for the need of keeping the balance – the bottom point of the *line of action* should be located at foot that projects the flow of the movement or complements the pose, as marked in yellow on the pose of the ballerina, shown in Figure 32-b.

Figure 32 – (a) "Two graceful ballet dancers performing against black background" (Arcurs 2010)**, amended, and with the *serpentine line* and *line of action* marks (b)**.

From the above presented examples of different art forms it is clear that the concepts of *line of action*, *power centre*, *contrapposto* and *serpentine line* produce a significant impact on the representation of the posture or pose of a figure, in different pieces of art if applied during the creation process. In others, like in acting and dance, although the creation of the body expressions is not directed by those concepts (or some of them), their rationale can be clearly identified, as shown by the marks superimposed on the images.

2.5 The importance of anatomy knowledge to define the pose

"Let the movements of young lads be limber and joyous, with a certain display of boldness and vigor. Let mature men have steadier movements, with handsome and athletic postures. Let old men have fatigued movements and attitudes and not only support themselves on both feet but hold on to something with their hands as well."

Alberti (cited by Peck 1951, p. 205)

Anatomy is always essential to any pose of a character, whether it is a naturalistic representation or a stylised one, as pointed out by Stanchfield (2006, p. 158), in order to maintain the credibility of the body movements, even when those are

very exaggerated and caricatured. As stated by Hale (2009, p. 142) "it must be understood at once that the form of the body is dictated by the bones", adding that "essentially, the body is a machine, with the bones in compression and the muscles in tension". Therefore, those two elements of anatomy – skeleton and muscles – must be considered in any visual representation of a body posture. It was not by chance that great artists like Leonardo da Vinci and Michelangelo studied it so obsessively to the point of dissecting corpses.

When creating a pose for a specific character the animator needs to know which elements or joints of the body contribute to that particular posture, in order to depict it very accurately, so that the audience can easily interpret the posture and get the right meaning.

Like an orthopaedist or a chiropractic, who analyse the patient's posture, in some kind of deconstructing process to identify problems and find the causes, in order to try and treat them, the animator has to work in a similar way but in a somehow reverse cause-effect. For instance, the character is required to portray a specific posture and the animator needs to find how that effect can be caused, in order to simulate that by manipulating the right joints of the skeleton. Therefore, it is important for the animator to know the causal relationship between articulations/joints and posture, so that he succeed in conveying the right meaning to the audience.

The rigger also needs to have a correct knowledge of anatomy, in order to create the most suitable rig for each character and avoid issues already mentioned in 2.6.2 .

For the purpose of this research, the focus will be on the torso – the part of the body from the pelvis to the shoulders – as the core of the body, from which all the dangly parts originate, as stated by Lemen (2011, p. 50). The pelvis is very important to the definition of the pose because most of the movements have their

origin in that area of the body, as stated by several authors. Franklin (1996, p. 131) says that "the pelvis is the hub of the body, a center of stability and originator of motion" and the animator and director Williams (2001) also states that "in most big actions of the body the source, the start of the action is in the hips" (p. 235). That region of the body – pelvis, or hips, as is often mentioned in animation – has a key function in the *contrapposto* and also in the *power centre*, due to its lateral, forward or backward tilt. The wider the pelvis (bigger distance between the hips) the more it swings, in the coronal plane, when doing the weight shift, as during a walk, because the foot of the engaged leg needs to be directly below the centre of gravity, and the knee also needs to be close to the line of gravity. The female pelvis is wider than the male and, for that reason, women usually swing the pelvis more, laterally. Since the pelvis is supported by the legs when standing, there is another important factor influencing the pelvis behaviour during the *contrapposto* – the oblique condition of the femurs (called *bicondylar angle*), that allows the knee to align vertically with the foot, in the coronal plane, helping to keep the balance of the body. Therefore, if the femurs of the character do not have that condition (ex: the knees are further apart from each other, more or less perpendicular to the hips or even further apart), then the pelvis has to compensate by swinging more to the side of the engaged leg, in order to get balanced, or the upper body has to bend more to the side of the engaged leg, especially in a male walking.

The vertebral column is very important to maintain the erect position and to manage the impacts of body motion, and due to its flexibility is able "... to produce and accumulate moments of force as well as concentrate and transmit forces received from other parts of the body." (Palastanga and Soames 2012, p. 407).
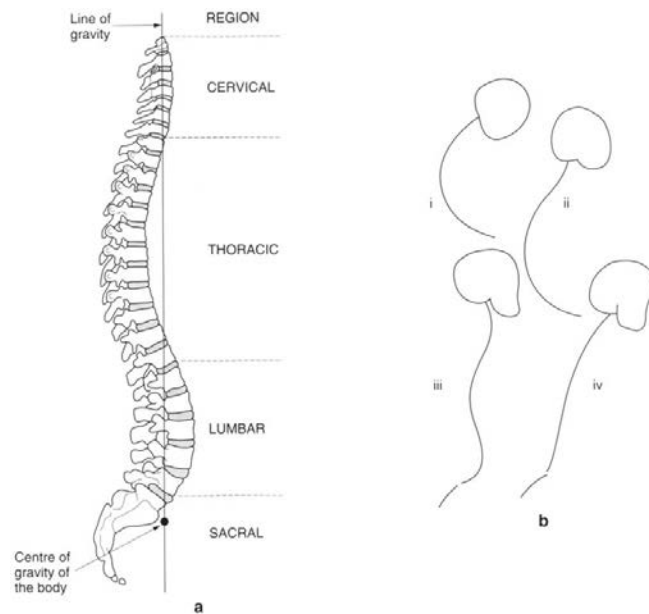
Figure 33 – Vertebral column (Palastanga and Soames 2012, p. 409).

Figure 33 (a) shows the adult vertebral column (side view) and also how the curvature evolves with age (b): i – early fetal development, ii – late fetal development, iii – adult shape develops in the child between 6 months and 2 years old, iv – in old age the curvature tends to assume a shape similar to the fetal one.

The vertebral column is divided into four segments or regions: sacral, lumbar, thoracic and cervical. The sacral region has no flexibility and the other three have different ranges of bending as shown in Figure 34 and Figure 35.
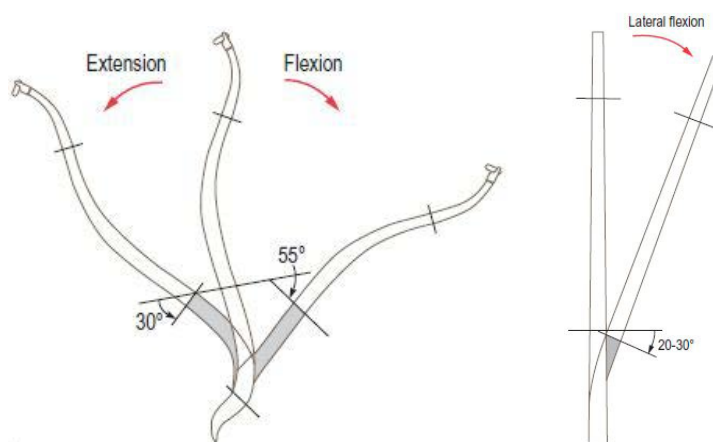
Figure 34 – Lumbar bending ranges (Palastanga and Soames 2012, pp. 462-3).
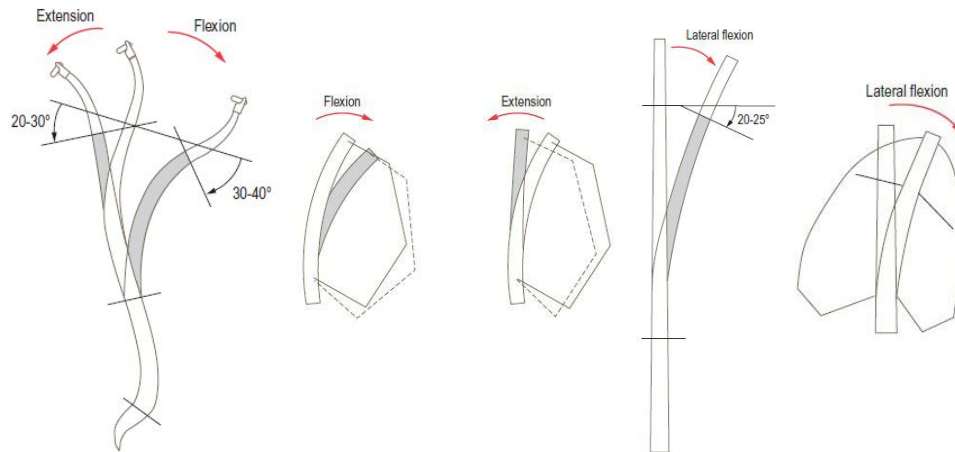
Figure 35 – Thoracic bending ranges and its effects on the thoracic cage (Palastanga and Soames 2012, pp. 464-5).

A closer look at those figures reveals that the two regions of the spine affecting the torso have a similar range of lateral flexion (in the coronal plane): the lumbar between 20 and 30 degrees and the thoracic between 20 and 25 degrees. This justifies the visual perception of a smooth curvature produced by a human torso bending laterally, when seen from the back or the front views, and that is especially evident in a nude torso by revealing the line of the spine (produced by the marks of the vertebrae) in the back or the tendinous *linea alba* in the abdomen (see Figure 36).

| a | b |
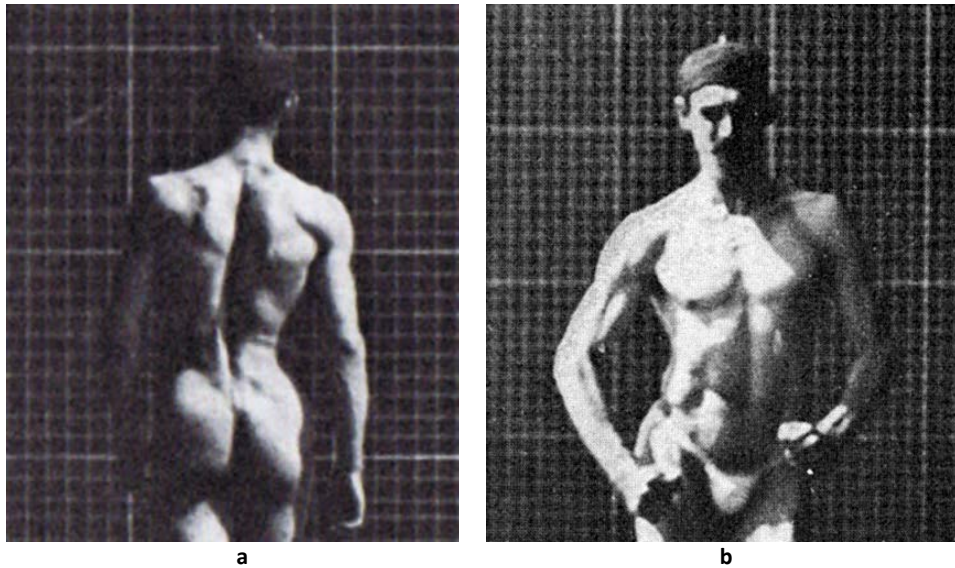
Figure 36 –The lateral flexion of nude torsos, by Muybridge, 1887 (amended from Muybridge 1955, plate 1 – pose 3 (a) and plate 5 – pose 4 (b)).

In the sagittal plane, those two regions have a similar range of bending backwards – extension –: the lumbar is around 30 degrees and the thoracic is between 20 and 30 degrees, which are fairly similar to the values of the lateral flexion. However, the bending forward – flexion – has a considerable wider range in both regions: the lumbar is around 55 degrees and the thoracic is between 30 and 40 degrees.

This means that, on average, the human torso has a fairly similar range of bending either laterally (left or right) or backwards and only when bending forward the range is wider. The thoracic region is a bit less flexible than the lumbar one due to the ribcage, which is also affected by the bending of the torso (see Figure 35).

Curiously, the cervical region, which affects the neck, has a much wider range of bending backwards – extension – than forward – flexion: 85 degrees of extension and 25 degrees of flexion, plus 20 degrees of combined extension/flexion of the suboccipital joints. The lateral flexion range is 40 degrees to each side (or 48 degrees if the 2 vertebrae of the suboccipital region are included).
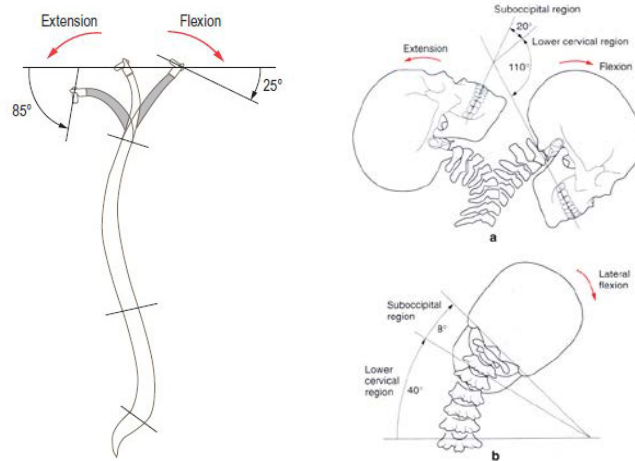
Figure 37 – Cervical bending ranges (Palastanga and Soames 2012, pp. 467-8, 475).

In terms of the twist – axial rotation – of the torso, the range goes from just a few degrees to each side in the lumbar region, to 35 degrees to each side in the thoracic region. The cervical region, which is the most flexible region of the spine, has a range of 50 degrees to each side, plus 15 degrees more to each side in the suboccipital joints, according to Palastanga and Soames (2012).

There is a lot of anatomical information that is very important and must be considered by the animator when defining the character's pose, as it affects the *line of action, the serpentine line* and the *power centre*.

For example, as a person gets older, the spine gets stiffer and gradually starts preventing her from twisting the torso and even the bending capacity decreases a lot.

Figure 38 – Old Man with Walking Stick (Digital Zoo).

As can be observed in Figure 38, old people tend to lead the movement with the knees, as discussed by Beiman (2010, p. 93), which means that in those cases the *power centre* is located in the knees.

Another example is the dorsiflexion – particularly the lumbar curvature (known as lordosis) – which tends to be more accentuated in women, especially if they wear high heeled shoes, or during pregnancy, usually producing a more forward tilted pelvis (Palastanga and Soames 2012, p. 410).

Therefore, in order to study and recreate body expression, it is important to know the body, at least the parts involved in supporting a posture or making the movements of the body – not just for locomotion purposes but for any movement involved in expressing actions, gestures or attitudes.

2.6   Characters Expression in 3D Computer Animation

"Some people have a sort of 'cyberpuppet' attitude: When they want a character to turn is head, they turn just the head and the body remains frozen. I keep saying you can't do that. You have to slightly adjust all parts of the body to show weight shifts that compensate for the body moving around."

Nik Ranieri (Disney Animator) cited by Jones and Oliff (2008, p. 158).

In 3D computer animation several techniques can be used to animate characters: Key-Framing, essentially based on Pose to Pose method; Motion Capture and Performance Animation, that captures direct actions of a real person or animal for immediate playback or to be processed and transferred to the synthetic character; Procedural animation, that uses an algorithm or a formula to describe and generate motion; Physics-based animation, which is based on physics laws, to generate dynamic simulations of the human body. However, typical results often do not show sufficient expression and personality. In fact, some of the systems are focused more on the capture than the creation of original characters with particular personality and expression and, therefore, the animator is required to tweak the motion to create fuller expression and motive.

As the aim of this research is particularly oriented to develop a new approach to help the animators to achieve more expressive and efficient results within the *Posing* phase of the process of 3D animation, the focus is on the *Key-framing* technique, which is based on *posing*.

Unlike traditional 2D animation where it is easier to structure a rough pose (especially if the animator uses the *line of action*) and keep concentrating on the action and body motion to make subsequent poses, animating with 3D software requires a different process to define the pose.

Different processes bring new problems to deal with in terms of practice and make the need for new research to overcome the difficulties. These topics are discussed in the following three sections.

2.6.1 Issues of current practice of posing 3D characters

In 3D animation for film, the character's poses are created at the *scene blocking* (also called *animation blocking*) phase of the animation process, when each scene is composed in a way that the character's expression is clearly seen and understood by the audience, applying the *Staging* principle of animation (Thomas and Johnston 1995, p. 53; Lasseter 1987), as planned in the pre-production. At this stage, when the animator receives a scene to animate, it comes with the characters in the pose they were modelled and rigged – often in the Vitruvio pose, also called T-pose, for an orthograde biped. The animator starts from there, and may follow two animation approaches, as discussed by Jones and Ollif (2008, p.142-144) and Lasseter (1987). One is creating the pose by keying all the controls of the elements of the character's body before moving to the next pose – *blocking* – which is used by most professional animators. Another is creating the pose by layers – commonly referred to as *layering* – working hierarchically a part of the body at a time throughout the scene and keying it in all the keyframes of the intended motion. Whatever the way, the animator has to manipulate several rig controls to arrange the body parts in such a way that the character looks like performing a particular action, after which he has to set keyframes for each of those controls at the estimated time in the timeline. Of course the animator may activate the auto key option, setting keys on everything or just on the controls and channels that are being changed at that time. Anyway, it is easy for him to be distracted with so many controls and forget about the whole body (Jones and Oliff 2008, p. 136; Meir 2008). Moreover, the process is repeated to create all the key-poses, extremes and breakdowns, so that the registered keyframes can be interpolated by the computer, according to the spline curve properties defined by

the animator in the *Graph Editor*, to create the in-betweens (as described on page 29) and generate the motion. This happens with any 3D software, when working in the *Key-framing* technique (whether using Inverse Kinematics or Forward Kinematics), unless the motion data is generated by Motion Capture systems.

The number of registered keyframes – including key-poses, extremes and breakdowns – is specific to the action being animated in a scene and depends also on the timing and the rhythm of the movement, although some professionals, like for example Anthony Strauss (2011), consider it a matter of animation workflow being adopted by the animator. However, the animator should plan the action carefully – studying reference material, doing sketches and thumbnails of the main poses, etc. – before starting to manipulate the character in the 3D software, as recommended by Lasseter (1994). By doing so, he will have a clear idea of the number of keyframes needed to create the expressions of the body, avoiding the tendency to start adding more and more keyframes in order to control the motion.

Some keyframes set on the controls of the character (including for the limbs) may need to be offset, at a later stage of the animation process, as discussed by Jones and Oliff (2008, p. 137). The purpose is to make sure that the different parts of the body do not start and stop moving all at the same time but move at different rhythms and produce the unfold effect mentioned by the animator and director Williams (2001, p. 230). As discussed in sections 2.1 and 2.2, this variation in time and rhythm (the *timing* principle) is very important to express the flow of energy going through the body – animating the force – and usually also requires applying the *Follow Through and Overlapping* principle of animation. Often that offset operation is done (in Maya) through the *Graph Editor* or the *Dope Sheet Editor* (this one simulates the traditional exposure sheet) but the extensive use of that procedure may become problematic. Anticipating or postponing the keyframe set on some controls of a key-pose will change the pose at the intended moment, which may jeopardize the expression of the body as a whole. Therefore, the result

is better achieved through a breakdown pose, even at a cost of having to create a few more of them, than to rely extensively on the offsetting of the keyframes. As explained by Lango (2006b), the process of editing the offset in the *Dope Sheet* may become very confusing and time-consuming and the resulting motion is often not very smooth.

Since the animated body expression is generated from the key-poses, extremes and breakdowns, the animator must carefully think first about the whole body and how it should convey a specific attitude. If not, the character may end up moving its arms and legs, rotating the head but with the torso more or less on its original orientation, i.e. with poorly expressive *key-poses* and the resulting animation showing poor body expression. Evidence of this is given in the writing of many contemporary practitioners, such as Baena (2008a), Navone (2008), Jones and Oliff (2008), Roberts (2007, pp. 121 and 232) and Meir (2003), among others, and some of them also suggest the use of the *line of action* when doing the poses in 3D.

Jason Ryan, supervising animator at DreamWorks Animation Studios, describes this way the 3D animation process and how he deals with it:

> "For me, the 3D process is very demanding, thinking about micro-managing every little part of the body. Thinking about rotations, translations and scales – there's nine different attributes or channels for each individual control of the body. That can be quite a daunting task for anybody, especially if they don't know what the animation will look like at the end. Therefore, I always think about the flipbook process first, which is like animating in real time with stick figures, and then I use the 3D software to refine the performance and make it even better."
>
> **Jason Ryan** (cited by Beaulieu 2011, p. 42)

Kelly (2008) also shows his concerns about the *posing* process and discloses a trick he learned from Glen McIntosh "if you nail the timing and posing of the body (hips, torso, etc.), then the position of the feet will already be dictated by the position/timing of the body, so if you just hide the feet and legs to begin with, and block in the body, you get the feet/legs for «free»" (p. 31). Later, he repeated that tip in a special edition of *3D World* magazine (Kelly 2013, p. 117), emphasizing that

it was especially useful for action scenes. However, that suggestion may not be a good idea, even if the character is shown in a medium shot, because the feet support the body and the way they are placed on the ground will determine the weight distribution of the whole body. Therefore, although it may simplify the posing process of the feet, may also lead the animator to neglect the importance of keeping all the parts of the body consistent in the pose, as discussed in the New Posing Approach chapter, on page 138.

In most of the big feature animated film productions in 3D, the animator is assigned an entire scene to animate all the characters in there, which is completely different from the traditional process, where each character was assigned to a team for the entire movie. This method of managing the scenes adds more problems to the acting dimension in animation, by making it more difficult to keep the consistency of the character's performance: besides the effort to get inside the character (its personality, state of mind, etc.) to create the proper expression, the animator has now to constantly shift from a character's mindset to another.

Reference material is habitually used in the *posing* process and is very important because it helps the animator to get different ideas. Traditional model sheets, expressions sheets, etc., may offer good references of most typical postures, attitudes and actions of a character but, whatever the size the collections might have, they do not provide explicit information for the creation of every single key pose required to generate the movement. Video reference can complement the traditional references, providing visual information of more specific actions, and is a very common practice nowadays among animators – often filming themselves acting the scenes. This practice is recommend by many professional animators, like for example Denovan (2015) and McKee (2011), at least as a starting point of the posing process "and then improve on your video reference as only an animator can", as recommended by McKee (2011). However, from an acting perspective, filming themselves may be a problem, as pointed out by Hooks (2011, p. 53),

because when doing so the animators already know the kind of movement they want to animate and, thus, are trying to act and also be aware of their movement at the same time, which inevitably leads to unnatural and stiff results. As solution to overcome this and obtain more spontaneous results, Hooks (2011, p. 54) recommends that the animator asks some else (a colleague, for example) to perform the action for him and record it. Therefore, when the animator wants to create very expressive poses, with original expressions and performances, (and this should always be the case) the use of video reference is only a good solution if the person who performs the action is a good actor. Otherwise, the animator will base the animation on a bad reference – unless the purpose is just to get reference of some mechanical movement. The same may happen with the Motion Capture technique and even when it is performed by good actors, the animators are often (if not always) required to clean and tweak the motion to create better body expression.

Animation practitioners are usually aware that the *posing* phase of the animation process is very critical to the final creative result of the animation, in terms of character's expression, as shown before when discussing the posing process. However, it should also be mentioned that many computer animators tend to adopt a casual approach to the *posing* process, probably due to the possibility the computer offers to *undo* and *redo* without having to start from scratch. That way they don't feel the need to visualize the entire picture/body and to plan the poses in advance, before start manipulating the character's rig. This is probably a strong reason for the quite heuristic way of learning and practicing, which is typical of many 3D computer animators. Such an approach would not be acceptable in traditional animation because, for example in *drawing on paper* technique, if the animator needs to change a key-pose, he has to erase and correct not only one drawing but a sequence of them before and after that pose. This is why the *line of action* has proven to be so important in 2D animation.

2.6.2 Evidence of posing problems affecting character's expression

Sometimes animators seem to manipulate the 3D character as a child manipulates a doll or an action figure, translating and rotating the arms and legs and rotating the head to obtain different postures but leaving the torso stiff. Dolls and action figures usually have a stiff torso and do not provide options to bend or twist it and even the Fine Arts mannequin does not do much better, since it only offers one rotation point in the abdomen, usually. However, 3D characters are commonly rigged with several controls for that part of the body and there is no technical reason for being treated with some sort of "cyberpuppet" attitude, as pointed out by Nik Ranieri (cited by Jones and Oliff 2008, p. 158).

When watching animated movies, shorts made by students or tutorials in the web, often there is the sense that many people are not aware of the importance of the torso in body expression. It tends to be neglected and regarded as some sort of a block, from where the limbs and the head come out – a frame that keeps the different parts of the body together – and, thus, left more or less unchanged, looking stiff and with an unnatural expression.

The problem has also been pointed by several practitioners, such as Lango (2009b), who mentioned in a video, posted in his blog:

> "... a big problem with CG puppets is that they are very stiff inside the torso. This all region [...] from shoulders down to the hips is a dead zone and that is just because we're letting the default basis of the rig to define much of what we are doing."

Thr Disney animator Bancroft (2012, p. 9) also states:

> "A common mistake when posing characters is to have the arms, legs and head do all the communication of the pose while the midsection (pelvis to torso) is straight as a board. A straight midsection or core can make your poses feel stiff. Also, you can miss out a stronger way to communicate the emotions of the pose."

The stiffness of the torso is directly related to the expression of weight, i.e. the distribution of weight among the different parts of the body according to the

action or attitude to be portrayed. This is corroborated by Bancroft (2012), who says that "in animation, showing a character's weight is an important part of creating a believable performance" (p. 57), stressing also the importance of the weight distribution to create a good balance in the pose (p. 60. The importance of the weight shift for the believability of the character expression is also emphasized by the animator Balda (2008).

These comments reflect well the problem of how the torso of a character is often regarded by many animators and the attention they give (or not) to it, and Lango (2009b) suggests the torque of the torso as a way to overcome the problem. In another video tutorial (Lango 2009c) he recommends the use of counter-rotation – a rational similar to the *contrapposto* – on the torso (the bottom part rotates back and the top part rotates forwards) to provide balance to a character when he leans forwards or backwards, as shown in Figure 39.

a   b
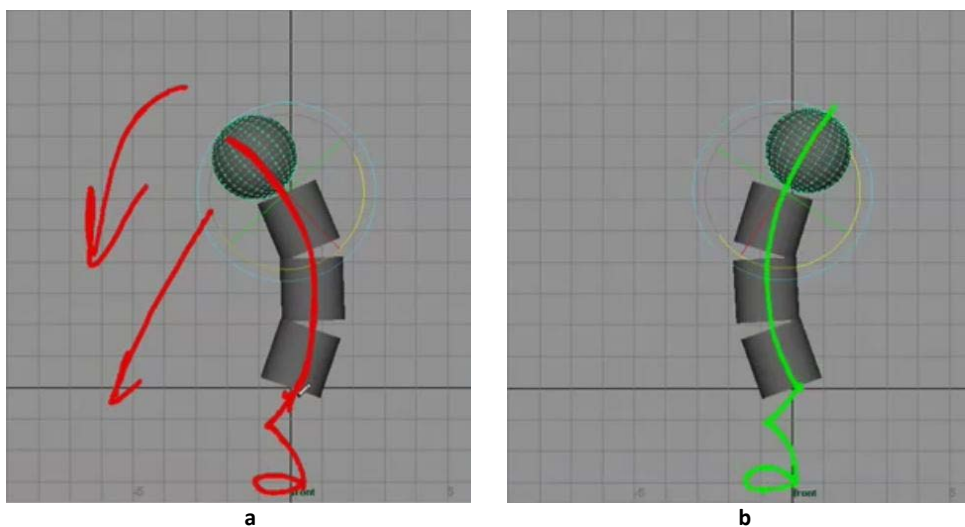
Figure 39 – Leaning forwards (a) and backwards (b) proposed by Lango (cropped from Lango 2009c).

Definitely that seems to help avoiding the problem of unbalanced poses like in those examples of a character looking down and up provided by Lango (Figure 40-a) and the smooth curvature of the torso helps to avoid the sense of stiffness, when compared to the examples in Figure 40-b.
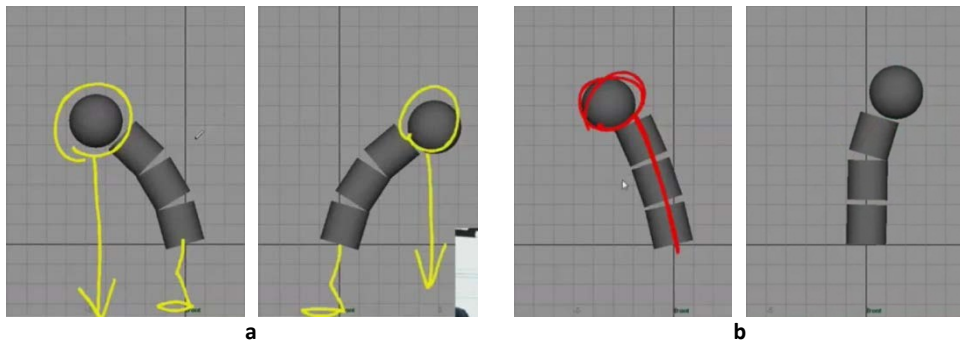
Figure 40 – Examples of unbalanced poses (a) and stiff torsos (b) (cropped from Lango 2009c).

Another practitioner, George Maestri (Lynda.com 2011b), suggests a similar way to avoid the stiffness of the torso, also starting by rotating the hips back and then bending the torso forwards, when creating a shy pose, for example (Figure 41–a), and rotating the opposite way, when creating an assertive pose (Figure 41–b).
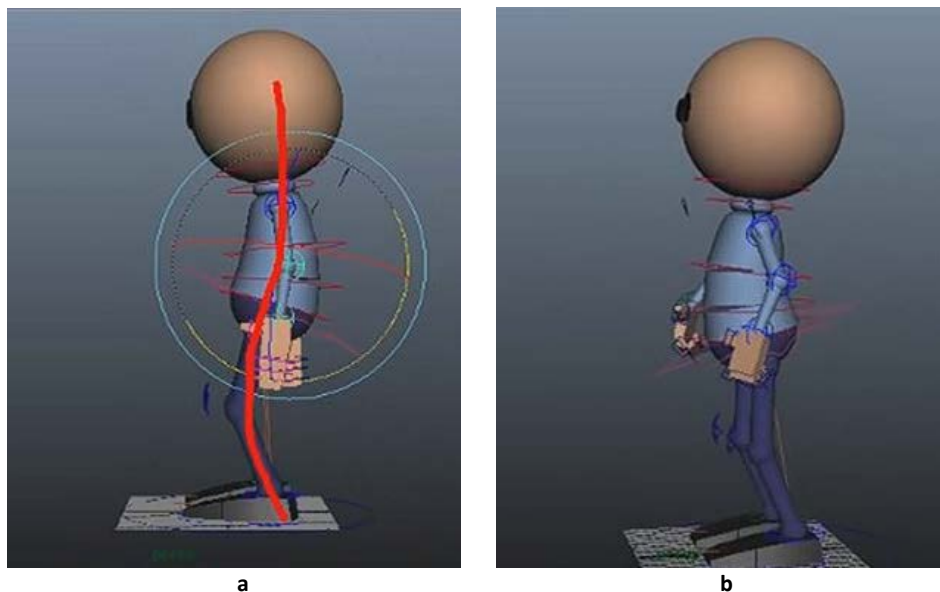
Figure 41 – Examples of a shy and sad pose (a) and a more assertive one (b), proposed by Maestri (cropped from Lynda.com 2011b).

He even emphasizes the fact that, by doing so, the shy pose produces a line of action with an *S* shape that makes it a much stronger pose.

However, the solution they propose – rotating the pelvis backwards when leaning forwards and rotating it forwards when leaning backwards – might originate

another problem because the rotation of the pelvis in the sagittal plane affects the expression of the personality and of the state of mind of the character. For example, tilting the pelvis backwards and projecting it forwards, as in Figure 41-a, is typical of a *macho man* posture, although the feet are correctly pointing inwards, as typical of a shy posture that the character was supposed to portray. Likewise, in Figure 41-b, the forward tilting of the pelvis, arching the spine inwards and pulling the pelvis backwards is typical of an insecure, anxious or submissive posture and might even imply a sexual connotation related to the *lordosis behaviour* (common to all mammals, including humans, as mentioned by the anthropologist Helen Fisher, cited by Coffey (2009)), which does not fit in with an assertive posture. The same interpretation can be made about the postures of the more stylized character shown in Figure 40 (a) and (b).

The above mentioned evidence of stiffness of the torso could be justifiable by an eventual lack of rig controls in that part of the body but the contrary is often the case: the rig has too many controls to manipulate the torso. This reveals a clear lack of understanding of the anatomy of this part of the body and how the underlying structure operates (as discussed on page 93) and of its importance to the body expression, not just by animators but also by riggers. Often, the riggers seem to be led more by the aim to build the rig full of controls, as complete as possible, to fulfil all the possible needs of animators, than by effectiveness of use, neglecting the common advice that in order to be effective the rig should be as simple as possible, as stated by many, like for instance Maegaki and Pinheiro (2011).

In fact, the complexity of the character rig might also not help to solve the issue of the expression of the torso because, often, the applied rig offers several manipulators for the torso (see examples in Figure 42 and Figure 43-a), as if, for instance, it was supposed to rotate and counter-rotate in several points along the section. On the other hand, in many cases the skeleton underneath that rig has

only a few joints for the same section (like just a few segments of straight lines – broken line), neglecting the fact that the spine has many joints and bends gradually describing a more or less smooth curvature of the torso (as discussed in 2.5). As stressed by Pierce and Pierce (1989, p. 146), "there are no sharp breaks in the supportive movement [of the spine], but a single integrated flow of bending", achieved through the synchronized action of the muscles – flexors and extensors – which progressively influence each joint, providing the appropriate "finesse and strength" to the particular action of the body. The same is valid for the neck, with many character rigs having just one skeleton joint at the base of that section, thus treating it as if it was a rigid part of the body.

| a | b |
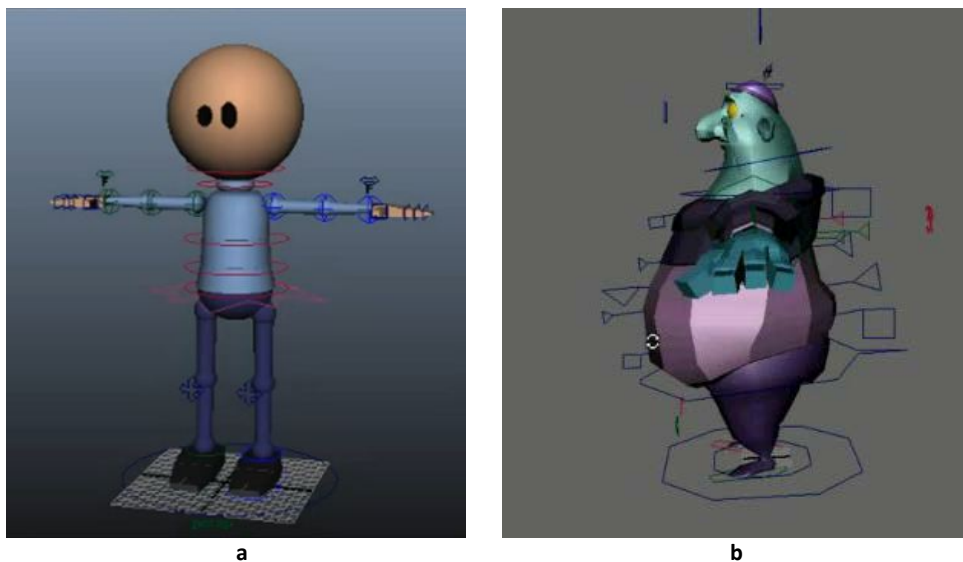
Figure 42 – Examples of character rigs (cropped from (a) Lynda.com 2011a and (b) Lango 2009b).

These kind of examples can be found even in tutorials offered by magazines of reference, like in the Maya Essentials issue, edited by 3D World and 3Dtotal, and published in 2011 (Figure 43).
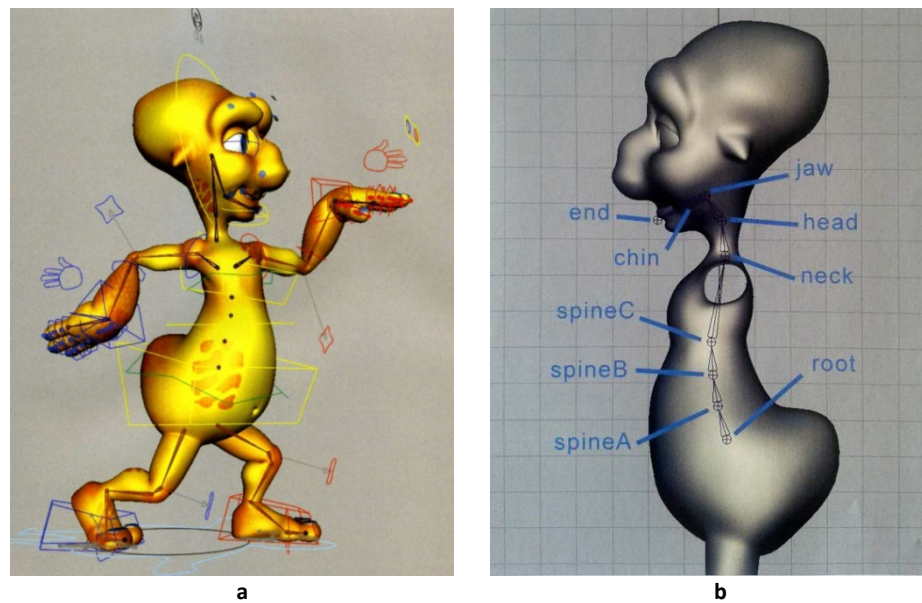
Figure 43 – Example of character rig (a) and spine joints (b) (Maegaki and Pinheiro 2011).

Therefore, many times the animator lose the notion of how much he did rotate each control of the torso, especially when there are several controls for that region of the body. It is easy to end up with some controls with a lot of rotation and others with almost no rotation, or with rotations in different axis, resulting in a non-natural and ungraceful bend or torsion – with a lack of fluidity.

Another frequent problem related with the character rig is the position of the shoulders. Surprisingly enough, one of the things that seem to be more often forgotten by animators (even by those teaching through video tutorials) is the need to reposition the shoulders to its normal (relaxed) position before starting animating it. Since the character is usually rigged in the neutral pose called "T-pose", the arms are raised to a horizontal position, which implies that the shoulders are higher than its normal position, too. So, when starting the posing process, it is not enough to just rotate the shoulders' joints to move the arms down – the clavicles' joints must rotate down, as well, in order to move the shoulders down to its normal position.

The layering approach of animating (described in previous section) usually adopted in computer animation is also not helping, because when following it the animator tends to focus on one part of the body at a time and, thus, may lose the perception of the whole body.

Regarding movies, for example the analysis of a scene from "The Smurfs" (Figure 44) shows that there are inconsistencies in some of the characters' poses, mainly due to a critical weight distribution. The following examples corroborate what Webster (2012, p. 64) stated: "One of the greatest difficulties animators face is creating the illusion of weight in an object or character".

Figure 44 – *The Smurfs* (2011).

The character with glasses has his hips tilted in a very oblique position, which suggests a pronounced shift of the weight to his left foot. However, the inclination of the torso and head are not in a way to counterbalance that weight shift, thus putting the centre of gravity in the right side of his chest. In fact, the body is supported by his right leg and not by the left one, which makes the character unstable, especially considering that his head is very large, when compared to the size of the rest of the body (about one third of the entire body). That pose could work if, for example, the character was looking at his right foot, although the tilt of

the shoulders would need to be adjusted, as well as the orientation of the head. It would also work if he was performing an action of peeping, leaning the head or the torso to his left side. As it is, the pose is not coherent, because the orientation of the pelvis and the shoulders, in coronal plane, (see cyan lines in Figure 45) indicate that the body weight is being supported by his left leg, while the centre of gravity is requiring his right leg to support the weight.

The imbalance looks even more critical in the first character on the left side of the image, with the centre of gravity in the left side of his left shoulder but the orientation – tilt – of the pelvis and of the shoulders (see cyan lines in Figure 45) suggesting that his body weight would be supported by his right leg.

Figure 45 – *The Smurfs*, with *lines of action* and pelvis and shoulders marks (amended from *The Smurfs* 2011).

The pose would work if the character was initiating a movement towards his left side, as the angle of inclination of the upper body suggests (see *line of action*, in yellow). However, that is not the case, since the character is staring at the human character, without moving his feet.

Furthermore, it is possible to notice that there is no twist in the body of that character, as the head, shoulders, pelvis and feet are all oriented in the same

direction, in the transverse plane, which also contribute to the problematic pose. The second character on the left side (near the toaster) also shows almost no twist, except for the head turning to his right side. The rest of the characters show some subtle twists but, basically, there is no dramatic effect, with all of them standing, oriented to Papa Smurf and the human character, with no apparent objective to pursue besides listening to their conversation and showing some amazement with the revelation about the "magic searching device".

Similar examples can be found even in more landmark movies like "Shrek", where the character often shows a deficient weight distribution, especially evident when he is walking (see Figure 46).

Figure 46 – Shrek, with *line of action* and pelvis and shoulders marks (a) (amended from *Scared Shrekless*, TV short, 2010).

In this example Shrek's body is leaning to the right, completely out of balance, as synthesized by the red line (Figure 46-a), since the body is supported by his left foot but the centre of gravity is located in the right side of his chest. One can argue that is inherent to a character walking – especially if he is an orthograde biped – which is the case, as Shrek is walking in this shot, but it is known that a walking body naturally works the weight shift by tilting and rotating the pelvis, shoulders and head – bending and twisting the spine, as well as creating a pendulum

movement of the arms – to compensate the lack of balance at any moment of the walking process. This is not what happens in this shot, as there is no weight distribution to counterpoise the body: the pelvis is completely horizontal (bottom blue line in Figure 46 - a) and the shoulders are not tilting to the side of the engaged leg, in order to produce the bending of the torso to that side. As it is, that pose would only work if the body was in the middle of a swaying movement to the right.

The case of Shrek is even more problematic because he has a very heavy body and, thus, it requires a more accentuated weight shift when walking, in order to better express his weight.

That evidence of lack of weight in *Shrek* is even object of analysis in a paper by Tai (2013) who considers that the problem is mainly due to the key-framing method of animation. Apparently, he ignores that in 3D computer animation the timing is done not just by creating the key-frames for a certain duration of movement but also, and necessarily, by adjusting the acceleration and deceleration of the movement between key-frames – "slow in and slow out" principle of animation (Thomas and Johnston 1995, p. 62) – usually through the manipulation of a spline in a *graph editor*, as in Maya software, for instance. Lasseter (1987) puts it very clearly by saying that "slow in and slow out is achieved by adjusting the tension, direction or bias, and continuity of the splines" that control the interpolation and "the spacing of the inbetween".

Another example of evidence of problematic weight distribution, this one of a character representing a normal human, instead of a monster, like Shrek, is taken from the film *Ratatouille* (2007) (Figure 47).

Figure 47 – Linguini, with incorrect *line of action* and pelvis and shoulders marks (b) and a corrected version (c)
(amended from *Ratatouille* 2007).

Figure 47-a shows the character, Linguini, walking towards his bicycle, in a pose that is commonly called *passing position*, and the pelvis orientation is not consistent with the supporting leg, as there is no lateral tilt (see bottom blue line in Figure 47-b). In this case the left hip should be lowered, due to the leg being suspended, as suggested by the bottom blue line in Figure 47-c.

One may say this is due to a perspective effect, but if we take several *passing positions* of Linguini's walk – including a reverse *passing position* --and trace a line along the waist line (see Figure 48), we can see that the pelvis (waist line) keeps exactly the same horizontal orientation in every pose, independently of which leg is engaged in supporting the body at the moment.

Figure 48 - Sequence of passing positions of Linguini's walk, with horizontal red line marking the waist alignment (amended from *Ratatouille* 2007).

Thus, the analysis of this sequence of *passing positions* confirms the lack of lateral tilt of the pelvis (either to the left, or to the right side) in all these poses. Furthermore, there is also no evidence of lateral bending of the torso and of the counterpoising of the shoulders in any of the poses.

This is particularly problematic in this situation of sadness, where the dispirited state usually allows the force of gravity of the body to manifest itself in a stronger way.

As mentioned on page 17, the expression of weight of a character is essentially achieved by the way the weight shift is represented in a pose and by the way it is animated from one pose to next one, not just in terms of form but in terms of timing, showing the expression of the effort required to sustain and move the heavy (or light) mass of the character's body. This issue will be discussed in further detail in chapter 6, showing how the proposed new approach can be helpful to improve the characters' pose and body expression.

The problems affecting character's expression can be found even in professional tutorials, through official webinars, like for instance, the "Artistic Posing

Techniques for 3D Human Figures Using Poser" (Cooper 2012). Figure 49 shows a reference photo of a model with a natural twist of the body, organized in a spiral flow, as promoted by the *serpentine line* concept, in spite of the precarious balanced pose, while the replicated pose with the 3D model, on the left, is displayed in a less natural expression, failing to represent that serpentine-like twist of the body.

Figure 49 – Artistic Posing Techniques for 3D Human Figures, Poser webinar (Cooper 2012).

In the 3D model, the pelvis should be less twisted to the right than the shoulders – as it is, the body twists to the right from the feet to the pelvis and then twists to the left till the shoulders (check the blue markers in Figure 50), like in *contrapposto*. The pelvis should also tilt backwards, to reproduce the smooth curvature of the torso, in a reverse C shape instead of the reverse S shape it shows, and all the upper body (including the pelvis) should be moved a bit forward (to the left, in the picture), to keep the body better balanced.

Figure 50 – Artistic Posing Techniques for 3D Human Figures (amended with *serpentine line* marks, from Cooper 2012).

If we trace a vertical line, as the line of gravity, from the bottom point of the *S-curve* (see purple line in Figure 51), it shows that the 3D model is not well balanced, because most of the upper body is diverging from the centre of gravity, which is in the pelvis, while in the photo the centre of gravity is closer to the chest, keeping a large part of the upper body aligned with it. In the photo, the head is leaning more to the front (to the left in the photo), which also contribute to the balance.

When looking at the figure in the photo, we can perceive the strength of the whole body, like a spring, while in the 3D model the flow of energy looks like broken around the lower part of the torso, where it bends backwards as if not able to support the upper part of the body, giving the sense that the whole body is about to fall down backwards. It fails to keep that flow line unbroken, as recommended by Stanislavski (2008, p. 70), to add beauty to the movement.

The *power centre* is not in the same place in both models: in the 3D model it seems to be in the navel area and in figure from the photo it seems to be in the knees.

Figure 51 – Artistic Posing Techniques for 3D Human Figures (amended with *S-curve and gravity line* marks, from Cooper 2012).

The orientation of the feet and knees is also not according to the given reference. All these issues contribute to the unnatural pose of the 3D model, which is very difficult to achieve or sustain in reality.

One may say, of course, that such a result is the artist's own interpretation of the given image and that Art is not supposed to merely replicate reality, but it was the author who stated the purpose to show "posing techniques for getting realism and extreme poses using Poser 3D figures" (Cooper 2012). The arguments exposed in the analysis prove that both images do not share the same body posture and, therefore, the 3D image does not succeed in displaying body expression of similar quality to the one provided as reference.

Another example of the problem with the representation of the flow of force in the character's body is often observed in poses intended to portray actions in which the character is supposed to project the force of the whole body on something, like when pushing a large and heavy object. The pose "Key 9" of Figure 52, for example, which could be considered the golden pose for the pushing action

in a tutorial created by Roberts (2007, p. 76), shows a clear problem with the flow of that pose.
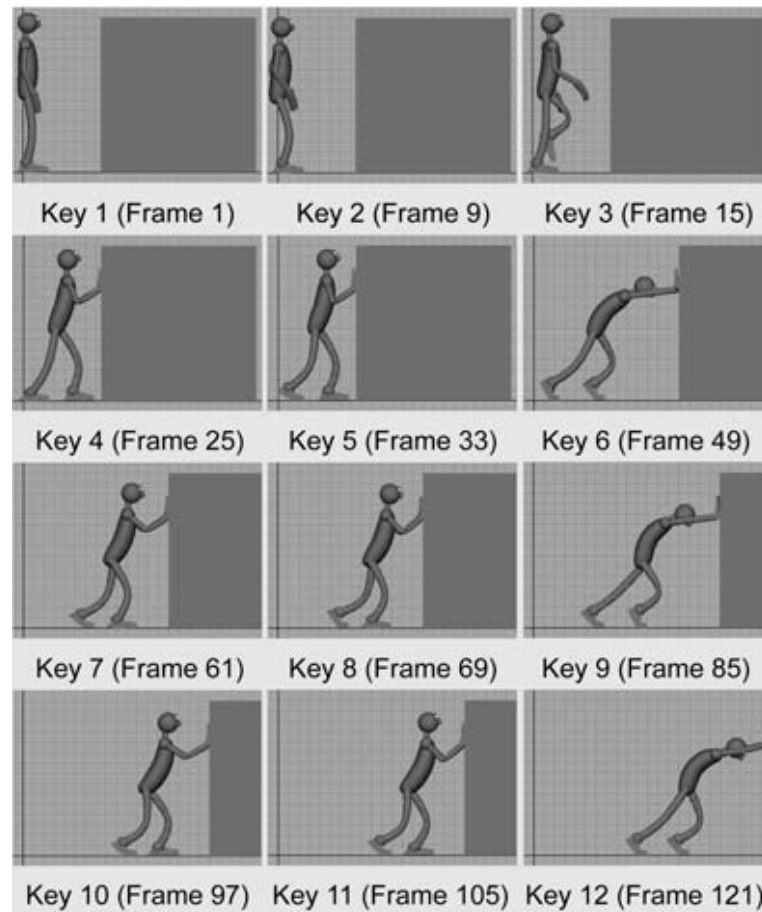
Figure 52 – Key poses for a pushing exercise (Roberts 2007, p. 76).

In this case, the *line of action* should represent the flow of energy going from the feet to the hands (the parts of the body touching the object), flowing as straight as possible, in a smooth and uniform curve (in a concave downwards shape, in side view), as shown in the image of a man pushing a car (Figure 53).

Figure 53 – Man pushing a car (amended with *Line of Action*).

If the curve is not uniform but has an inflection point breaking the flow, like an *S-curve* with an accentuated angle of inflection, for instance (see Figure 54), then it suggests that the force is diverting its orientation from the final point where it was supposed to be projected and applied to the object.
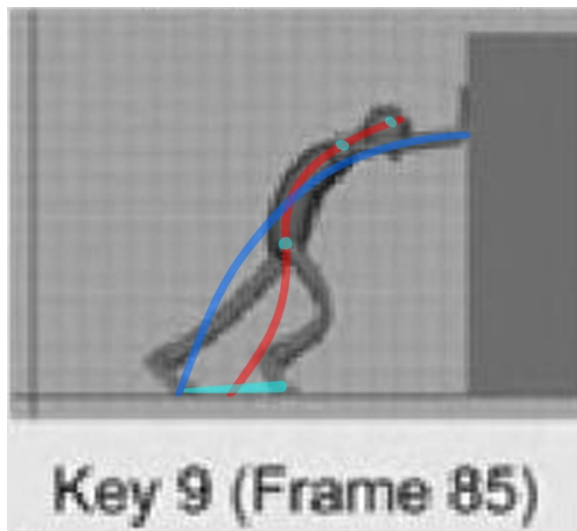
Figure 54 – Key 9 pose, magnified, with *line of action* (blue) and *serpentine line* (red) traced over it (amended from Roberts 2007, p. 76).

It is true that, in order to add more rhythm to an action, in animation it is often recommended to alternate opposite pose shapes (Jones and Oliff 2008, p. 119) like, for instance, after one key-pose with the body resembling a "C" curve, the

next key-pose should show a reverse "C" curve shape (or vice versa) and so on. However, that does not seem to be a good idea in cases of actions that require the expression of extreme force, with the whole body taut to produce and project that force.

2.6.3   Research on 3D character expression involving posing

CGI technology has made tremendous progress in the last two decades, allowing the possibility to virtually replicate almost any kind of reality. This has fostered the creation of highly realistic virtual worlds and opened new possibilities to the animation of synthetic characters and especially virtual humans, for animated films, games, special effects with digital stunts for live action films, visualization and simulation, etc.

However, as the image realism increases the viewer expects also a higher degree of realism in the behaviour and non-verbal expression of the animated characters (Beck et al. 2012). When expressions are not convincing, they fall into what Mori (1970) calls the *Uncanny Valley* and this has happened with several films such as Final Fantasy, Polar Express and Beowulf, for example.

The quest to overcome the *Uncanny Valley* tends to concentrate on the face, developing different systems of facial performance capture, perhaps because the same happens in the area of affective computing research, where the focus has been mainly on facial and oral cues, as discussed in section 2.1. The character Nestor Sextone, appearing in the short animated movie "Sextone for President" created for SIGGRAPH/88, is considered the first virtual human actor, or Synthespian, as it was named by his creator Jeff Kleiser (Plantec 2003, p. 186). Although initially shown in a full body shot, his performance is centred in facial animation based on the then new phoneme interpolation solution.

Digital doubles of several actors were created for films such as *The Matrix* sequels, in 2003, *Spider Man*, in 2004, and *Superman Returns*, in 2006, with the facial expressions scanned in high resolution, as discussed by Alexander et al. (2010), but the emotive facial performances were still not satisfactory, and therefore avoided to be shown in close-ups. *The curious Case of Benjamin Button*, in 2008, was considered the first film to successfully use facial expressions created digitally.

Another project specially focused "on the animation representation of the face" was Artificial Actors (Institute of Animation), which led to the development of a Facial Animation Toolset in 2006 (and has been evolving since then into several versions), working on animation packages (like Maya) to produce facial deformations.

The Digital Emily Project (Alexander et al. 2010) is one of the most successful outcomes of that research focused on capturing facial expression. It is a very realistic computer-generated character, developed by Image Metrics and USC Institute for Creative Technologies, that displays very convincing and believable facial animation, replicating facial performances captured with a standard video camera and processed with Image Metrics proprietary software. The result was so impressive that Plantec (2008) considered it was about to achieve a breakthrough in virtual human face animation.

However, "to bridge the Uncanny Valley it is necessary to consider emotions throughout the whole body", as stated by Beck (2007).

Most research done on posture and gesture for 3D computer animation is focused on the measurement of body postures and movements and on its relationship with intended body expression and corresponding recognition, to be applied in procedural animation, as discussed by Gross et al. 2010, Chi et al. 2000, Bull 1987, among others. Often it relates with nonverbal behaviour research, mapping body configurations into affect, aiming to build models of emotion expression

(Kleinsmith and Bianchi-Berthouze 2013) to generate autonomous behaviours in virtual humans. Yet, "Procedural gesture animation techniques typically steer the head and the arms and leave the rest of the body relatively stiff", as pointed out by Van Welbergen et al. (2010), and addressed by Huang and Pelachaud (2012), too.

One example of the research focused on the face, hands and arms is the BEAT Toolkit (Cassell et al. 2001), allowing the animator to input text to produce synthesized speech synchronized with nonverbal behaviours. It was designed to integrate other systems and allow the animator to add new "personality profiles, motion characteristics, scene constraints, or the animation styles of particular animators".

The EMOTE system (Chi et al. 2000) to procedurally generate gestures (focused on the movement of the upper body limbs), based on the Effort and Shape components of Laban Movement Analysis, in order to enhance the expressive quality of the movements portrayed by virtual humans and make them look more natural. This system was later improved by Badler et al. (2002) with a Parameterized Action Representation (PAR), with the goal of creating autonomous virtual agents. There was also an attempt to Implement the EMOTE system as a plugin for Maya animation software by Hartman (2002).

Software solutions have been developed aiming to contribute to the creation of more expressive virtual characters, such as the Actor Machine (2006), made of several modules and based on libraries of procedural assets, with the purpose to create and direct digital actors, allowing the animator to coach the application, too. Endorphin, which is a dynamic motion synthesis system to simulate character's movement in real time, "by accurately simulating the 3D character's motor nervous system and physical body" (NaturalMotion 2004) and with no use of keyframing or motion capture techniques, although allowing to create poses – Active Pose events. Noble and Tang (2006) presented an animation tool "that dynamically deforms the limbs of computer-generated characters based on the

pose and motion of their virtual bones", to enable animators to add a layer of expressiveness. A few years ago, Autodesk Maya developed a plugin initially named "Fullbody IK" (FBIK), allowing the animator to manipulate the character's body parts (such as limbs), by selecting the FBIK effectors, and have the rest of the character's body follow those movements. The plugin was borrowed from Autodesk's MotionBuilder, with the purpose of making the rigging process of a character easier and also to make the character's posture easier to achieve, but it turned out to generate problems – often collapsing – during the animation process. With the release of Maya 2012 version that tool was replaced by HumanIK (Human Inverse Kinematics) which was unified between Maya and MotionBuilder, with the same solver and the same user interface. This solution automatically adjusts parts of the body – torso and legs – when a hand is pulled further than arm length, for example, which may produce a nice *line of action*, but it does not distribute the weight correctly and does not twist the body gradually. It still has constrains, such as the requirement for the arms to be absolutely parallel to the **X** axis, in order that the rig can be applied to the character. Another interesting animation tool is Ikinema, which works within Maya or other 3D packages, providing instant rig creation and is especially oriented to *mocap* and game development.

Often the outcomes of research in character animation are the creation of animation tools, essentially based on libraries of expressions, such as the Body Shape Solver presented by Neff and Fiume (2006 and 2007), which was unusually led by aesthetics concerns (Neff and Fiume 2005). Solutions using motion data, such as the automatic rigging and animation solution, developed by Baran and Popovic (2007), to attach a skeleton to a character's mesh and automatically animate it. The data-driven solution for virtual humans, proposed by Kipp et al. (2007), aiming to procedurally recreate gestures in the style of human performers, obtained from video data, so that the expression of the virtual character looks more natural.

However, basing the animation of a character on a collection/library of expressions is always a limited option, first because the existing collection (whatever its size might be) is limited and, secondly, because all the characters will tend to behave similarly under similar circumstances. In this sense, using pre-existent motion data to animate a character is like creating some sort pastiche animation, where the motion will probably not reflect the physicality and the personality traits of the particular character.

Other solutions are the Sketch based tools, which tend to provide more power to the animator as an artist, such as the sketching Interface presented by Davis et al. (2003) to create "3D articulated figure animation, from 2D sketches"; Or the character sketching tool (Thorne et al. 2007), presented as one of the two components of an animation system, to sketch "the skeletal links comprising the basic character shape".

Lately, some sketch-based tools have been exploring the concept of *line of action* as a solution to intuitively manipulate a character rig, which are discussed below.

SketchPose: Artist-Friendly Posing Tool presented by Duncan and Swain (2004) at SIGGRAPH 2004, to allow animators to position sets of controls of a character with stroke of a mouse, directly in the camera view. This solution was created with the purpose of freeing the animator of the complexity of manipulating dozens of controls, allowing him to focus on the performance of the character. There is not much information about it (and Disney never replied to my emails) but the authors claim that it "has become an important part of the animator's toolbox" at Disney, especially useful to manipulate tentacles or hair. Mark Swain reaffirmed later, in Josh Carey's blog (Carey 2007b), that it has been used at Disney for various applications.

Josh Carey attempted to replicate the SketchPose tool presented by Duncan and Swain (2004), as explained in his blog (Carey 2006; Carey 2007b), where he

presents his version *Jc_sketchPose* tool. The beta version 0.9 can be found through this link: http://www.vfxcreator.com/jc_sketchPose/. It aims to work on single chain skeleton objects and not in the entire body of a character. The rotation and twisting functionalities were difficult to solve, as Carey mentioned (Carey 2007a) and Mark Swain also referred to that problem in Josh's blog (see Carey 2007b) "The Rotation aspect is one of the more difficult parts of the tool. I guess it could be done in *mel* but it will be a little slower. The interaction is also difficult without using the API".

Another interesting solution (clearly inspired in the SketchPose, by Duncan and Swain 2004) is proposed by Öztireli et al (2013), presenting a sketch-based interface that uses the *line of action* concept to manipulate the skeleton, drawing the skeletal deformations (even with curved bones), based on a differential blending algorithm. Their purpose is the creation of caricatured poses with a high degree of deformation (like the *rubber hose* style), stating that it "allows fast and intuitive creation of highly expressive poses". However, they say "highly expressive poses" just because of the high degree of deformation achieved, but they do not show any concern for the believable arrangement of the body parts, in terms of weight distribution, balance, force, rhythm, and controlling the subtleties of each joint rotation or translation.

Guay et al. (2013) also present a solution clearly inspired in the SketchPose tool (Duncan and Swain 2004), although they do not refer to it. They propose an interface to intuitively sketch a line, to which the character is automatically aligned into a pose, through a mathematical definition "by solving an optimization problem". However, their idea of *line of action* and its implications in a pose does not seem that correct, considering some example images provided. Furthermore, extending the *line of action* concept to an extra line – "secondary lines" – used just for the upper limbs of the body reveals a limited understanding of the rationale behind it. That line represents the flow of energy sustaining the body and,

although the arms and hands are often aligned with the *line of action*, like in a pushing action, for example (as discussed in section 2.6.2), it does not make sense to refer to a line, which goal is to define the position of just the arms, as a *line of action*. That would be a line of gesture, maybe… The arms and hands do move describing a curved "path of action", like most things in nature, as defined by the "Arcs" principle of animation (Lasseter 1987; Thomas and Johnston 1995, p. 62), since their movements depend on the rotation around pivot points (shoulder, elbow, wrist), but the *line of action* guides the whole body posture required for any action. Furthermore, the arms move independently from one another, whether in reaction movements for instance to keep the balance of the body, or in actions with intentional movements. There is no flow of energy going from one arm to the other, unless in some exceptional case like, for instance, the arm wave kind of dance. Therefore, applying the *line of action* to guide the position of the arms seems useless and, in some cases, it may even promote the symmetry in the arms' position, as shown in the examples. That problem, which is usually called "twinning", as discussed in section 2.2, page 33, is something that must be avoided at all cost when animating a character because it gives a robotic expression, since in nature the limbs do not move or position in symmetry but rather the contrary. Thus, proposing to pose the two arms with a single stroke is something silly from the animation point of view. From the above exposed reasons, it seems that the authors of this paper have limited knowledge about character animation or even about the *line of action* and the *S-curve* in Arts and, therefore, the project is directed by erroneous assumptions which lead to some inaccurate conclusions and propositions.

A sketch-based interface, as the name suggests, aims to help with the manipulation of the character but, *per se*, does not help the animator to define the arrangements of the body parts into a meaningful pose.

Other common solution to address the posing is the use of libraries of poses, working as plugins (e.g. Pose Manager (PoseMan), poseLib (2012), Pose It (2012), etc.) within the animation software, allowing the animator to create and store collections of key-poses for each character he is animating.

Some authors (Gutierrez et al., 2008, p. 50) say that "In the next generation of animation systems, motion control tends to be performed automatically using artificial intelligence (AI) and robotics techniques.", substituting the "traditional" technique of key-frame animation in the production of animated films. However, as Jeff Light (Vitz et al. 1996) stated some years ago "animating the subtleties of real human or animal motion is highly complex. Motion capture or procedural animation approaches may provide partial answers, but are not a panacea". Things have improved a lot since then but there is still a decisive lack of achievement in animation software that points to a gap in finding definitive solutions for character animation expression. Even some new approaches to control the character's posture, such as those of Wei and Chai (2011), Öztireli et al. (2013) and Guay et al. (2013), do not consider the body as a whole when it comes to nonverbal communication, focusing their research on the movement of the limbs. That is, the tendency is still to ignore that it takes the whole body to express the emotions and intentions, as pointed out by Ed Hooks (2008) and Aubert (2003, pp. 9-10).

The process of animating 3D characters – and posing, in this case – depends on the technology, and vice versa, and will continue to evolve together. Argyle and Trower (1979, p. 22) wrote that body language "is beyond machines", like the computers. It was a long time ago but it seems still true. Considering what has been done, so far, and what has not been achieved, yet, it is important to keep searching for new solutions to improve 3D character's expressiveness.

2.7 Summary

This chapter discussed the theoretical framework of body expression and character posing in the 3D computer animation arena, including other contributions that are considered important to the posing process. Body expression involves an understanding of body language – its representation, perception and interpretation – which is essential for character animation, assisting the process to define the pose according to the situation. In the posing phase of the animation process, the animator must very accurately create the right posture and implicit body motion, in order to convey the particular personality and emotions of the character. A pose is good when it fits the purpose of illustrating what is happening, i.e. when it conveys the intended expression according to the circumstances and to the characterization of the character, allowing the audience to perceive and recognize that intended expression. Therefore, it is important to create the correct configuration of the body, in order that the audience can understand what they see and get involved with the story. Furthermore, each expressive action of a character must be defined by, at least, one key-pose or golden pose, independently of the number of extremes and breakdowns. Only after creating the key-pose(s), extremes and breakdowns and having generated the in-betweens from the registered keyframes, the resulting animation will show exactly the particular way the character moves and acts.

3D computer animation can still learn from traditional animation and other arts, and posing can be improved if some concepts are systematically integrated in its process. That is the case of the *line of action* and of the *power centre* (borrowed from acting), already used in animation. Likewise, some concepts related to fine arts, like *contrapposto* and *serpentine line*, can be useful for posing, in order to improve the representation of the character's pose. In a sense, any statue (or painting) depicting a posture or action of a person, for instance, is a golden pose created by the sculptor, since he has only one pose to make the sculpture

meaningful (to tell the story, to express the emotion, mood or attitude). As it was shown, those four concepts can be identified in poses produced in different art forms, which reveals its importance for posing. Moreover, anatomy knowledge is also important for character animation and here the focus has been particularly on the anatomical qualities of the torso and its contribution to give flexibility to the body and therefore to avoid the stiffness look of the animated characters.

Posing involves many factors and concepts and also the technicalities related with the virtual manipulation of the 3D character in the animation software, making the process of creating the pose a very demanding task. Often the character is manipulated like a doll or an action figure, as if the most important thing to manipulate in a 3D character is the limbs. Even in terms of research in animation, some researchers have been focusing more on the movement of the limbs, maybe influenced by the importance it has in gesturing, neglecting the importance of the whole body for the character's expression. In fact, most research has been led by procedural animation and affective studies for virtual humans, aiming to establish correlations of behaviour and create libraries of expressions or poses, and not so much to give the animator the ability to create expressive poses.

Considering what has been discussed and the objectives of this research, a new posing approach will be proposed in chapter 4.

3   Methodology

This research adopted a practice-led approach, since it was focused on a particular stage of the animation process and practice. The research hypothesis had a somehow heuristic motivation, as it came from the author's experience as animation lecturer and animator, and that experience was used to develop the new approach to posing. Furthermore, practice-based is commonly considered the most appropriate methodology to follow when doing research in the field of arts, with the objective of producing knowledge on a new model of practice.

Some authors, like McNiff (2002), refer to this kind of research as practitioner-based research or self-reflective practice and Schön (2006) calls it reflective practitioner research, as the focus is on the researcher's self-reflection. Candy (2006, p.3) considers that "there are two main types of research that have a central practice element": the practice-based research, when the contribution to knowledge is based in a creative artefact; and the practice-led research, which "is concerned with the nature of practice and leads to new knowledge that has operational significance for that practice". They have in common the opinion that this practice approach falls (or tends to fall) into the area of Action Research.

A methodological difference of this study is in having defined a hypothesis and objectives, which contrasts with the McNiff (2002, p.6) statement that "action research is open-ended" and "does not begin with a fixed hypothesis".

Furthermore, the focus of this research was "to advance knowledge about practice", like Candy (2006) says, and the main objective was not to create new artefacts or creative outcomes – although some poses were planned to be created as well as a 3D pose tool, to test and evaluate the conceptual hypothesis. As Candy (2006) states, "in a doctoral thesis, the results of a practice-led research may be fully described in text form without the inclusion of a creative outcome".

The nature of this research was essentially qualitative because, as Hazel Smith (Smith and Dean 2010, p. 4) says, "qualitative research is the best way to gather data about an issue or idea [...] to allow the subjects to express their thought in their own way" and "permits both documentary evidence and investigational evidence".

Since the aim of this research was to contribute to improve the quality of 3D character's expression, all the stages of the process – issues of current practice, case studies, applications and demonstrations results – are also analysed and evaluated on its quality.

Furthermore, considering that body expression is about visual perception, evidence must be given also visually, either for identification of rationale of the concepts and description of the issues, or for the demonstration, analysis and discussion of the case studies.

Since the problem was clearly identified from the beginning, the necessary contextual review (see chapter 2) was carried out, to deepen knowledge and gain new insights on body expression, character posing practices and the concepts that were part of the research hypothesis, in order to develop the conceptual idea for a new approach. This included research related to body language, anatomy knowledge, and how it is applied and expressed in different arts – sculpture, painting, drawing, acting and dance – as well as in character animation. The character expression in 3D computer animation was also focused, particularly the practice of posing. The current professional practices of posing in 3D computer animation and also information about how animators are/were taught to do it, were investigated in different kinds of media. This included evidence of problems and analysis of attempts that have been made to improve the process. The investigation was further extended through an exploratory experiment, as an informal address of ideas in order to develop the conceptual solution and its underlying technical theory (see appendix A).

Several specific issues were identified (or confirmed), which could be solved, or avoided, by following the rationale of the proposed approach, as documented in sections 2.6.1 and 2.6.2. Those issues emerged as case studies – focused on particular situation – and were carried throughout the research process.

The conceptual approach and the 3D pose tool were developed simultaneously, in an iterative cyclical process – developing, applaying, evaluating, adjusting, evaluating again… – involving the researcher´s reflection about about his practice and that of other professionals and considering also existing theories about pose creation, while overlaying images of masterpieces and the case studies, towards the formulation of a new theory of posing and its complementary tool.

The new approach, as a theory of practice, is explained in chapter 4 and the process of development of the tool is documented in chapter 5. Each chapter includes its particular reflections.

The applications of the new approach and the demonstration of its advantages were achieved first by replicating poses of masterpieces, as a visual validation of the approach. Then, by taking some of the examples given as evidence of problems affecting the posing of 3D characters (discussed in section 2.6.2), analysing each case and applying the new approach on them – generating new poses – to show evidence of how it can help solving those problems (see chapter 6). The choice for those two movies (Smurfs and Shrek) was led by the intention to pick examples from one case with cartoony characters acting in a humans' world and another with human-like characters in a fairy tale's world, showing that the evidence of problems is common to characters acting in both worlds.

These applications of the new theory of practice were presented through case studies, using images on which are superimposed marks of the rationale of the new posing approach (in chapter 6). This was followed by images proposing new 3D poses with better body expression generated specifically for each case, with

the conceptual guidance of the new approach and including the representation of the pose tool (which was used to assisted their creation), as a visual representation of the *expression cord* – synthesizer of the conceptual guide, to demonstrate the usefulness of the proposed approach.

This way, the conceptual hypothesis was tested and the procedural benefits and its value as a model of thinking and engagement were evaluated through a self-reflective process. It also involved adequate written references supportive of each case under analysis from body language experts, as well as from animators and animation authors collected in the contextual review process and presented and discussed in chapter 2.

The testing and validation of the pose tool with a significant sample of professional practitioners and students will be object of future research, after the prototype has been finalized as a plugin.

In summary, this thesis presents a theory of practice, which was developed through reference to field literature, evidenced through pertinent case studies and evaluated through a self-reflective address of personal practice and application.

4   A New Posing Approach

Michelangelo considered the torso as "the key expressive area of the body" (Chapman 2010, p. 24), conveying the movement and torsion of a figure, through the positioning of the shoulders and the pelvis, as discussed in chapter 2. Likewise, the torso is the core of this new posing approach centred on the expression of the body as a whole. The key to avoid the problem of the lack of expressiveness of the character's body resides mainly in the torso and how it is manipulated by the animator – or at least that is the point where the problem begins and if not properly addressed the pose will not be expressive. As discussed earlier, in section 2.5, the torso is the part of the body from where most motion originates and therefore affects all the other parts of the body that are connected to it in a pose and, in turn, the pose is essential to create the body expression of an animated character.

Animating with 3D software requires a different process to create the pose, when compared to traditional animation techniques, like drawing on paper, for example, as discussed in section 2.6. It is more difficult to keep the focus on the whole body of a 3D character while manipulating its multiple rig controls in order to create the pose for a particular moment of action. Moreover, the sense of the whole body in a pose might be further affected when the animator adopts the layering approach of animating, focusing on one part of the body at a time, as discussed in 2.6.2.

Apparently, the importance of the torso – and of the spine as its structuring element – to the expressiveness of the character's body has been neglected (or even ignored) by many in the 3D animation field, especially in what concerns the anthropomorphised characters. As mentioned in section 2.6.2, even nowadays there are riggers and other animation professionals working that part of the body as if it was a broken line constituted of a few segments, instead of representing the way the anatomical structure of a humanoid operates.

The torso bends in a curve, more or less accentuated, from the base (pelvis) to the top (base of the neck, although the spine continues till the base of the head), and that is particular evident on the lateral bending, as shown in Figure 55. In fact, the lateral bending and the twisting of the spine "are always associated movements and neither can take place independently of the other" (Palastanga and Soames 2012, p. 460). Therefore, there is no need for manipulators between those two points (pelvis and top of the torso), when the character is not intended to perform a *rubber hose* style of animation. If rigged properly (as explained in section 4.5), the curve of the spine can be defined and controlled just by translating and/or rotating the controls in the pelvis and in the top of the torso, without having to spend time manipulating extra controls in between. This kind of solution provides a very accurate depiction of the posture of a humanoid or anthropomorphic character, while allowing the animator to create the poses in a very efficient way, too, as will be explained later.

Figure 55 – Example of a bending torso, by Kampert (2010).

This picture is also a good example of the *serpentine line* concept, with the torso twisting to the left, gradually – from the bottom to the top – as part of the whole body twist, continuing the twist suggested by the feet and legs and being

completed by the twist of the neck as a result of the head rotation to the left, too. The arms and hands complement that twisting expression, as an extension of the direction of the shoulders and of the flow of the body, as well.

The pose of that dancer also serves as an example to show that, besides the torso section, other parts of the body must be harmoniously arranged with it, in order to produce the whole body expression. There is a clear axis, comprising the *pelvis,* the *shoulders* and the *head*, along with the position of the feet (that influence the upper body of the orthograde biped, particularly in any standing position), which shall be manipulated in a 3D character through the corresponding control points, in order to create a harmonious posture. The imaginary line of that axis and the control points connected by it have a central role in the posing approach proposed here, which is shaped by a combination of concepts.

In the following section (4.1) the four concepts that contribute to the new approach will be discussed, and the resulting synthesis, represented by an imaginary line, as the expression of energy that structures a pose, along with the rationale of its use, will be explained in section 4.2. The visualization of the approach concepts as a visual tool will be described in section 4.3, followed by some considerations related to aesthetics (section 4.4) and character rig (section 4.5). The proposed workflow for this posing approach will be discussed in section 4.6.

4.1   The concepts contributing to the approach

The initial hypothesis of this research is that a solution to help the animator to improve the body expression of the 3D character and make the posing process more efficient, should lie within the combination of four main concepts – *Power Centre*, *Line of Action*, *Contrapposto* and *Serpentine Line* – as stated in chapter 1.

The contribution of each of those concepts to the proposed approach, as a conceptual guideline to the posing process, is discussed below.

The creation of body posture (whether in animation or in other visual and performing arts) is essentially determined by the personality attributed to the character and is also influenced by his state of mind and emotions, which are determined by the interactions and other circumstances along the story.

The *power centre* concept associates a posture with a place where the energy that holds the pose or leads the movement seems to be centred. That imaginary spot of energy is particularly apparent in a thrust of the body (or part of the body) that often contributes to the expression of attitudes or emotions. However, the use of *Power Centre* implies that each posture shall be considered as a cluster of several body parts and its positions, following the rationale of gesture reading presented by Pease and Pease (2004, p. 21) and discussed in section 2.1.2. In animation, one must work in similar but inverse way: given a described circumstance or action, the animator shall question which elements – cluster – of the character's body must be manipulated to create the appropriate pose and convey the intended expression for that specific action. It is up to the animator to decide how each part of the body is influenced by a particular *power centre* and how it manifests in the character's performance, in terms of rhythm, later.

The placement of the *power centre* spot works for the animator as a referent of a particular characterization or mood, which is expressed by a particular pose (visually concrete and objective in terms of arrangement of the body parts). The pose is, in turn, interpreted by the viewer as a certain meaning of mood, attitude, etc., that is commonly associated with that perceived posture. Of course, it deals with the subjectivity of the animator's interpretation on, and his imagination of, where is the centre of energy that produces a certain expression in a body.

The position of the *power centre* in a resting or static pose may remain unchanged, defining the posture characteristic of a particular personality, or mood, but may alter its place when there is a change in the state of mind, for example. Moreover, it may change from place to place when performing very dynamic actions, for example, in order to pull the part of the body that leads the movement at a particular moment, similarly to what Chekhov suggested with his *imaginary center*, as discussed in section 2.4.4. Sports provide many examples for these dynamic actions, like for instance: the confident football player, with a *power centre* in the navel, which will move to his foot that is kicking the ball; or the basketball player jumping and throwing the ball through the hoop, with the *power centre* in the hand that holds the ball. An even more comprehensive example of that changing of place is the high jump athlete's performance, using the *Fosbury flop* technique, where the *power centre* can be clearly perceived moving along the body, in an effort to keep above the bar the part of the body that is sliding over it at each instant.

So, the *power centre* is initially "given" by the personality but may be changed by the circumstances affecting the character, like in those examples above or in other resulting from the status transaction when interacting with others, or affecting his mood, etc. For example, a proud character has the *power centre* at his chest, but when he is feeling sad or humble the *power centre* is down on the floor, as seen in Figure 7, from the film *The Last Laugh*.

Thus, applying the *Power Centre* concept during the posing process can be very useful to define the character's posture and the way his movements will be animated, since it helps to determine which part of the body leads the movement. It is useful even if just as an imaginary spot that the animator keeps in the back of his mind while animating the character.

The *line of action* also deals with the thrust of the body, which is very important to a meaningful pose, as discussed in section 2.2, especially to the expression of

accentuated action. Similarly to what happens in drawing, where "the form's exact thrust or direction" must be decided before drawing the shape of the form, as stated by Hale (2009, p. 120), the animator must decide first about the thrust or direction of the character's body, before creating the pose. Thus, the *line of action* works as a structuring element of the pose (Goldberg 2008, p. xix), as discussed in section 2.3.1. This concept follows the philosophy of gesture drawing (as mentioned in section 2.4.3) and serves the purpose of helping the 3D animator to concentrate more on expression of the action or the posture and the intention, motive or driving force behind it. By doing so, the animator refrains himself from being a slave of the 3D model and its rig – with all those controls – in the initial phase of the posing process. Obviously, he needs to manipulate some of the rig controls in order to get the character's body following the intended *line of action* but he does it according to that guiding element.

The angle of the line – a more diagonal or vertical position – usually defines the dynamic intensity of the thrust of the body, i.e. the expression of force of the posture is greater if the curve has an oblique direction, which makes it more dynamic. For example, when depicting a forward movement, the whole body leans, showing the top ahead of the base, as discussed by Loomis (1971, p. 115) and "the faster it goes the greater the slant" between the base and the top. That direct relationship to the thrust or inclination of the character's body helps the animator to define not just the movement but also the expression of the intention behind it, according to the defined purpose of that movement or action, in the given situation. That is, the direction may also discriminate the dramatic meaning, like for instance the diagonal leaning forwards to the centre of interest when showing interest or liking and backwards, when expressing avoidance, astonishment, passiveness, etc., as discussed in section 2.1.2. Therefore, the direction and shape of the line may vary, reflecting different meanings and also different intensities. For example, the poses that follow the shape of a plain curve are likely to express stronger force than if following an accentuated curve or *S-*

curve, since the flow of energy is not deflected along the form, and it also implies that the movement to achieve that position is faster.

The *contrapposto* concept can give an important contribution to posing, by helping the animator to work the weight distribution of the body, which is fundamental to portray a figure in action, as stated by Loomis (1971, p. 38). Creating the illusion of weight in a character is not easy, as stated by Webster (2012, p. 64), but, if the animator follows the rationale of the *contrapposto,* he may organize the body parts and work the balance in a logical and easy way, producing a sense of weight that looks natural. The process shall be directed by the pelvis, considering the influence of the engaged foot or feet, and then propagates to the other parts of the character's body. For example, when creating a relaxed posture in which the body is supported mostly by one foot, after positioning the character's feet, he may start adjusting the pelvis control to produce a lateral tilt, moving the hip of the less engaged leg down, and continue from there, counterpoising the body as described in section 2.3.3. Likewise in the passing position of a walk, when the body is supported by one foot, creating a similar lateral tilt and moving the hip of the suspended leg down.

As part of the process of distributing the weight and keeping the balance of the body, the pelvis also needs to swing laterally – to the side of the engaged leg. When working that lateral tilt and swing in a male character, the animator must be careful not to exaggerate on the push of the hips sideways, since that may make the character look like gay, portraying a female posture. The swing needs to be wider for female characters because the female pelvis is wider than the male pelvis and, therefore, requires a wider lateral displacement in order to keep the alignment with the supporting foot, as discussed in section 2.5. This is particularly accentuated when walking in the catwalk style, with the feet moving along a straight line and wearing high heels shoes, as discussed by Roberts (2007, p. 127).

There are exceptions to the way of distributing the weight based on the influence of gravity. For example, whenever the action requires the main effort to be produced on the legs, as the primary action, like when a person in a standing position raises a foot or a knee with intention, the natural tendency of the human body to reduce the effort will be subdued to that requirement. In such a case, the pelvis tends to tilt laterally by lifting the hip on the same side, almost immediately, due to the activation of the hip flexors (the muscles that connect the spine and pelvis to the top of the thigh bone – femur) of that side of the body. This effort to raise the leg – either bending or straight – requires the body to adjust differently, starting from the pelvis up to the torso – usually reversing the lateral tilt of the pelvis and shoulders and the "C" shape curve of the torso, when comparing to the relaxed standing position or the normal walk. This inversion of the common *contrapposto* will also depend on the complementing movements to be performed by the upper body. There are several other examples – kicking the ball, running faster, taking longer strides, etc. – where the hip of the supporting leg will no longer be the highest but the lowest and the counterpoise will be achieved the other way around.

Either way, the organization of the body parts promoted by the *contrapposto* generates tension and relaxation between left and right sides, along the character's main axis, possibly extended to the upper limbs (as described in section 2.3.3). These sort of antagonistic movements – suggesting the parts moving in opposite directions – imply opposite forces and thus produce a sense of tension and effort to drive the body into a specific pose, while fighting against the force of gravity (the body weight). The interaction among the parts of the body also produces a change of shape of those parts, as well as a change in the rhythm of the body shape, and its representation is very important to give the perception of life, mood, emotion and attitude, and to justify the action. That illusion of weight, along with the fluidity and rhythm of the character's body, must be complemented later with the appropriate *timing*, as mentioned on page 17. Furthermore, by

emphasizing by the bilateral contrast in shape of the body, the *contrapposto* also promotes the asymmetric pose, which is important to avoid the twinning effect, as discussed in section 2.2.1 – page 33.

The *serpentine line* concept can also contribute to improve the creation of expressive poses in 3D character animation, as it defines the flow of force going through the body which structures the pose. With its twisting and winding characteristics, it promotes the torsion of the whole body, which is important to suggest the expression of effort or energy in a pose, as discussed in 2.3.4. Its resemblance to a torsion spring is essential to express dynamic intensity, and in fact it may work as a torsion spring, for instance when an action is preceded of an anticipation – storing energy during the anticipation movement and releasing it in the action. The animator needs to make sure the torsion is accompanied by the corresponding effort in the action (i.e. not just for the sake of being twisted) in order to look convincing, as discussed in section 2.3.4.

Those characteristics are also particularly useful for the expression of dramatic intensity, psychological pain (not just the physical one), emotional tension, inner conflict or turmoil, as mentioned by Roberts (2007, p. 184). For example, by orienting the torsion (i.e. shoulders/top of the torso) towards the centre of interest or against it (trying to avoid it – e.g. scared expression).

The *serpentine line* does not necessarily produce always an *S-curve* shape – it may be a *C* or reverse *C-curve* shape, depending on the action or reaction being portrayed, such as the liking or avoidance attitudes, for example.

In terms of arrangement of the body, if the *serpentine line* rationale is followed, "each part of the body varies in some way from the corresponding opposite part", as recommended by Thomas and Johnston (1995, p. 67) to avoid the symmetry and twinning problems (discussed on page 33). This may add to the rhythm of the weight distribution, in the coronal plane, given by the *contrapposto*. Furthermore,

it makes the character look more natural in dynamic poses, due to its fluidity and tension qualities. The head is, usually, oriented to the centre of interest but could be towards the point he is moving to (or away from it, in case it is something he wants to avoid), or oriented to the supporting foot, for example.

Like with the *contrapposto*, the lateral tilt of the shoulders also counterpoise the pelvis in most *serpentine* postures but there may be exceptions, depending on the action. For instance, when the character is trying to reach something in a high position, standing just on one foot (or ball of the foot) and stretching the body to reach it with the hand of the opposite side, both the pelvis and the shoulders will tilt laterally to the same side.

The *serpentine line*, along with the *contrapposto*, help to define the rhythm of the pose, since they determine the way the different parts of the body interrelate and are organized into a whole – by producing different displacements (including orientations) among those parts – and, therefore, promote the variation of rhythm from pose to pose, which are important to define the character and the quality of the expression of his motion, as discussed in previous sections (2, 2.3.3, 2.3.4 and 2.4.3).

The combination of these four concepts, applied systematically during the posing process, will allow the animator to organize the body parts in a logical way, that makes it look natural (and recognizable) and, therefore, creating more expressive and appealing poses, as discussed by Lasseter (1987). If, for some reason, there is a moment when the character is static – not performing a clear dynamic body expression – then the animator may not need to have a *line of action* in mind when creating the pose. However, the concepts of *power centre, contrapposto* and/or *serpentine line* are always needed to organize the body parts and create the appropriate posture, full of expressiveness and appeal.

This combination of concepts is synthesized in a conceptual guideline aiming to structure the main body of the character, from the feet up to the head, which can be agglutinated into an imaginary line, as described in the following section.

4.2   A synthesizing imaginary line

The imaginary line or cord, with three-dimensional properties, resulting from the combination of the *line of action*, the *contrapposto* (with the resulting *S-curve*) and the *serpentine line,* synthesizes the force – the flow of energy going through the main body – that sustains and structures the pose. Such a cord, allowing a particular curvature and twist, is also the synthesis of the rhythm produced by the different parts of the body in a particular moment. Thus, by changing in shape through time – between key-poses, for example – it represents the variation of the flow of energy that organizes and drives the pose at any given time, working in a similar manner to what Stanislavski (2008, p. 70) called "the inner line of movement", which he considered the basis of the plasticity of motion. That imaginary inner line defines the flow of the movement of the body (going through its parts), coordinated with tempo and rhythm, as Stanislavski stressed, and the inner flow of energy must be clearly established when creating the key-poses of a movement, or even a somehow static posture.

This proposed imaginary line is more than the *line of action* concept discussed in sections 2.3.1 and 4.1, which usually goes from the bottom of the body to the other extremity where the force is projected and, in many cases, starts from the foot opposite to the direction of the movement, which is likely to be the main support of the body at the beginning of the movement; it may as well start from the other foot (in the direction of the movement), when representing the ending of the movement, as shown in Figure 3.

Differently from the traditional *line of action*, this one, an *expression cord*, as I would call it, shall go through the middle of the upper body, linking the control points at the centre of the head, the base of the neck and the centre of the pelvis. The bottom point of the cord shall be placed close to one foot or the other, depending on which one is supporting more weight of the body, and that position – where the line of gravity, like a plumb line, meets the ground – will contribute to define the curve of the segment of the cord corresponding to the legs, in the coronal plane (front or back view) and also in the sagittal plane – in case the feet are not side by side but in a stride position, for example (see Figure 56). The top point of the segment is obviously dependent on the pelvis, which displacement, in nature, is primarily determined by the feet's position and the constant effort to keep the balance of the body. The angle of the tilt of the pelvis will also contribute to determine the curve of that segment, as it is particular evident in the postures shown in Figure 78, for example.
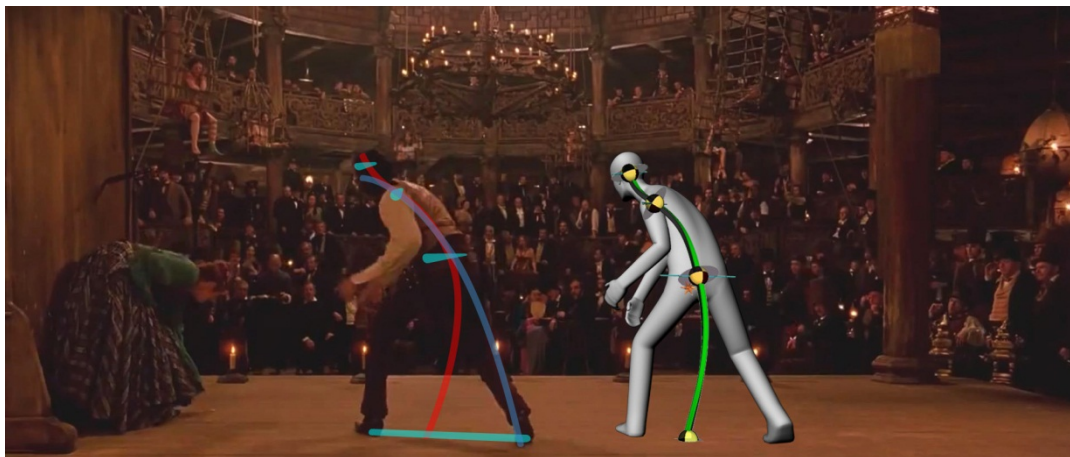
Figure 56 – The traditional *line of action* (in blue) and the *expression cord* (in red), with its control points amplifiers (in cyan), traced over the character Bill; and the NGuy, with the 3D Pose Tool, replicating that pose, on the right side (amended from *Gangs of New York* 2002).

Contrary to the representation of the *line of action* that some authors tend to make (for example, Webster 2005, p. 54), the *expression cord* shall not follow the shape of the legs, i.e. shall not bend with the legs – going through the knee(s). The reason is that, for instance, when someone in a standing position bends his legs

they act like a spring – absorbing and/or producing the force that supports or drives the body up into a particular position – and the imaginary flow of energy continues to go directly (straight or in a smooth curve, depending on the orientation – tilt – of the pelvis) from the feet to the pelvis. In that case, the imaginary cord shortens the segment corresponding to the legs, keeping the smooth continuity of the arc between the pelvis and the feet control points (as illustrated in Figure 57) and, by doing so, expressing better the flow of the driving force of the pose.

a	b
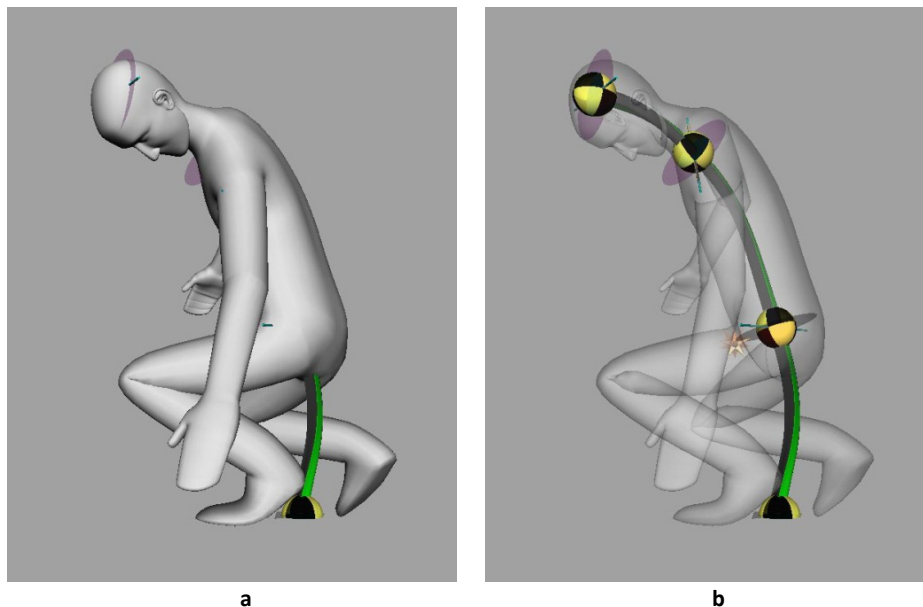
Figure 57 – NGuy with the 3D Pose Tool, displaying *X-ray* off (a) and on (b). The character is bending his legs, producing the shortening of the legs' segment of the *expression cord*.

Regarding the torso section, in anatomical terms, although the spine has an '*S*' shape when seen from the side (sagittal plane) in the body upright position (Figure 33 - a), the *expression cord* shall go through the *line of gravity*, in order to bend only when – and how – the torso bends. The shape of this segment of the *expression cord* is determined by the rotation and/or translation of the control points of the pelvis and/or the top of the torso.

The segment of the *expression cord* going from the base of the neck to the centre of the head shall also go through the *line of gravity*, in order to bend and twist as

the neck does. The shape of this segment is determined by the rotation and/or translation of the control points of the head and/or the top of the torso.

There is an exception to the *expression cord* going through the *line of gravity*, when the character is not in the neutral upright position but has another permanent condition, like for instance a hunchback or an old person with an accentuated curvature of the back. In those cases, the overall shape of the upper body does not match the *line of gravity* and, therefore, the *expression cord* shall follow the particular posture, going through the middle of the torso and of the neck, in order to reflect that peculiar characterization.

For the *expression cord* to express the flow of energy in a fluid way it shall have the flexibility and smoothness of a *Bezier curve*, keeping the imaginary line unbroken and adjusting the smoothness of its curve after any control point manipulation.

In addition to the *expression cord*, the animator shall imagine several segments of straight lines crossing the body, horizontally in the coronal plane, as position amplifiers for the pelvis, the shoulders, the head and also one connecting both feet on the floor (as represented over many images in section 2.4). Moreover, each amplifier's line shall always maintain a perpendicular relationship with the line of the *expression cord* at the point where they intersect each other – where the control point lies. That condition is what makes the *expression cord* produce an *S-curve* shape, or at least a smooth curvature in the two sections adjacent to a control point, whenever one amplifier changes orientation in the coronal or sagittal planes, thus simulating the qualities of the *Bezier curve*. Those amplifiers will be a complement particularly useful to provide additional mental guidance about the twists and lateral tilts of those control points and, by using them, the animator will easily arrange those parts of the character's body according to the concepts of *contrapposto* and/or *serpentine line*. It should be noted that the orientation of the shoulders (and its position, naturally) may vary from that of the top of the torso, because the shoulders are very flexible and able to move

independently of each other. In fact, in a twisting movement of the whole body, often the shoulders overlap the orientation of the top of the torso in the transverse plane, or even in the coronal plane.

Manipulating those control points (while keeping in mind its amplifiers) according to the *contrapposto* concept will produce an *S-curve,* especially evident in the coronal plane, as shown in Figure 78, for example. The curve of the *expression cord* will have a subtle twist and counter-twist in the legs and torso segments, while the head segment may twist in the opposite direction or be an extension of the torso segment, often depending on where is the object of the character's gaze.

When the control points are manipulated according to the *serpentine line* concept, it will produce an *S-curve* or a *C-curve* (or maybe one on a view plane and another on other view plane), depending on the attitude to be portrayed. The *expression cord* will have a twist that may correspond to the entire body – from the feet to the head (e.g. Figure 80) – or just from the feet to the top of the torso, while the segment from the top of the torso to the head may have a counter-twist (e.g. Figure 84), which again depends on where the object of the character's gaze is located.

The *power centre* concept also influences the shape of that imaginary cord, as it acts like a magnet that leads the part of the body that is under its influence. Taking the example of a football player kicking the ball, as shown in Figure 58-b, the *power centre*, located in his right foot, is driving the main movement and pulling the pelvis forward, making the *expression cord* to bend in a more accentuated curve in the sections that are influenced by the pelvis control.

a	**b**
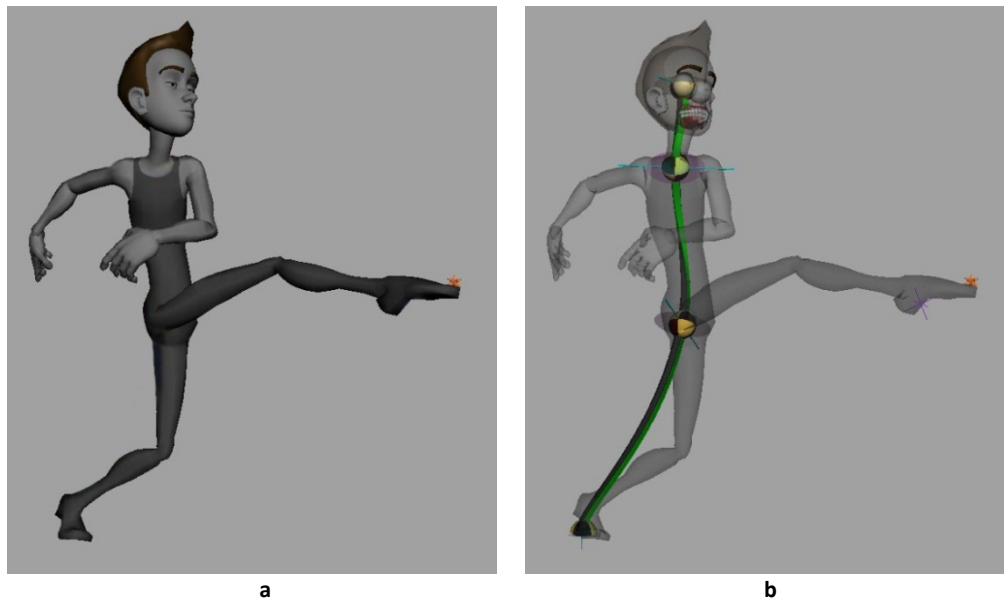
Figure 58 – Key-pose of a football player (Morpheus) representing the final moment of the movement/action of kicking the ball. Normal view, with _Power Centre_ spot (a); and X-ray view, showing the _expression cord_, too (b).

The angle of inclination of the _expression cord_ depends particularly on the dynamism or implied speed of the movement being represented in the pose, similarly to the _line of action_, as discussed in the previous section. This is determined by the degree of misalignment (parallel offset) between the centre of gravity of the body and the supporting foot or feet (or the backward foot, when the entire body is off the ground). That discrepancy occurs in the direction of the movement and varies according to its intensity – the higher the intensity, the bigger the discrepancy tends to be. The intensity also affects the position of the centre of gravity of the body – the higher the intensity, the higher the position of the centre of gravity will be (shifting from the normal position in the middle of the pelvis towards the chest). Checking with the _line of gravity_, may help the animator to decide how much inclination the body shall have in a pose to be coherent with the thrust or the momentum of the action.

However, not all dynamic poses are represented by an overall inclination of the body – and its cord – towards one direction. In the anticipation pose, for example, although representing the initial moment of a dynamic action – usually twisting

and bending in opposite direction to the main action, to gain force – the body never gets out of balance and, therefore, there should be no misalignment between the centre of gravity and the supporting foot (or feet). Otherwise the body would not get the firm base of support for projecting the force on the opposite direction and would fall, instead. When performing an anticipation, the bottom part of the cord is usually oriented towards the main action and the upper part leans to the opposite direction, producing an accentuated "C" or reversed "C" curve shape. That shape should reverse in the reaction phase of the movement, after the main action has occurred.

The expression of speed of the movement is complemented afterwards, by working the *timing* of the sequence of poses – duration (number of frames) plus acceleration, deceleration (relative position of each element in space) – as mentioned in sections 2.1, 2.2 and 2.6.2.

The position of the bottom point of the cord is primarily determined by the position of the feet, as mentioned before (page 131), since those are the base of support of the body of any orthograde biped, in an earth gravity environment. In an upright static stance, with both feet on the ground and the weight of the body evenly distributed, the projection of the centre of gravity to the base of support will be between the feet, as discussed by Smith et al. (1996, pp. 51-52). However, that projection may change to the toes, when the body is standing on toes, or even be centred in just one foot, if that one is bearing all the weight of the balanced body, as illustrated in Figure 59.
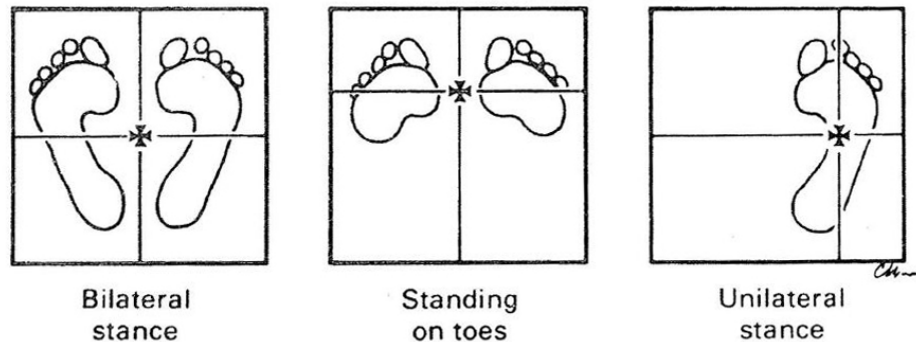
Figure 59 – Projection of the centre of gravity of a body in a static stance to the base of support (Smith et al. 1996, p. 52).

Moreover, a lateral variation of the projection – moving closer to one foot or the other – may also occur, determined by any particular weight distribution (like when promoted by *contrapposto*), or by the inclination and/or bending of the body usually required to portray a specific attitude, which will change the corresponding position of the centre of gravity. The forward variation – moving from the ankles to the tip of the toes – will also be influenced by the inclination and/or bending of the body. Furthermore, those kinds of variation may also occur in response to some kind of interaction with external elements that affect the centre of mass of the body, like a character holding an object in his hands, while keeping his arms straight, for example.

Those variations – which part of each foot (heel, ball or tip of the toes) is providing the support – and also the change of position of one foot – forwards or backwards – in relation to the other will determine the orientation (rotation around the Y axis) of the imaginary bottom point and bottom amplifier of the cord.

This rationale has exceptions, like for example when the character is not standing on his feet but seated, with both legs suspended off the ground (pulled by gravity, only). In that situation, the rationale of this approach should be applied only from the pelvis up to the head. Therefore, the *expression cord* should be considered only in those two sections, since the flow of energy sustaining the body originates

from the pelvis, under those circumstances. However, if the character is seated but the feet are still in contact with the ground, acting as complement of the body base of support that helps to keep the balance of the upper body and also provides a base to power certain movements of the upper body, then the cord begins from the feet or foot that provides the impulsion. This is the case, for example, with the sculpture of *Laocoon and his sons* (Figure 60) because the legs are not suspended but, instead, are an active part in sustaining and giving consistency to the dynamic posture of the entire body. The struggling body expression of *Laocoon* shows a clear flow of energy going from his left foot up to the torso and the head.

Figure 60 – Laocoon and his sons (40-30 BC), attributed to Agesander, Athenodoros and Polydorus, of Rhodes (JuanMa 2008).

So, the position of the character's feet may be dictated by the particular position of the upper body (inclination, bending and/or twisting), including the arms orientation, inherent to the portrayal of a specific action, but the opposite is also true: the position of the upper body may also be dictated by the position of the feet. Therefore, the idea of blocking just the upper body first, hiding the feet and legs and hoping to easily get their position in each pose, later, as suggested by

Kelly (2008, p. 31 and 2013, p. 117), and was mentioned on page 86, may not be a good idea, since it neglects the importance of the driving force that sustains the whole body. Although Kelly says that he only uses it in action scenes, the rational of that suggestion does not consider the fact that in an earth gravity environment the position of the feet is often decisive to determine (and therefore to justify) the arrangement of the parts of the upper body, either in a dynamic action or a standing pose. In any case, the rhythm of the pose – the way the body parts relate to one another – and, therefore, the flow of force are affected. If that idea is followed, the resulting poses may look as if the legs were being dragged by the pelvis, lacking the expression of energy going through the body and failing to make the pose look convincing. Probably, as Kelly (2013) admits, at the end the animators "have to at least slightly readjust the hips and torso" (p. 117) and, therefore, will also need to readjust the arms (and the head, probably), because the torso affects the parts of the upper body which are connected to it.

Another exception example, related with environment conditions, would be, for instance, when the character is acting like a monkey in the jungle, swinging from branch to branch (or like Spiderman). In such a case, the body starts to organize from the holding hand and arm (which conditions the weight distribution of the body), then the shoulders, the pelvis, etc., reversing the flow – shoulders > spine > pelvis.

The rationale of the *expression cord* helps the animator to work the weight and its distribution in the character's body, which is essential to any posture, as discussed in section 2.2. This is done through the use of the *contrapposto* concept, i.e. counterpoising the body by arranging its parts in oblique forces according to the intended attitude and considering the base of support of the pose. By doing so, the animator starts working the balance of the character's body, which is another key issue to an effective animated body expression (also discussed in 2.2). If the character's body does not look balanced when in a standing position or

appropriately unbalanced according to the action being performed – representing the effort to overcome the inertia and control the momentum in each phase of a specific movement – then the expression of the body will be compromised, as it will look wrong and will fail to convince the audience (e.g. Figure 92).

This solution also promotes the asymmetry of the pose, since the *contrapposto* and the *serpentine line* change the position and orientation of the bottom and the top parts of the torso, varying the position of each of the pivot points where the legs and arms are attached – hips joints and shoulders joints. Those variations naturally suggest different arrangements for each of the limbs, leading the animator to create the position of each arm and leg in harmony with the main body where they are connected (or the other way around, when a hand or foot leads the movement). This way, it helps to avoid the so called *twinning* problem mentioned on pages 33 and 112, and to generate more explicit body forms and shapes.

Therefore, the proposed *expression cord* helps the animator to ensure the perception of the character's pose by the audience, which is always (or should be) a concern when posing, in order to make the actions readable, as referred by Maestri (2006, p. 147), and is usually checked through the silhouette (mentioned on page 32).

Although the legs are not directly controlled by the *expression cord,* the curvature of its bottom section in the coronal plane, along with the position of the pelvis control point, may implicitly suggest when one of the legs bends. The indication is given through the lateral tilt of that control point, producing an oblique orientation of the imaginary amplifier in the coronal plane (and, inherently, the curvature of the cord), providing that the rig has the *Inverse Kinematics* activated for those limbs. That way the lower extremity of the amplifier indicates that the distance to the ground is shorter, i.e. if the foot is on the ground, the leg of that side must be

bent, unless the control point is also translated upwards (like when trying to reach something in a high position).

The counterpoising promoted by the *contrapposto* and the twisting and winding effects promoted by the *serpentine line* are both reflected in the form and shape of that *expression cord* (even if just an imaginary one). This means that the *expression cord* should never be left completely straight and untwisted, both in the sagittal or the coronal planes, and in any of its sections, even if the character is shown just in a close-up shot. Otherwise, it will mean that the character's body parts are not properly arranged as a whole, in that pose. Although the expressive quality of the imaginary line is determined by (and reflects) the intended pose, it should aim at what Ruskin (1991, p. 136) recommends in his Law of Curvature:

> "graceful curvature is distinguished from ungraceful by two characters; first in its moderation, that is to say, its close approach to straightness in some part of its course; and, secondly, by its variation, that is to say, its never remaining equal in degree at different parts of its course."

He adds that such variation has two conditions: no part of the line shall look like a segment of a circle and the curve itself is composed of small graceful ones. Similar recommendation is made by Hogarth (Hogarth and Paulson 2007, p. 48) referring to his "Line of Beauty" (like the *S-curve*), saying that its curvature must not be too rounded nor too straight. Moreover, in order to add beauty to the movement, that imaginary line must be fluid and unbroken, as stressed by Stanislavski (2008, p. 70) and was discussed in sections 2.4.4 and 2.6.2 – i.e. should not have inflection points. Examples of this broken line issue can be seen in Figure 51 and Figure 54, in section 2.6.2, and Figure 92 and Figure 96, shown in chapter 6.

The torso plays an essential role in making the imaginary line fluid, since it accommodates that line going through the middle of it. Moreover, the tilts and twists of the pelvis and the shoulders (at the bottom and the top of the section) influence not only the corresponding segment of the line but also the adjacent segments corresponding to the legs and the neck. Therefore, the torso section is

fundamental in creating expressive character's postures and the *expression cord*, with its associated concepts, is an important guide for the animator to achieve that purpose. However, the contribution of the torso to the body expression is not confined to the bending and twisting that determines much of the curvature and flow of the *expression cord* through the whole body. The shoulders' position is also an important complement to the body posture, as discussed in section 2.1.2, and must be considered in the posing process, even when the pose does not involve significant movement of the arms/hands. Likewise, the orientation of the knees and feet must be considered, too.

By encompassing the main axis of the body – *pelvis, shoulders* and *head* – the *expression cord* (and its underlying concepts) becomes a good solution to avoid the stiffness look of the torso discussed in sections 1.1 and 2.6.2. It is also a good solution to address the expression of the flow of energy progressing through the body and the way the body parts are directed to produce the tension and/or relaxation more appropriate for a posture or a dynamic action. Therefore, it responds to the requirements of a good pose mentioned in section 2.2.1 and helps to the creation of expressive and appealing poses.

In summary, the concept of *expression cord*, with its amplifiers, works as the guiding image in the animator's mind (by analogy with the rational for creating shapes presented by Arnheim 2004, pp. 93 and 461), i.e. a "skeleton of forces" or configuration of visual forces that determines the character's pose. It structures the main axis of the body and determines its visual expression qualities – shape and direction, while dynamism or speed is implicitly expressed in a pose by the two first ones. The sequence of poses and its timing will accurately define the speed and rhythm of the movement.

The embodiment of this *expression cord* – and its underlying concepts – as a visual tool is described in detail in section 4.3.

4.3   Embodying the approach concepts as a visual tool

The imaginary *expression cord* and its control points, incorporating the concepts discussed in previous sections, should look like the model presented in Figure 61, lying in the middle of the body of a standing 3D character (see page 327) at rest, as explained in section 4.2. However, that *cord* must be visible from the outside in order to provide visual guidance and feedback to the animator.
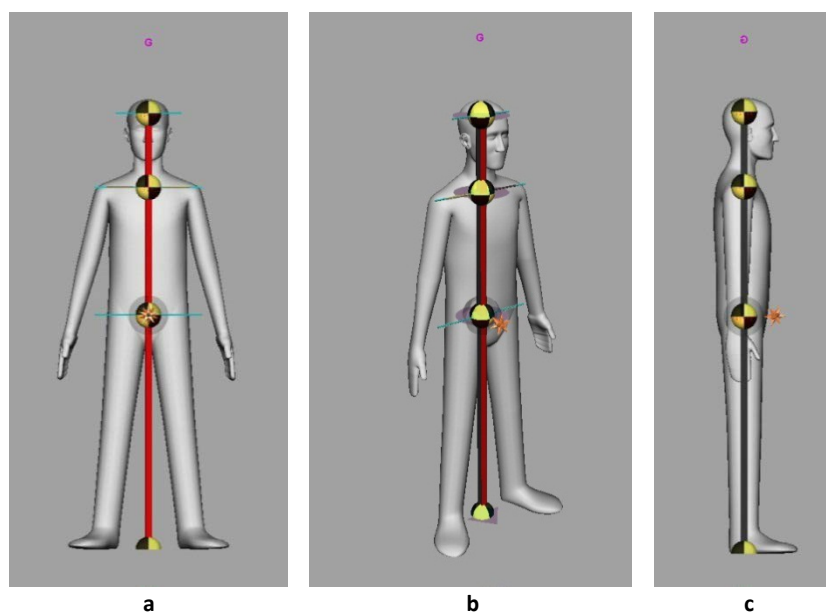
Figure 61 – 3D character with 3D pose tool. Front (a), ¾ in front (b) and side (c) views.

The *cord* should behave like a *Bezier curve* and the control points to manipulate it should be represented by spheres located at the pelvis, the top of the torso and the head, and a half sphere between the feet. In the example above, the position of the *Head* control is placed higher than the alignment with the ears/eyes (see page 184) in order to display a longer length of the top section of the *expression cord*, for demonstration purposes.

As a visual tool it must generate automatic visual feedback about the rotation and/or translation of the hips, top of the torso and head, as well as the bending of the torso and the neck, and also about the position of the feet. The feedback is

given by the shape of the cord and the position and orientation of the spheres and amplifiers. The feedback about the twisting is be given by the torsion of the *expression cord*.

The change of position of the control spheres, in translation, could be suggested by analysing its position in relation to the line of gravity (or balance). For example, in a standing pose, if the pelvis and top of the torso controls are at different distances from the line of gravity, that means the character's pose could be unbalanced and would need some correction, unless it is part of some movement. In that case, the greater the difference, the stronger is the implied movement. If the hips, the top of the torso and the head controls are in the same side of the line of gravity, that means the character is moving (even if it is just falling) to that side. And, again, the degree of the leaning of the line defines the intensity of the movement of the body.

A spirit level could be added to the visual tool, in order to indicate the level of tilt (rotation on the X and/or Z axis) of the control spheres (see Figure 62) and, thus, provide additional information about the orientation of those manipulators. This could be achieved with a half sphere inside each sphere, which orientation would be calculated from the difference between the initial and the present rotation values of the sphere. The contrast between the triangular shapes (interpolated in black and yellow) of the outer sphere and the horizontal line produced by the half sphere would generate the spirit level effect, as shown in the examples below.
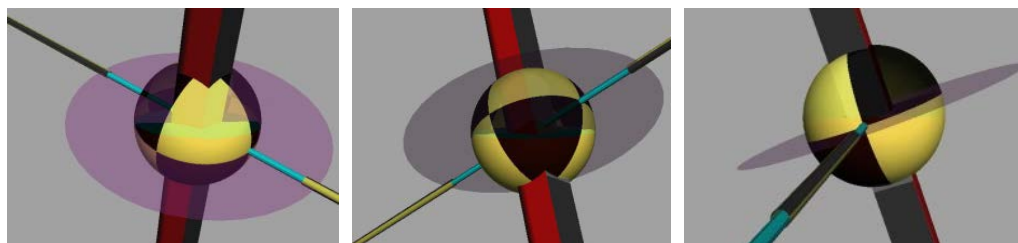
Figure 62 – Examples of 3D pose tool manipulator with spirit level function and shoulders amplifiers.

Moreover, since the shoulders are inside the torso, its positions may be not easy to notice in some occasions and, therefore, two shoulders amplifiers like those included in the 3D Pose Tool (see Figure 62 and Figure 67) could be visually useful to the animator.

A gravity line could also help the animator to work the balance, by providing a visual guidance on where the centre of gravity of the character should be aligned, in case of static and balanced poses. Moreover, it may also help him to decide about the degree of inclination the body shall have – centre of gravity of the body not aligned with the initial line of gravity that is determined by the feet's position and weight distribution – in case of dynamic poses of an action, as discussed in 4.2.

Regarding the visual representation of the *power centre,* its placement is not supposed to be defined with mathematical precision, since the concept exists at an abstract level (in the animator's mind, in this case) and only the corresponding body expression is visually perceived. This could be done by creating a symbol (a simple shape) in the 3D software, which would be attached to the character's rig and placed where appropriate, according to the position where the source of energy of the character is supposed to be, in any given moment. That spot could display different quality levels (such as being movable, changing size, colour, or intensity, etc.), as Chekhov (2010) mentioned about the *imaginary center* (see section 2.4.4) and, therefore, should be parented to the main body, so that it goes with the character but also allow it to be moved around the body, to the most suitable position. Therefore, a virtual spot within the pose tool interface would work as a reference of a particular *power centre* of the character and would be very useful to remind the animator of the character's particular characterization initially attributed, and how it should behave. Furthermore, being able to be moved around according to the circumstances affecting the character, it could work as an indicator of the *power centre* change, marking the part of the body that

should lead the way or even the area outside of the body that holds the posture in each particular moment of the scene.

The use of a virtual spot based on the *power centre* concept, working as a label attached to each character, could also be very useful to keep consistency of the character's performance, by helping to overcome the problem resulting from the same character being animated by different animators in different scenes and also the problem of the animator having different characters (with different personalities) to animate in the same scene.

There are many other possible ways of implementing this concept in 3D character animation, which could involve an automated (to a certain extent) relationship between each specific *power centre* and the corresponding posture, following the cluster rationale mentioned in sections 4.1 and 2.1.2. This could be done by creating a collection of postures associated with a list of *power centres* for each character, and registering them in a scale (in the character's Attributes, in Maya) through a *Set Driven Key* solution (where the value of one attribute is driven by the values of another), controlling the higher levels of each control hierarchy. It would be part of the character's rig included in the Maya scene file provided to the animator and, when posing, he would select the value of the *power centre* attribute that would be more convenient to a given situation.

However, in order to define the cluster of body elements that should be affected by a particular *power centre,* one must consider how it affects the skeleton of the character (especially the main axis). This leads to a list of elements (or joints), which can be affected in multiple combinations:

- Head tilt and/or rotate;
- Neck bend and/or twist;
- Shoulder translation (usually controlled by clavicle rotation);

- Elbow orientation/translation (usually controlled by the shoulder pole vector);

- Spine bend and twist;

- Pelvis tilt, on *Z* or *X* axis;

- Knee orientation/translation (usually controlled by the hip pole vector);

- Foot orientation/translation.

The examples of *power centres* usually provided are just references to characters and their behaviours, as mentioned in section 2.3.2 and do not go further into the description of its implications on the articulation of the body (the position of each part of the body – specially the pelvis, shoulders, knees, etc.) in order to portray a specific posture. Probably, this happens because the authors consider that it is up to the animator to decide how to arrange the body parts to create the pose.

Taking the *macho man* (or *ladies' man*) type, for example (see Figure 5-b), the *power centre* at the groin should produce a character's posture with the pelvis pulled forward and tilted backwards (by translating forward on the *Z* axis and also rotating on *X* axis). The legs would be slightly bent – bringing the pelvis slightly down – with the knees far apart, pointing outwards, and the feet also oriented outwards. In the upper body, the chin would be slightly down, the shoulders to the back and slightly down, and the elbows far apart, too. Even when walking, it involves a laid back position of the upper body combined with a pelvic thrust with every stride, as mentioned by Roberts (2007, p. 126).

Another solution to implement the concept would be applying the rationale of the force of gravity in which, by default, the body is pulled down to the ground unless another force – the *power centre* – pulls it upwards to the position/posture more convenient to portray a specific personality or attitude. Arnheim (1996, p. 142) has an interesting statement related with this rationale when he writes about beauty and its dependency of the dynamic expression of the body:

"beauty does not depend on shape as such but on the dynamic expression conveyed by it. Dominant among the dynamic features is the sense of physical and mental vitality, which manifests itself, for example, in the body's response to the force of gravity. Giving in to gravity, which pulls us to the ground, expresses a lack of vitality, a lack of initiative, a listlessness and weakness. Gravity is overcome by striving upward, which stands for energy, youthfulness, action. Therefore, beauty is impeded by anything that sags – a sagging cheek or shoulder, a sagging breast."

This quotation is very important to understand the concept of *power centre* and its applications to 3D character animation. This, in fact, inspired the solution that should work, metaphorically, as a string puppet – marionette – in which a specific string (or set of strings) needs to be pulled up in order to put the body in the appropriate posture to convey the body expression. The *power centre* control spot would work, metaphorically, like the control bar of the marionette, allowing the animator to choose among the characteristic postures that were pre-defined with the clusters for that specific character. This control spot would act like a visual reference connected to a pop-up lever, sliding vertically along a power intensity scale, or it could be integrated in the *channel box*, as an attribute, consisting of a scale of values.

A visually more intuitive solution to manipulate the *power centre* would be the association of the position of its control spot, or locator, with the cluster of controls of the parts of the body required to achieve the representation of the posture corresponding to the specific *power centre.* Depending on its position – orientation and distance in relation to a reference point in the body – which would be calculated by the system/plugin, the character's body would assume a particular posture. This could even result from a blend of two main postures and the degree, or percentage, of influence of each other should be defined by how far or close the control spot is from each of them. It would work like a system of coordinates in the 3D space, in a similar rational to the *kinesphere* of Laban, with an imaginary bubble surrounding the character's body, including the extension of the limbs in any direction.

Either way the *power centre* and its corresponding posture would be the starting point from where every pose, or at least every scene, would be initiated by the animator.

The visual representation of the *line of action* is provided by the shape of the *expression cord* presented earlier (Figure 61) and may be applied as such, with a nuance proposed in the previous section. That is, basing the bottom point of the line on the spot where the line of gravity touches the ground – the centre of the base of support (Smith et al. 1996, p. 51) – as discussed in section 4.2, instead of the traditional way – often starting from the foot opposite to the direction of the movement, as discussed in section 2.3.1.

Nowadays, there are tools that allow the animator to draw a line on top of a character, like the *grease line* tool (in Maya), and thus he can draw a *line of action* and use it as a guide to structure the pose. However, that is not enough as it might not reflect the position of each of the body parts of the 3D character.

In terms of manipulation, besides the earlier mentioned control points of the *expression cord*, it could also be done with a stroke-based solution, like those sketch-based interfaces discussed in section 2.6.3, to help defining the inclination and flow of the body, in the second step of the approach – applying the *line of action* concept. Such a solution, by tracing a simple stroke, would make it faster to define the overall slant and curvature of the *expression cord*, which could be fine-tuned afterwards and would be worked in the subsequent steps of the approach.

The *contrapposto* is visually represented by the position – orientation and translation – of the spheres and its amplifiers (Figure 61), which is also reflected on the shape and form of the cord. Its manipulation is achieved by translating and rotating the control points corresponding to the head, top of the torso, pelvis, and feet (centre of the base of support).

The *serpentine line,* like the *line of action*, is represented by the shape of the *expression cord* but also by its form – the three-dimensional quality that shows the twisting condition. However, its manipulation is achieved the same way as the contrapposto, with all the precise adjustments related with the counterpoising and torsion being done directly on the specific controls.

Following the philosophy of gesture drawing – focusing on the essence of the pose – will be more effective with visual guidance like that provided by the 3D Pose Tool, presented in the next chapter. The process can be even more efficient if the animator is allowed to manipulate the main axis of the character's body – pelvis, top of the torso and head – directly through the tool controls. Furthermore, the process could also be enhanced if the 3D cord is defined by the stroke of a sketch-based solution, as mentioned earlier.

Several ideas have been presented and discussed, envisaging solutions to provide the visual dimension of the proposed approach and its contributing concepts. The development of the 3D model and its rig, as a pose tool, is discussed in section 5.1.

4.4   Aesthetic considerations

The proposed approach promotes the creation of naturalistic postures when posing a character, in the sense that the body parts will be organized in a pose according to references from nature, thus, providing believability (Williams 2001, p. 34; Hayes and Webster 2013, p. 4), as discussed in section 2.1.2. However, that does not mean it will dictate a naturalistic performance of the character, as the poses may be pushed, at the animator's will, to a level of *exaggeration* (Lasseter 1987; Thomas and Johnston 1995, pp. 65-66) that creates a performance more in accordance with the *interpretation* animation category (Webster 2012, p. 34), typical of stylized or cartoony animation. The purpose of this approach, although basing the posing on natural dynamics of the human body, is not to merely

represent the reality but to transpose it, going beyond realistic performance, similarly to what Lecoq (2009, p. 45) advocates for acting.

Although promoting a naturalistic aesthetics of the body posture, it can also be applied to cartoon characters because in spite of them being ruled by the so particular *cartoon laws of motion*, the structure of the body and the way the limbs are disposed is still governed by the representation of how the anthropomorphised body would look and behave in natural conditions, most of the time. But that does not mean it has to have the aesthetics of the *rubber hose* animation, with the characters behaving as if they have no skeleton structuring and constraining the form of the body. As an example, Figure 63 shows Bugs Bunny and Sulley in a similar pattern of body expression, representative of a naturalistic relaxed and contemptuous posture, also associated with a self-satisfied expression, as mentioned by Argyle (1996, p. 205, citing Sarbin and Hardyck).

a	b

Figure 63 – (a) Bugs Bunny (The Wacky Wabbit 1942) and **(b) Mike** and **Sulley** (Monsters University 2013).

Actually, this approach can even be applied to more abstract forms, as long as its formal pattern presents what Arnheim (2004, p. 461) calls a "skeleton of forces" (as mentioned in section 4.2) that characterizes the intended meaning and allows the viewer to interpret it, because, according to Arnheim (2004, p. 461), the expression of a body can be reduced to a play of forces. Of course, it will not be very useful if applied to limited animation, like South Park (made in 3D computer

animation but replicating the style of traditional cut-outs technique) which characters have very limited body expression, mainly due to a lack of flexibility of the torso.

The concepts combined in this approach – *power centre, line of action*, *serpentine line* and c*ontrapposto* – are not mere guides to structure a pose, as they have also an aesthetic purpose: to assist the creation of expressive poses. Therefore, the use of these concepts requires the understanding of the rationale behind each of them.

Furthermore, it must be noted that the idea is not to make use of those concepts as a matter of style in itself, where, for instance, every pose must obey to the *serpentine line* concept and compulsorily incorporate it in a clear way, just for the sake of showing its effect, like in Mannerism (in Sculpture and Painting), as discussed in 2.3.4. The torsions must be accompanied by the expression of effort, to suggest energy, as pointed out by Shearman (1990, p. 83), in order to convincingly express emotions, intentions and attitudes. However, animators should be aware that in nature the human postures alternate, in most cases, between the *contrapposto* (in relaxed standing poses) and the *serpentine line* (in dynamic poses) representations, or a cyclic alternation of both (like in a walk), as discussed in chapters 2 and 6.

Therefore, these concepts must be combined and applied with moderation and according to the circumstances, as discussed earlier, keeping in mind that the creation of the poses is dictated by the intended expression to be achieved or story to be told (whether for film or other purpose) and those poses will determine the expressive qualities of the animation generated from them.

The objective is to apply these concepts as a solution to organize the several parts of the body in a fluid and harmonic way, based on natural references, to assist the creation of 3D character poses in any style of animation. As discussed in section

2.1.2, animators must depart from reality in order to make characters' actions look believable, arranging the masses of the characters' body in a natural way when creating a pose, even if their designs do not look like real people or animals, as pointed out by Williams (2001, p. 34).

Moreover, the proposed approach is a solution to help the animator to organize the character's body (its parts) considering the cluster (Pease and Pease 2004, p. 21) associated to the pattern (Arnheim 2004, p. 449) of posture that is recognizable by the audience as a particular expression of the body. People recognize things as they happen in nature (as discussed in section 2.1.2) and in that sense it promotes an aesthetics of naturalistic expression of the body, but not to the point of seeking accurate depiction of every detail, in terms of forms, and rejecting more idealistic or symbolic expressions/solutions, or even *over-determined* expressions produced by exaggerating the reality, as discussed by Wells (1998, p. 27). It must be stressed that the objective is to assist the creation of expressive poses through the strengthening of its believability, so that the character's body appears more engaged in the action or attitude he is supposed to perform. Clearly, the objective is not to constrain the freedom of creation of the character's body expression, through some sort of a "realistic image system" (Wells 1998, p. 25).

In the end, the animator makes his own representation of that expression applied to a specific character, using his creativity to adapt the pattern to a particular character and context. So, in that way is not a mere reproduction of reality but a creation to effectively communicate a certain expression, with an aesthetic purpose, too – not only believable but eliciting a perception of beauty.

Therefore, this is about naturalistic representation of behaviour or of the implied movements, through the arrangement of the body parts into patterns of expression (as referred by Arnheim 2004, p. 449), and not so much about the

representation of forms, and definitely not about the photorealistic rendering of forms discussed by Power (2009).

The naturalistic representation of the patterns of expression also depends on the quality of the controls of the body parts, which will be discussed in the next section.

4.5   Character rig considerations

A 3D character is manipulated by the animator into an intended pose through a set of controls (manipulators) that are previously built in the character according to its characteristics and its role. Therefore, the quality of the set of controls, including the corresponding internal structure and the solutions it offers, will determine the way the character will be manipulated during the posing process, with consequences to the efficiency of the entire process – the time consumed and the creative result of the poses.

The fact that the torso behaves (bends and twists) in a very harmonious and progressive way – like a concertina – (see section 2.5), as the example in Figure 55, shows that there is really no need for a rig with controls in the middle of the torso, or even in the neck, as long as those sections of the skeleton have *ikSplines*, with progressive influences assigned to their control vertices. Those rig controls in the middle of those sections would be useful only for the previously mentioned *rubber hose* animation, which style requires free deformation of the body parts.

The efficiency of the proposed approach may be increased if the rig is built without extra controls in the middle of the torso (as discussed in 2.6.2 and at the beginning of this chapter), because that will make it easier to bend and twist the torso in a gradual way – producing a fluid and naturalistic curvature. Furthermore, it will also make the animating process less time-consuming, as there are less controls to be

manipulated – just one control at the bottom (pelvis) and another at the top of the torso (see Figure 64).

a	b
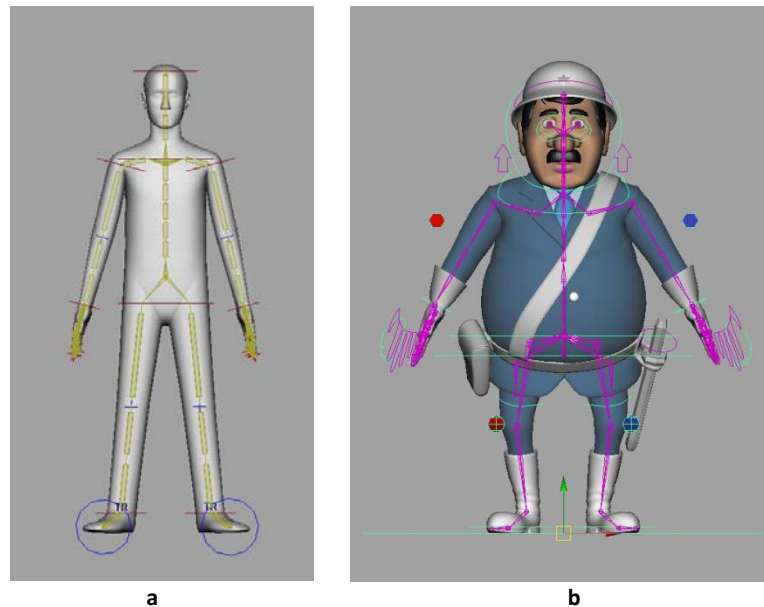
Figure 64 – NGuy with HumanIK rig (a) and Police with a rig created specifically for him (b).

In the rig examples shown above, the section of the spine corresponding to the torso is created with several joints that are controlled by an *IK Spline* solver (in Maya software), which curve is controlled by two manipulators, one in the pelvis and another at the base of the neck. Even the section of the neck has more than one joint, and the same kind of solver applied to it, to allow producing a similar curvature when leaning or rotating the head and, that way, avoiding the stiffness of the neck (as if was a stick on the top of the torso).

Furthermore, whether the pelvis control is independent of the upper body control or not, it shall affect the base of the spine, by changing the orientation of the first bone of the spine, which consequently influences the entire spine (more strongly on the bottom section) and gradually decreasing the curvature towards the top. That is what happens in reality and can be easily observed in a nude torso in action, as for example in Figure 36 (section 2.5), being particularly evident in the coronal plane view, in situations when the pelvis is tilting laterally, as replicated in

the character shown in Figure 65-b. The difference in the resulting geometry deformation of the torso (as well as in the bones string of that section of the spine) is evident when compared with the same character in Figure 65-a, in which the rotation of the pelvis does not affect the joints of the spine.
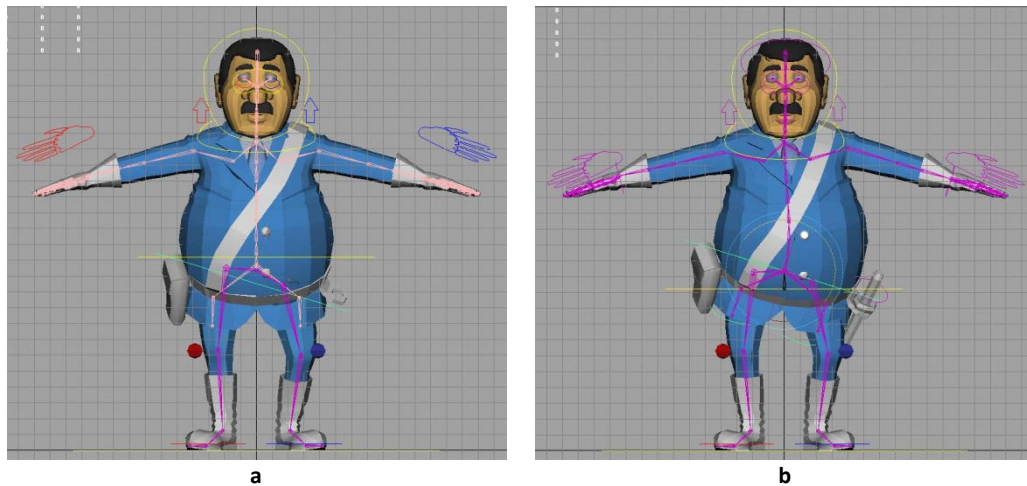
Figure 65 – Police proxy, with skeleton and rig controls. Rotating hips without the pelvis (a) and with the pelvis (b).

Some may argue that keeping the pelvis/hips rotation independent gives more freedom of manipulation but, knowing that in reality the rotation of the pelvis (in whatever axes) influences the spine (and the legs, as well), why not establish that connection automatically in the rig? That way the animator does not need to spend time creating the corresponding effect in the spine, afterwards, and it also avoids the possibility of that harmonization being forgotten to be done.

Therefore, this thesis proposes a simpler rig in what concerns the manipulation of the torso and head – pelvis, top of the torso and head pivot points – corresponding to the controls of the 3D Pose Tool (discussed in 5.1.3).

4.6   Workflow of the approach

There are two schools of thought as how to pose a character in computer animation, within the key-framing technique, as mentioned in section 2.6.1. Basically, the animator may pose the entire body at once by keying all the controls of the elements of the character's body before moving to the next pose; or he may create the pose by layers, taking a part of the body at a time and keying it in all the keyframes of the timeline of the intended motion. Animating with 3D software requires the manipulation of several controls of the virtual character, even if to create just a rough pose, which makes it more difficult for the animator to keep concentrating on the action and the driving force that structures the body as a consistent expressive whole.

Therefore, this thesis proposes a workflow that mixes those two methods, posing first the parts of the body directly affected by the main longitudinal axis of the body – represented by the imaginary *expression cord* – followed by the arms (up to the wrist level), leaving the hands/fingers and other appendages, or loose parts, as well as the facial expression to be posed at a later stage. That is like layering the posing process within each pose, in a sequence according to the flow of energy going through the body. The idea is to "re-centre" the character animation into the whole body expression rationale, keeping it as the main priority when posing.

In order to achieve that, the animator shall focus first on the character's personality and his mood in that scene, considering what has just happened to him – the reasons for the present situation (a scene begins in the middle, as Hooks (2011, p. 24) says). Furthermore, he needs to focus on the action that better expresses the character's emotions and the pursuing of his objective while overcoming the obstacle and imagine the golden pose or poses that best illustrate that action or attitude.

Initially, it is of fundamental importance to characterize the character according to the provided biography, giving him the suitable posture (as discussed in 4.1), which will be afterwards attuned to the attitude required for each scene, which shall reflect the story context, as pointed out by Beiman (2010, p. 20). Each character should be manipulated to behave in a particular way – his own way – expressing his personality, mood and attitude according to the circumstances, as discussed in section 2.1. The animators should not rely just on the "performance" of the actors who are giving voice to the characters, usually filmed for reference when their dialogues are being recorded. Unless they adopt an approach similar to the making of Rango, where the actors did the research to characterize their character and really acted the characters in the scenes, interacting with each other.

Thus, after putting the character in the right place (and general orientation) in the scene, the animator should create the character's neutral or idle standing position, as his personal posture – characterization – considering his biography. This requires attention to the influence of the *power centre*, the position the shoulders, the tilt of the pelvis, the knees, the feet, etc. That pose is actually neutral only for that character, because that position already defines a character (the T-pose, or similar, is the neutral one for every character). Therefore, that is the normal pose – the starting pose – for that character. In fact, the character could be provided to the animators already in that normal pose instead of the T-pose, for the sake of consistency of his posture in every scene.

Whenever the character is provided in the T-pose, the shoulders (and arms) must be repositioned to its normal (relaxed) position for a standing pose, before starting to animate it, as discussed in section 2.6.2. The shoulders' position and movement can help expressing different meanings, from happiness and determination to lethargy and depression, as discussed by Roberts (2007, pp. 118-9). Furthermore, the animator shall keep in mind the importance of pelvis orientation in the sagittal

plane (the forward/backward tilt), knees and the feet controls rotations (Y axis) to the definition of the personality, confidence status and *power centre*.

In practical terms, this can be done by manipulating the character's controls to get him into the intended posture and setting the necessary keyframes in the first frame (or keep them in frame -1) of the timeline. Those keyframes could even be saved in the first animation layer (in software packages like Autodesk Maya), enabling the animator to easily adjust the *Power Centre* influence, by taking advantage of the *Passthrough* option and animating the *Weight* value. Following that rationale, the animator could create different *Power Centres* and keep them in several animation layers, to be used according to the situation, and those layers could even be saved and used in all scenes with that character, if included in the reference file, for example. It may be taken further into creating an extensive collection of postures, as described in section 4.3, or using a library manager plugin, like those mentioned on page 113, for instance.

Once the characterization is clearly defined – either in an initial pose, stored in a layer, or just internalizing it – the animator shall create the Key-pose(s) or golden pose(s), by imagining the storytelling moment that best represents the intended action or attitude, as mentioned earlier. He shall keep in mind that an action pose is usually best expressed if representing the start or the finish phase of the motion (often the final moment describes more about what happens/happened), although sometimes the one representing the middle of the action expresses it better, as discussed in section 2.2. It is crucial that only after getting those key-poses right the animator should start adding the extremes (contacts) and breakdowns.

If the intended pose is static or there is little motion, the character has to be worked at least in terms of characterization, defining the *power centre* and corresponding posture, and also in terms of *contrapposto*, distributing the body weight in accordance to the intended expression. Although the animator may consider there is no need for the *line of action*, since there is no action to be

expressed, he must think of the arrangement of the body parts in such a way that expresses the force that holds the body in that particular pose, which shape expresses a particular rhythm, that is synthesized by the *expression cord*. The feet shall be placed in the convenient way to support the pose and the pelvis shall be adjusted in the different axes, according to the supporting foot and making sure it is not aligned with the feet (rotation around the Y axis). The top of the torso shall be adjusted in the different axes, according to pelvis and making sure it is not aligned with the pelvis in the Y axis.

When creating a dynamic pose, besides the characterization the animator has to define the thrust or direction of the body and which part of the body is leading it, according to the intended attitude to be portrayed. The shape of the body and the inherent arrangement of its parts, are dependent on that thrust or source of energy and, therefore, so will be the pose of the 3D character. By doing that the animator will be following the *line of action* concept, along with the *power centre*, to orient the pose and define the inclination of the body. Then he has to consider the feet's position, either to respond to stability needs determined by the inclination of the body, or to express an unbalanced position, i.e. to give consistency to the upper body. After that, he must distribute the weight, following the *contrapposto*, and arrange the body parts in a way to express the flow of energy going through the body – the *expression cord* – producing a twist of the whole body. The *serpentine line* rationale will be complemented by the turning of the head to the centre of interest (usually).

In both situations, if using the 3D Pose Tool, the animator can check around the character if there is any straight line segment in the *expression cord*, in any perspective, and correct it. The animator may also want to check with the *line of gravity*, to see how balanced or out of balance it needs to be, depending on the intended pose – if it is a static or a dynamic one, and how much thrust it is supposed to imply.

After having created the golden poses, the animator shall follow the same posing rationale to create the extremes that will show any extreme position, change of direction or the contact positions to the ground or to the props, for example. Then the breakdowns, to define how the transition happens between a golden pose and an extreme or between two extremes, in terms of shape and/or space variation, as explained in section 2.2. For each of them the animator will set a key at the desired frame in the timeline, according to the estimated time, registering the values of all the involved controls attributes. Maya software offers a breakdown key option based on that rationale, as a special kind of keyframe that once placed between two regular keyframes will proportionally adjust its time, while keeping the attributes values of the pose, whenever the time (frame number) of one of the adjacent keyframes is changed. For that reason this Maya option is especially useful when working the timing, as the keyframes can be set as keys and converted to breakdowns, later, and vice versa. However, the breakdown is not just about the transition but also about showing *how* the character moves (as discussed in section 2.2) and therefore shall not be a mere in-between shape in an in-between space. The in-betweens are automatically interpolated and those variations in the pose along a sequence of in-betweens can be adjusted by editing the spline curve of each keyed attribute, in the *Graph Editor* (in Maya), to give the desired expression of acceleration or deceleration to the movement.

It is commonly recommended the use of stepped curves in the *Graph Editor* at the initial stage of the posing process, since it allows each key-pose to be kept with no transition between them. The animator can use the stepped curves just for the golden poses (or key-poses) and the extremes, keyframing the controls of all the elements that need to change from the previous one to create the movement. Then, he may use the linear curves when creating the breakdowns, because that way it is only necessary to change and set keyframes of the parts of the body that need to be different from the normal interpolation between key-poses and extremes (or between an extreme and a breakdown). Unless the animator wants

the breakdown to go "somewhere else", as mentioned by Williams (2001, p. 218), in which case he needs to create an entirely (or almost) new pose. This procedure will avoid having all parts of the body keyframed at the same times/frames.

In order to express the flow of energy through the body, the position (translation and/or rotation) of each body part must be offset in time, progressively, like a chain reaction, producing the unfold effect discussed in section 2.6.1. This implies that for instance the rotation of the pelvis, top of the torso and head, in the coronal plane, shall happen in a sequence (first the pelvis, then the top of the torso, then the head) and not all at the same time/frame. And the same must be done with the translations in that plane. Likewise, for the rotation and translations in the transverse plane, in a sequence of opposites (*contrapposto*) or in a gradual twist of the main axis of the body (*serpentine line*). This simulates a wave effect prompted when the body moves, giving sense to the motion of each body part and, thus, preventing the parts from moving without nexus between poses. That effect, which is called "reverberation" by Pierce and Pierce (2002, pp. 141-166), who consider it "the play of aliveness", is also responsible for the vibratory response of the relaxed or loose parts of the body in motion, as overlapping actions.

In a more comprehensive example, when a body moves from the T-pose to a counterpoised pose, the pelvis swings (tilts and translates) towards the supporting foot, first, and the shoulders will take a few more frames to achieve the counterbalancing position, which will be supported by the appropriate curvature of the torso. The head will, then, take a few more frames than the shoulders to reach its particular position, in accordance to the curvature of the neck. Likewise, there will be an offset in time of the position of each joint control of the upper limbs, from the shoulder to the elbow, and then to the wrist and, maybe, to the fingers. The relaxed leg responds to the swing of the pelvis, which lowers the hip

joint on that side, through a synchronized reaction involving the hip joint, the knee, the ankle and, maybe, the ball of the foot.

The number of frames taken by the offset in time of the position of each part between two poses will, of course, depend on the intended expression, considering the particular rhythm of the character. As Chekhov (2010, p. 71), stated "everybody goes through life in different tempos" and, therefore, rhythm is very important to make a character unique, as discussed in section 2.1.1.

It should also be noted that in many intentional actions, like looking at or leaning towards something, the head (and the eyes, before that) leads the movement and, therefore, the flow of energy will be expressed in a top-down offset order, at least to a certain extent.

Although this offset effect can be worked by anticipating or postponing the keyframe set on some controls of a key-pose, it may be more efficiently achieved through additional breakdown poses, as discussed in section 2.2.

The proposed workflow allows the animator to apply the concepts of the new posing approach in an efficient sequence in time, and contributes to ensure that the essential steps of posing are covered and not forgotten in the process.

4.7   Summary

A new approach to the posing process of 3D characters has been proposed and discussed in this chapter, with the aim to address some body expression issues, such as the stiffness of the torso, and to improve the efficiency of the process as well. It integrates the qualities of four concepts into the creation of the pose, combining them in a systematic way. The qualities of direction and intensity of thrust are given by the *line of action* and modulated by the *power centre*, which

reflects the status, level of confidence, ego or mood. Moreover, the qualities of weight distribution and balance are given by the *contrapposto*, through the tilt of the pelvis, shoulders/thorax and head – which promotes the *S-curve* – and also through the torsion of the torso. Consequently, it promotes asymmetry and tension between the sections of the body, and adds rhythm to the entire shape. Those qualities are absorbed by the *serpentine line*, which takes them to a higher level of intensity especially in dynamic or dramatic poses, by accentuating the twisting effect and extending it to the whole body.

This approach is synthesized in a conceptual *expression cord*, which represents the flow of energy through the body, structuring its main axis, and guiding the animator when dealing with the configuration of visual forces that are determinant to the creation of a pose. It synthesizes the forces within the body and of the body as a whole, with a relationship with the form of the character, and shall display the qualities of moderation and variation of a graceful line. The degree of inclination, curvature and twisting of the character's body shall depend on the intensity of the expression and not applied as a matter of style, without physical or psychological justification. The rationale of the imaginary *expression cord* allows the animator to follow a similar philosophy to gesture drawing (mentioned in section 2.4.3) and distil the essential qualities of the character expression, either from an imagined pose or from one seen in reference material. Several ideas have been presented and discussed, envisaging solutions to provide the visual dimension of the *expression cord* and its underlying concepts.

The approach promotes a naturalistic aesthetics but only in terms of body expression, i.e. how the body parts are arranged in a logical way, that makes it (and its inherent motion) look natural and, therefore, more recognizable and expressive, and not in terms of how the body form is rendered. Furthermore, the proposed solution can be applied to different styles of animation, as long as the character is an orthograde biped or anthropomorphic one. Concurrently to the

naturalistic representation of behaviour of the character's body, and also to make the manipulation more efficient, this thesis also proposes a simpler rig in what concerns the manipulation of the torso and head – pelvis, top of the torso and head controls. Also with the purpose of making the posing process more efficient, it is proposed a workflow to maximize the application of the new approach and to make sure that the essentials of creating a pose are not neglected in the process.

The conceptual guiding nature of this approach will be enhanced if a virtual tool is added to the animation software, providing visual guidance to the animator and, that way, making more effective the complex process of creating expressive poses. Therefore, a 3D Pose Tool to complement this approach will be presented in next chapter.

5   The 3D Pose Tool

This tool is intended to integrate the concepts of the new posing approach, working as a virtual 3D representation of the *expression cord* and its amplifiers, according to the rationale described in chapter 4. The goal is to help the animator to define the character's pose in a 3D interface, by allowing him to firstly focus more on the action and the motive or driving force behind it – and less about the rig and the controls he needs to manipulate – following the philosophy of gesture drawing (mentioned in section 2.4.3).

The 3D Pose Tool was conceived to be used in orthograde biped characters standing or moving in a vertical position, with the feet on the ground, in Earth like condition – influenced by gravity. If not, some adjustments are required, according to the character, such as the connection of the *Bottom* control to the feet controls, the orientation of the tool and main control, for example.

The following sections describe the development of the tool, the process of attaching it to the character's rig, making the controls connections and, finally, how it operates.

5.1   Developing the tool

The 3D Pose Tool was developed to respond directly to the challenges and needs identified in the approach chapter and evolved side by side with the approach development. Being a tool for artists, it must provide the appropriate level of control over the expressive aspects of their work (Neff and Fiume 2003). The following sections discuss the development process – design, modelling, rigging and display modes – and justify the options that were taken to achieve the aimed result.

5.1.1 The design

Good design is a compromise between function and aesthetics of the object or device being created and that was kept in mind when designing the 3D Pose Tool. The functions of this tool are, firstly, to serve as visual guide to the animator during the posing process, working as a symbol and synthesizer of the concepts mentioned in the approach; and, secondly, to be the interface through which the animator manipulates the main axis controls of the character – in the *active* mode option. Therefore, the different parts of the tool were designed to facilitate the perception of its transformations (including form changing nuances) during the manipulation, and to make its selection easy, too.

The tool has three spheres and one half-sphere, connected by a vertical tube, as shown in Figure 66. This tube was initially cylindrical but was changed to a parallelepiped form, in order to better show the effect of being twisted – rotation along the Y axis – because preliminary tests revealed that just the vertical black and red strips on the cylindrical form were not enough to make subtle twists perceived. Each sphere is divided horizontally in two hemispheres and vertically in four sections (by two meridian circles), producing eight triangular shapes, interpolated in black and yellow, in order to provide visual marks that allow the spheres' position and rotation (in any axis) to be easily perceived (see Figure 67). The yellow areas are half transparent, in order to let the spirit level placed inside to be seen.

Those control spheres are also intersected by horizontal purple discs and thin blue tubes to serve as orientation amplifiers. These amplifiers were inspired in the blue light beams used in the documentary *How Art Made the World* (2005), on chapter 8 of Programme One, to make clearer the orientation of the different parts of the body that was replicating the Doryphoros' pose (see Figure 9). It was decided to include two additional yellow and black tubes over part of the amplifier corresponding to the top of the torso, to amplify the individual movement of each

shoulder. The horizontal discs dividing each sphere also contribute to a better perception, by amplifying any tilt of the spheres controls. In the bottom control – half-sphere – the disk is replaced by a triangle, which fits better the purpose of pointing a direction.

The *Pelvis* control has an additional grey transparent shape, replicating the black triangular shapes of the control sphere (see Figure 68), to serve as an optional control that includes the *Pelvis* control and the lower levels of the hierarchy – *TorsoTop* and *Head* controls – and is available only in the *active* mode version. The reason for that shape is to keep it visually coherent with the control spheres, while suggesting a layer on top of the *PT_Pelvis* sphere that controls it. The degree of transparency allows the visibility of the Pelvis control through it.

The *Power Centre* label is represented by a 12-pointed star, in orange colour, to serve as an easily identifiable locator.

5.1.2   The 3D model

The tool was virtually modelled in Maya, as shown in Figure 66, according to the design discussed in the previous section. The three spheres are made of polygon geometry, as well as the bottom half-sphere, and are displayed with level 3 of smoothness – *Fine*. The tube with the form of a parallelepiped is made of *NURBS* geometry, with a 14 patches surface in each side, displayed with a level 3 of smoothness, to produce a more organic deformation of its form and to allow it to behave like a *Bezier curve*. The thin tubes – amplifiers – intersecting each sphere are made of polygon geometry, displayed with level 1 of smoothness. The purple disks, intersecting each sphere, are made of *NURBS* geometry, displayed with a level 3 of smoothness in order to keep its roundness. The bottom triangle is just one polygon.
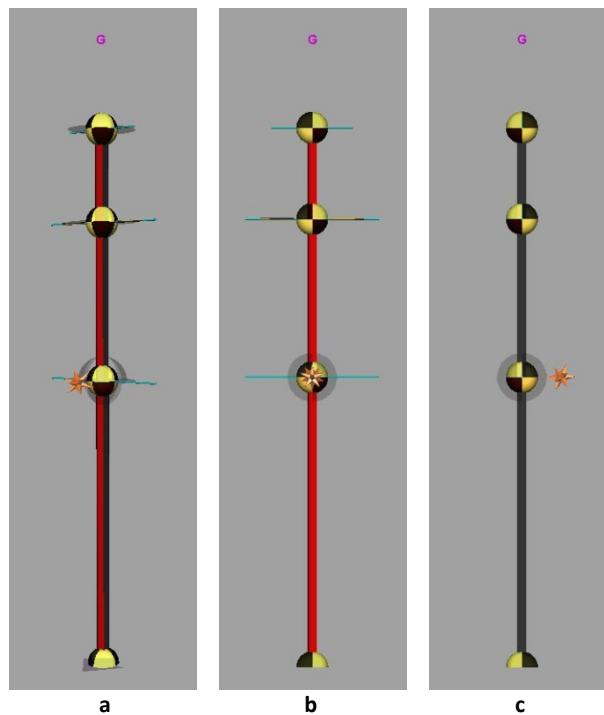
Figure 66 – 3D Pose Tool, in perspective (a), front (b) and side (c) views.

The *Power Centre* locator is made of polygon geometry, displayed with level 1 of smoothness in order to keep its sharpness. The additional shoulders amplifiers tubes are made of polygon geometry, displayed with level 3 of smoothness for a roundness shape.

The surface material applied to all the above described pieces of geometry is the *Lambert*, with the colour or colour set corresponding to each element. The exception is the *Power Centre* locator, which has a *Blinn* material, in order to display a shiny orange colour.

The half-sphere placed inside each of the three spheres, representing the spirit level, is also made of polygon geometry and has a *Lambert* material with a red colour on the half-sphere surface and a cyan colour on the circle surface, which are displayed as orange and yellow, respectively, when seen through the transparency of yellow triangles.
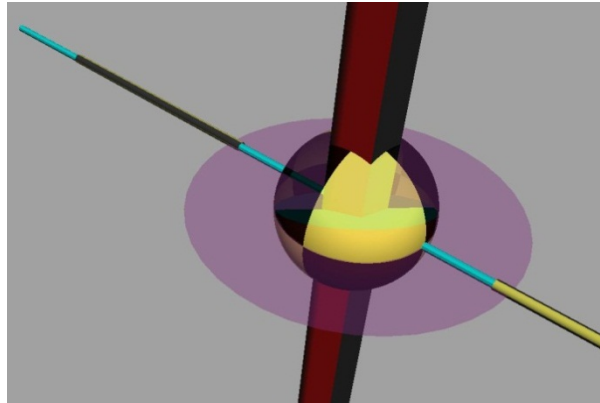
Figure 67 – Detail of a sphere control, with spirit level and amplifiers.

For the *PT_Pelvis_Hierarchy* control was created a piece of geometry made of polygons, similar to the black triangular shapes of the control sphere, with a *Blinn* material assigned to it, displaying a grey colour (due to a certain degree of transparency of the black colour), as shown in Figure 68.
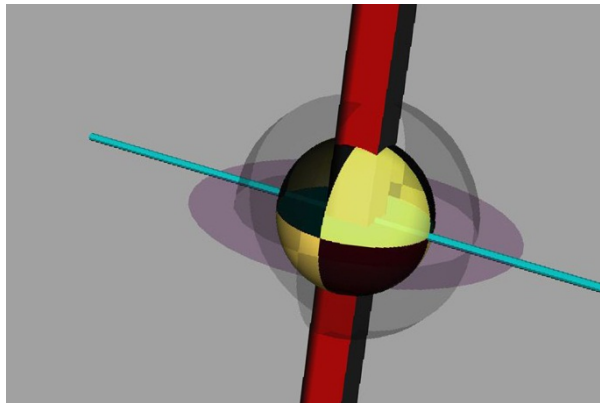
Figure 68 – *PT_Pelvis_Hierarchy* control, with the grey transparent shape replicating the black triangular shapes of the control sphere.

There is also a purple *NURBS* curve, representing the feet aligner that serves as a rail along which the *Bottom* control slides towards on foot or the other.

5.1.3   The rig and controls of the tool

Similarly to what happens with a 3D character model, the mesh of the 3D model of the tool has to be rigged, in order to be effectively manipulated by the animator.

Rigging (also known as character setup) involves creating a structure – working like a virtual skeleton, to which the geometry (skin) will be bound – and some control handles connected to the key points of that structure, so that it can be manipulated as desired.

Differently from a character, the final solution for this tool was not a skeleton (with joints and bones) to control the deformation of the geometry of the tube representing the *expression cord*. Initially, that approach was tried, with the tube being controlled through a set of *IK splines* (one for each section of the tube) applied to a "skeleton" – a joint chain made of small bones. However, the results were not satisfactory, even when a gradual weight influence was applied to the control vertices (CVs) that compose the curve of each *IK spline*. The position of the control spheres in relation to the cord that intersects them was not accurately kept after being submitted to some manipulation. Sometimes those controls would have an unpredictable behaviour, jumping into weird positions and even crashing, thus making it a non-reliable solution. As an inverse kinematics (IK) solution, it worked well only when translating the controls. The rotation manipulation had no effect and the twist (rotation around the vertical axis – Y) could only be achieved if a connection was established between that rotation axis of the manipulator and the twist attribute of the *IK spline*. The reason is the *IK spline* that controls a chain of joints (bones) is based on a line (*NURBS curve*) and a line does not twist around itself – along its path – (ex: a vertical line can be changed only by translating its points in any direction). The *IK Spline* is designed to be controlled by translating its begin and end points and also the control vertices in between, in case they are connected to rig controls that allow its manipulation. The problem remained when the *cord* was controlled by a sequence of 3 *IK splines*, one for each segment of the *cord*.

Therefore, a different solution had to be found for this tool to meet the particular requirements of the *expression cord*. The final version is structured by four *Bezier*

curves, working as *wire deformers*, placed vertically at each edge of the parallelepiped tube (see Figure 69-a) which form and shape are controlled through the manipulation of the *clusters* of the control points and tangents of the *Bezier curves* for each section. Those clusters (14 in total) are organized in groups – one for each manipulator (sphere) of the tool – which are under the control of the corresponding manipulators, through a *Parent Constrain* relationship.

a   b
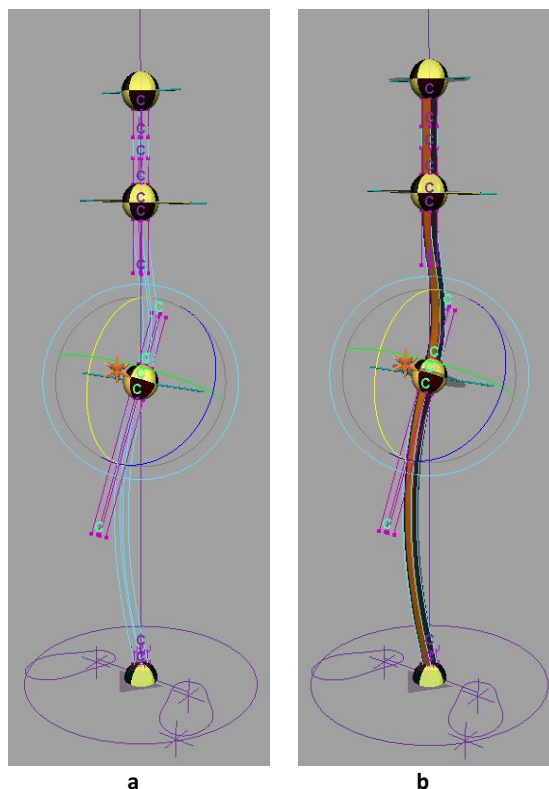
Figure 69 – 3D Pose Tool structure and controls, with Pelvis control being rotated in the sagittal plane, showing the *wire deformers* in cyan (a) and the cord geometry (b) controlled by them.

The reason for using 4 *Bezier curves/wire deformers* instead of just one is that it would have similar limitations to the curve of the *IK spline* – the rotation around itself would have no effect. With this solution, the rotation of the control spheres, in any axis, produces a translation of the curves control points, thus, generating the intended effects on the 4 curves (*wire deformers*) and, consequently, on the *cord*. Each section of the tube – Feet to Pelvis; Pelvis to TorsoTop; TorsoTop to Head – is influenced by the two adjacent spheres (controls of the tool). This

solution allows a smoother deformation of the cord to be produced when rotating, twisting or translating any of the manipulators (control spheres) of the tool, as shown in Figure 69-b.

The skinning process, i.e. binding the skin (geometry) of the tube to its structure (the *wire deformers*), is also important, in order to allow the correct change of form and shape. Each *wire deformer* influences the control vertices of the geometry located in its corner at 100% and the ones in the middle are influenced gradually 67.5% and 32.5% by each adjacent *wire deformer*. The influences were precisely distributed through the Component Editor.

The *expression cord* has, therefore, the qualities of a *Bezier curve*, with 2 anchor points between the 2 end points. One end point is controlled by the *Bottom* half-sphere and the other one is controlled by the *Head* sphere, while the 2 anchor points are controlled by the *Pelvis* sphere and the *TorsoTop* sphere. Those are the four control points of the *expression cord,* designed to manipulate the 3D Pose Tool. The Top and Bottom clusters of each control sphere control the tangents, which were set to the *unbroken* status to help keeping the smoothness of the curvature, and the tangents control points were set at appropriate lengths, so that one influence does not overlaps the influence of the adjacent anchor tangent. The length of the tangents' influence can be adjusted later by moving their positions along the Y axis, when placing the tool and adjusting the controls to the character's body, and also whenever the character bends his legs – shortening the distance between the *Bottom* and the *Pelvis* controls – to keep the fluidity of the cord (as discussed in section 4.2). That proportional adjustment of the tangents' length on the Y axis will be done automatically with the plugin.

That *cord* has yet another quality, which is not present in a *Bezier curve*, or in any other curve: the ability to twist around itself. This is achieved by the use of those 4 curves together, resulting in a synchronized translation of its influenced CVs around a central pivot point, when originated by the rotation of a control sphere

around the Y axis, thus producing a twisting effect on the corresponding geometry. Moreover, this solution allows different degrees of twisting for each section, which may produce a more or less gradual twist along the entire cord, or even a twist and counter-twist, if the rotation of one control sphere is followed by the reversed rotation of the next one.

The tool has, therefore, 4 main controls, or manipulators – *Head, TorsoTop, Pelvis* and *Bottom*. There is also the option to manipulate the entire upper body together, using the *Pelvis_Hierarchy* control. The manipulator at the base of the neck (or top of the torso) was given the name *TorsoTop*, because the neck is affected by the position and orientation of the head in relation to the top of the torso (the neck is a flexible part that connects them).

The default position of the *Bottom* control of the tool in a character standing in an upright position, with both feet on the ground, is the point in between the feet where the line of gravity meets the ground – the centre of the base of support of the body (as discussed in chapter 4). That middle position is automatically determined according to the position of the character's feet and is adjusted whenever a foot changes position, through an *Expression,* created by W. Li (personal communication, 29 January 2013) and reproduced below, that makes the *Bottom* control to slide and keeps it in the middle:

```
PT_FeetCircle.translateX = ( PT_FootRight_locator.translateX -
PT_FootLeft_locator.translateX ) * ( PT_FeetCircle.Slide + 1 ) * 0.5 +
PT_FootLeft_locator.translateX;

PT_FeetCircle.translateY = ( PT_FootRight_locator.translateY -
PT_FootLeft_locator.translateY ) * ( PT_FeetCircle.Slide + 1 ) * 0.5 +
PT_FootLeft_locator.translateY;

PT_FeetCircle.translateZ = ( PT_FootRight_locator.translateZ -
PT_FootLeft_locator.translateZ ) * ( PT_FeetCircle.Slide + 1 ) * 0.5 +
PT_FootLeft_locator.translateZ;
```

However, the centre of the base of support of the body changes from pose to pose and, when creating a pose, the lateral adjustment of the *Bottom* control has to be done manually, changing the value of the *Slide* attribute, because its position depends on how much weight is supported by each foot. This could be determined automatically, based on which heel is up and/or which knee is bent, but that would not be very accurate, because the body weight may be almost entirely on one foot while the other foot is still completely on the ground and without bending the knee of the same side, as can be observed in daily life. Moreover, the orientation of the *Bottom* control, rotating on the Y axis, is automatically defined through an *Aim Constrain* applied to it, which is targeting a foot locator. By default, it is oriented to the ankles but it may be necessary to orient the line to the heels or to the ball of the feet, or even to the tip of the toes, depending on where the centre of the base of support of the body is. Therefore, although the plugin solution could suggest a position, the final decision must be left to the animator, because it depends on the intended expression. For that reason, there is also the option to (un)*Lock To Feet* (in the *Channel Box*) and give the animator full control of the *Bottom* control, if needed.

Since there are two options for operating the tool – *active* or *passive* modes – two different hierarchies are required to organize the nodes that comprise the tool's structure. In the *active mode*, the *Head* control is dependent of the *TorsoTop* control, which means that it may move independently but is also subjected to the movements of the parent control (*TorsoTop*). There is also an optional dependency between the *Pelvis* and the *TorsoTop* controls, making the latter dependent of the *Pelvis* control, whenever the animator selects the *PT_Pelvis_Hierarchy* control, allowing him to manipulate the controls of the pelvis, the torso and the head, together (see Figure 70).

The *PT_Pelvis_Hierarchy* control is placed before the *PT_Pelvis_Manip_group* to offer the possibility for the *Power Centre* solution to accommodate pre-defined

poses (depending on a *Power Centre* lever, with *Set Driven Keys* applied to the Controls' groups, for example), in the *active* mode. For the same reason that *PT_Pelvis_Hierarchy* control is also grouped to itself – the group may also be controlled by *Set Driven Keys* but also allows the control, inside the group, to be manipulated afterwards. The *PoseTool_AdjustTorsoCtrl* is parented to the *PT_Pelvis_Hierarchy* control and not to the *PT_ball_Pelvis* control, so that the *Pelvis* can be manipulated independently from the *TorsoTop* and *Head* controls when the *PT_ball_Pelvis* control is selected.

However, in the *active* mode, *PT_Ball_Pelvis* and *PT_Pelvis_Hierarchy* share the same translation values, i.e. when the *PT_Ball_Pelvis* is translated the *PT_Pelvis_Hierarchy* moves or updates to the same position.
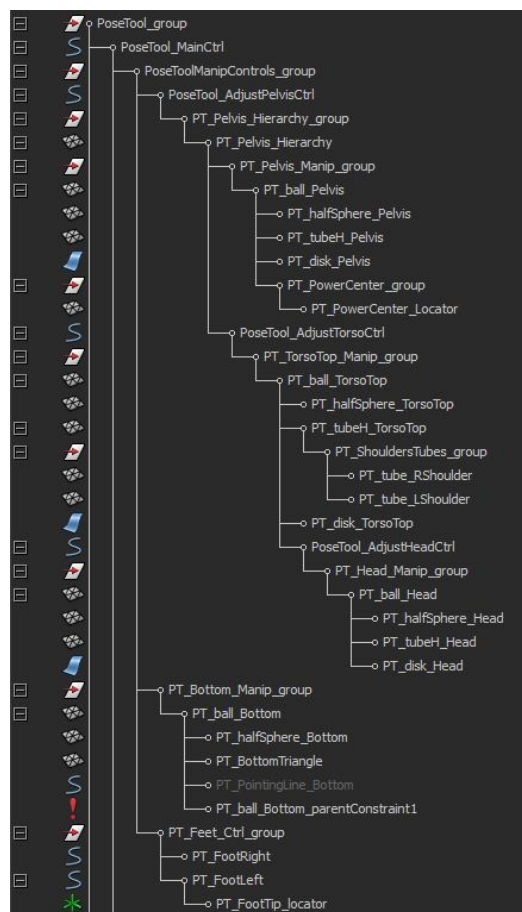
Figure 70 – Maya Outliner – Hierarchy of the 3D Pose Tool in the *active mode.*

The same rational could be applied to the *TorsoTop* to allow the *PT_ball_TorsoTop* control to manipulate the top of the torso independently from the *Head* control (see Figure 71), although in most rigs the head control is usually dependent of the top of the torso/chest control and, therefore, this extra hierarchy level is not used much.
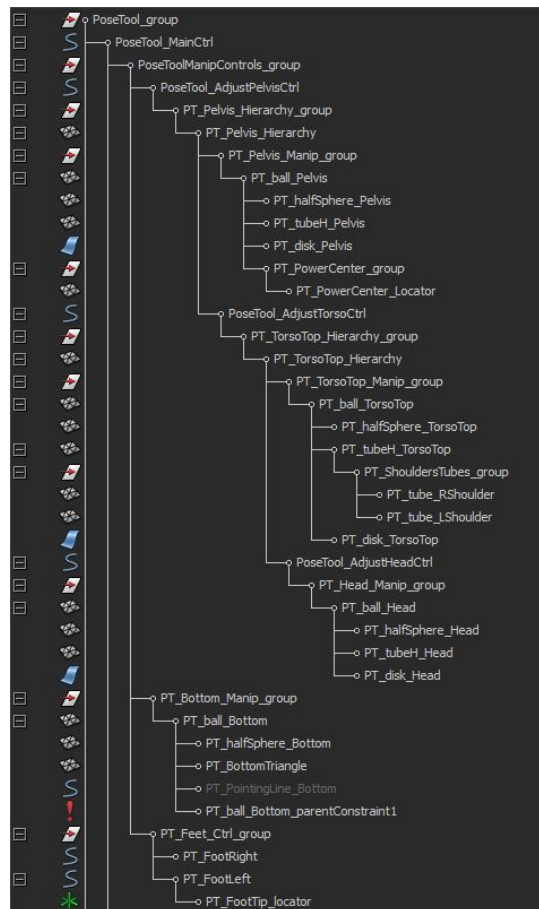
Figure 71 – Maya Outliner – Hierarchy of the 3D Pose Tool in the *active mode*, including *TorsoTop*.

In the *passive* mode, there is no hierarchy between the Pelvis control and the Torso and Head controls – The Head control is not parented to the Torso control and this one is not parented to the Pelvis control (see Figure 72).
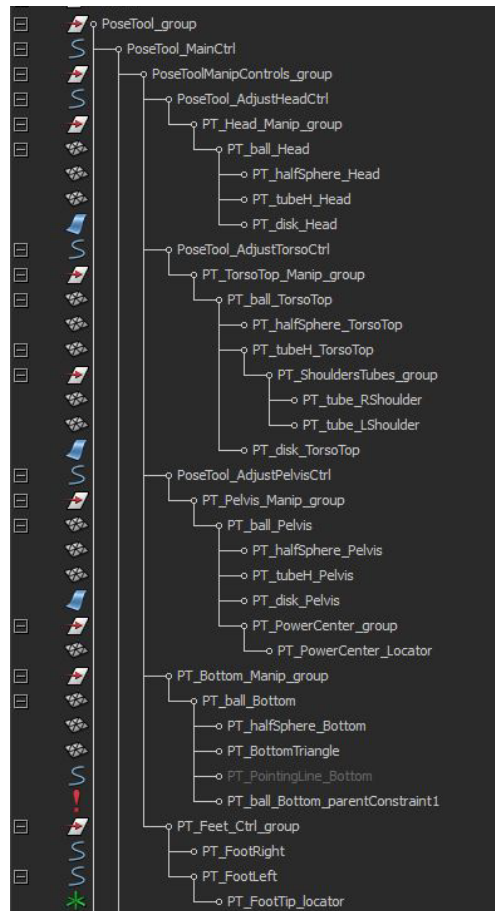
Figure 72 – Maya Outliner – Hierarchy of the 3D Pose Tool in the *passive mode.*

The adjustment controls of the tool (*PoseTool_AdjustPelvisCtrl, PoseTool_AdjustTorsoCtrl, PoseTool_AdjustHeadCtrl* and *PoseTool_MainCtrl*), are used only during the attachment process (as explained in section 5.2). They are grouped in order for the sphere controls to have zero-values in the *Channel Box* before the start of the posing process. Those controls are represented by *NURBS* circles, which become hidden once the attachment process is finished.

5.1.4   The tool display

The visual representation of the 3d Pose Tool varies depending on the circumstances, allowing for specific visual feedback to the animator during the posing process, as described earlier. It is supposed to be clearly visible on top of

the character's geometry, although being placed inside it, with similar properties to the *X-ray Joints* effect in Maya (as seen in Figure 64). Multiple attempts to simulate the *X-ray Joints* effect applied to the tool did not succeed. This issue was discussed with a number of experts (Autodesk never replied), including Robert Bateman employed by NaturalMotion, Ltd, who have concluded that is nearly impossible to be achieved in Maya without having access to its source code.

Therefore, the solution to the problem of visibility of the tool was the creation a *script* to make the character's geometry transparent, to a certain degree, while keeping the visibility of the tool to its normal value, and another script to put it back to normal (see page 329, in Annexes). Two buttons were created in a Maya shelf named *PoseTool*, linked to these scripts, in order to make the on/off selection easier. This solution (as seen in Appendices, p. 303) allows a better visibility of the tool and of the character than the standard *X-ray* shading option provided by Maya, although not as good as the Maya *X-ray Joints* kind of shading would do.

Those visibility constrains make the spirit level solution useless because it cannot be clearly perceived through the transparency. The same constrains make the operations in the *active* mode a little confusing, since it is not so easy to select the manipulators of the tool. The visibility of the tool can be also turned off in the *Display Layer* window.

The shape and form displayed by the tube that embodies the *expression cord* vary according to the transformations – translations and rotations – applied to the controls of the tool. Besides bending and twisting, the tube may even shortens in its bottom segment (going from the feet level up to the pelvis control), whenever the character bends his legs, keeping the fluidity of the line, i.e. the *expression cord*.

The tool also provides visual feedback through the colour changing in the three segments of the tube since each of them may change the colour of its anterior and

posterior faces, automatically. The default colour is red, for the untouched condition, and may change to orange, yellow or green, according to the manipulation of the tool's controls that influence each section of the geometry. Section 1 is influenced by *PT_ball_Bottom* and *PT_ball_Pelvis* controls; Section 2 is influenced by *PT_ball_Pelvis* and *PT_ball_TorsoTop* controls; and Section 3 is influenced by *PT_ball_TorsoTop* and *PT_ball_Head* controls. Therefore, two of the controls – *Pelvis* and *TorsoTop* – influence the two sections which are adjacent to each other, while the *Bottom* and the *Head* controls influence just one section of the tube, each (section 1 and section 3).

For example, when the *Pelvis* control translates or rotates and the other controls remain unchanged, the tube's form is affected in the section 1 and 2 and, therefore, the colour changes in both sections. Likewise, when the *TorsoTop* control translates or rotates and the other controls remain unchanged, the tube's form is affected in the section 2 and 3 and, therefore, the colour changes in both sections, too.

The conditions for changing the colour attribute are depending on the transformation attribute values for Translation (Translate X and/or Z), Rotation (Rotate X and/or Z) and Twist (Rotate Y) of the manipulators influencing each section, as follows:

- If the attribute values for Translation, Rotation and Twist of both manipulators influencing each section are zero, then the colour remains red (R = 1, G = 0, B = 0);
- If the attribute values of both manipulators influencing a section are different in one of the three (Translation, Rotation or Twist), the colour change to orange (R = 1, G = 0.5, B = 0);
- If the attribute values of both manipulators influencing a section are different in two of the three (Translate, Rotate or Twist), the colour change to yellow (R = 1, G = 1, B = 0);

- If the attribute values of both manipulators influencing a section are different in all of the three (Translate, Rotate or Twist), the colour change to green (R = 0, G = 1, B = 0).

The MEL script performing evaluation of the aforementioned values was created by D. Kravtsov (personal communications), specifically for this 3D Pose Tool, and can be found in Annexes, page 330.

The calculations are not always accurate in the *passive* mode of the tool (which hierarchy is defined so that each control can be moved independently of any other control) when certain rotations are applied. This is due to the fact that in this mode the positions and rotations of the nodes are calculated in local space, while they should be calculated in global space. A full solution would involve calculation of the global transformation parameters with respect to parent matrix, including evaluated transformation of the entire parent hierarchy. This would require additional development allowing for evaluation of parent matrix in world space within Maya expressions. The resulting matrix could be decomposed, so that global position and rotation parameters are used for the construction of Maya expressions performing colour calculations.

In spite of the display limitations, the overall objectives of the 3D Pose Tool development were achieved since it provides a simple and functional 3D representation of the elements described in the approach and produce the intended behaviours according to the manipulation.

5.2 Attaching the tool to the character's rig

For the tool to provide an accurate visual feedback and/or control of the character's pose it must be properly attached to the character's rig. The user must follow the instructions as shown in the Attaching Window (see Figure 73), in a

process that involves two phases – placing and connecting – each of them including several steps.
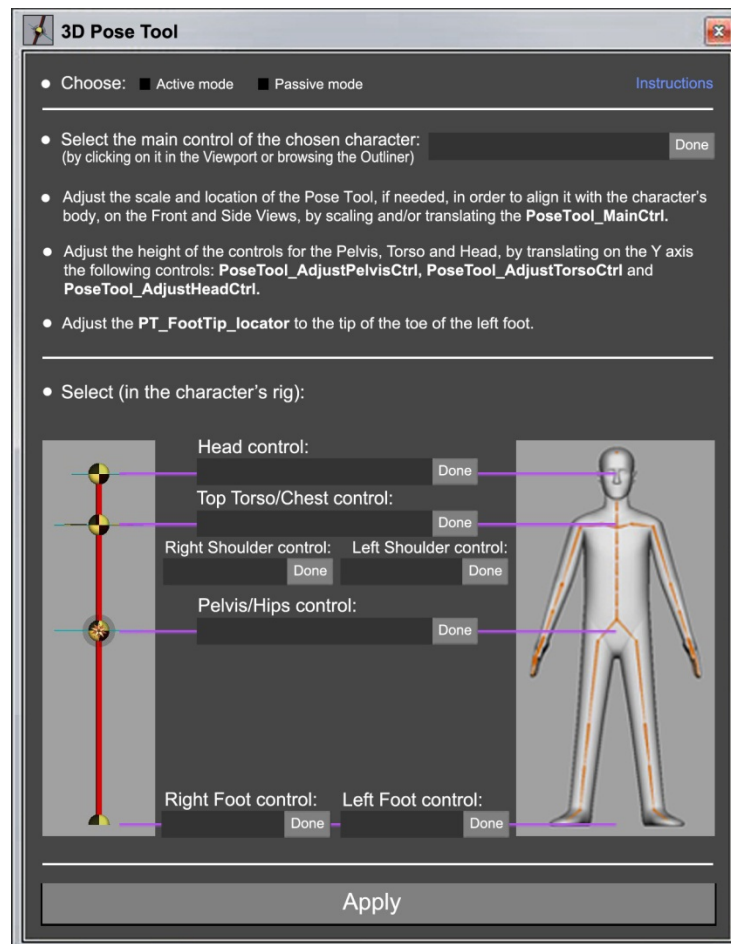
Figure 73 – Attaching Window of the 3D Pose Tool.

Initially, the "Done" buttons are inactive. Once the control is selected, the "Apply" button appears in the User Interface. Once the "Apply" button is clicked, the "Done" button is activated.

Hitting the "Instructions" link opens a PDF file showing the detailed instructions.

5.2.1   Placing the tool

The first step is to place the tool in the appropriate position in relation to the character's body, i.e. aligned with it in the front and side views, by translating the

main control – *PoseTool_MainCtrl* (the largest circle at the bottom of the tool, as seen in Figure 74). The size of the tool should also be adjusted to the character's size, if needed, by scaling the same control.
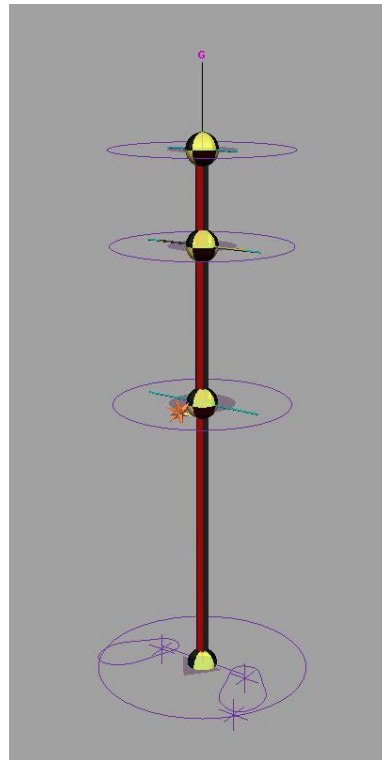
Figure 74 – 3D Pose Tool, with adjusting controls (circles), as it appears in Maya viewport, at the beginning of the process.

In the front view (coronal plane), the tool should be aligned with the spine of the character, at the centre of the body. In the side view (sagittal plane), the tool should be placed slightly in front of the ankles, especially if the character's posture is based in the human body, because, as Pierce and Pierce (2002) point out, the balance requires a "slightly forward tilt of the body so that weight is centred in the arches of the feet" (p. 49). Moreover, it should also be vertically aligned with the fulcrum of the head – below the ears – and the shoulders and hips' joints, unless the character is modelled in a particular poor posture. This way, the cord of the tool matches the line of gravity of the body and the animator may take advantage of the *Gravity Line* included in the tool, as a useful visual mark to help him defining the intensity and momentum of the body motion.

In the event of the character not being in the neutral upright position but in some other peculiar pose, resulting from a permanent condition of the body (for example, a hunchback or an old person), then the placement of the tool controls (including their orientation) should be manually adjusted before the final connection is established. By doing so, the cord of the pose tool would become curved, and therefore expressing some peculiar characterization, before any character manipulation has been done. However, that would be the correct thing to do in order to match with the predefined posture, because the other option would be to leave the cord straight, without matching the character's peculiar posture, which would not fully serve the purpose of this posing approach. If the posture is not permanent, i.e. may change during the character's performance, and for some strange reason was rigged in that pose, then the tool controls must definitely be adjusted, so that the *expression cord* can reflect that kind of characterization.

The second step is to adjust the height of the three adjusting controls (*Pelvis, Top of the Torso* and *Head*) to the corresponding ones in the character, so that they match his main body proportions. Each of those controls shall be translated along the Y axis, starting with *PoseTool_AdjustPelvisCtrl,* then the PoseTool_AdjustTorsoCtrl and finally the PoseTool_AdjustHeadCtrl. Ideally, the sphere control of the *Pelvis* shall lie in the centre of the pelvis area – between hips joints and the first joint of the spine and not horizontally aligned with the hips joints. That way, when tilting forwards or backwards (in the sagittal plane) it produces a similar degree of influence in both the Hips and the Spine. Otherwise – if aligned with the hips joints – for example the groin would not move forward naturally when the pelvis tilts backwards. The sphere control of the *Top of the Torso* shall lie in the horizontal alignment of the last joint of the character's torso (equivalent to the last thoracic vertebra), which is usually a little above the shoulders' joints level. The *Head* sphere control shall lie in the horizontal alignment of the eyes or the ears, which is the level of the fulcrum of the head.

However, it may be acceptable to place the head control of the tool at a higher level, if the neck of the character is too short, in order to have a longer length for that section of the *expression cord* and, therefore, to show better the corresponding curve.

Matching the position of the pivot point of a control of the tool with the corresponding one of the control of the rig is not crucial, because they are connected through a *Parent Constrain* with the option *Maintain Offset on*, keeping it relative to its target.

The animator may also need to adjust the length of the controls amplifiers tubes, by selecting the *PT_tubeH_Head*, and/or *PT_tubeH_TorsoTop*, and/or *PT_tubeH_Pelvis*, in the *Outliner* of Maya software, and scaling it along the X axis (Scale X). In the case of the *PT_tubeH_TorsoTop* it will scale the shoulders' amplifiers, too.

There is also the option to adjust the *PT_FootTip_locator* to the tip of the toe of the left foot (only *Translate X* and *Z* are available). The purpose of this locator is to help calculating the position of the ball of the feet, so that when a foot rolls or does the tip toeing, the feet locators/line *PT_FeetAligner* adjusts to align with the ball or the tip of the toe. This solution will be implemented in a second phase and besides the alignment, it may also automatically suggest how much the *PT_FeetCircle* (to which the *Bottom* control is constrained) should slide on the X axis to the opposite foot, as discussed in 5.1.3.

5.2.2   Connecting the tool controls to the character controls

After having placed the tool, it is necessary to establish a relationship between the controls of tool and the corresponding ones of the character, in a process described below.

By selecting the *Main Control* of the character, as requested in the Attaching Window (Figure 73), the animator tells the system to *Parent Constrain* the tool to that character, so that they move together when manipulating the main control of the character.

Upon selection of the *Head* control of the character's rig, the *Translation* channels of the *PT_ball_Head* of the tool are *Parent Constrained* to the selected control (if it is *passive*, or the opposite order if in the *active* mode). The *Rotation* channels are *Orient Constrained*, with the option *Maintain offset on*.

The process shall be repeated to connect the *Torso/Chest* control of the character's rig to the *PT_ball_TorsoTop* of the tool, and also the *Pelvis/Hips* control of the character's rig to the *PT_ball_Pelvis* of the tool.

If the *passive* mode is chosen, the order of the connections is reversed, except for the shoulders' and feet controls, which are always constrained by the corresponding character's rig controls.

For the shoulders controls, both controls of the tool (*PT_tube_Rshoulder* and *PT_tube_Lshoulder*) are *Parent constrained* (with *Maintain offset* on) to the selected controls of the character's rig, whether in the *passive* or the *active* mode, because the purpose of those small tubes is just to provide visual guidance about the status/position of the shoulders. Since some rigs have the shoulders controlled through rotation and others through translation of its controls, the *Parent Constrain* is the right option, because includes both –translation and rotation.

When selecting the *Right Foot* control of the character, the *PT_FootRight* of the tool is *Point Constrained* to the selected control, just on the X axis, without *Maintain offset* selected. This way the *PT_FootRight* jumps to the pivot point of the character's foot control, but keeps the Y and Z axes at 0 – normal position.

Then a *Parent Constrain* is applied to the same control (on *Translate Y* and *Z* and *Rotate X,Y and Z*), with *Maintain offset* on. Likewise to the *Left Foot* control.

The *Bottom* control of the tool (*PT_ball_Bottom*) is controlled by the *PT_FeetCircle*, through a *Parent Constrain* on *Translate X* and *Z* and *Rotate Y*, with *Maintain offset* on, which is already applied, to allow switching On/Off the influence. The *PT_FeetCircle,* in turn, is controlled by the feet position, through the *Maya Expression* mentioned in 5.1.3.

At the end of the process, when clicking the *Apply* button, the *NURBS* circles representing the adjust controls of the tool (*PoseTool_MainCtrl*, *PoseTool_AdjustPelvisCtrl*, *PoseTool_AdjustTorsoCtrl* and *PoseTool_AdjustHeadCtrl*) become invisible.

Adjusting the tool to the character and establishing the connections between controls is critical for a correct manipulation and behaviour of the tool, and may generate problems if not done properly, but the Attaching Window solution proposed for the plugin will make the process very easy and safe.

5.3   Operating the tool

The 3D Pose Tool may be operated in the *active* or the *passive* modes. In the *active* mode, it controls the corresponding controls of the character's rig, except for the feet, which remain under the control of the character's feet by default. Therefore, it works as a high level control interface of the character, particularly of the controls related to axis comprising the pelvis, the top of the torso and the head. In the *passive* mode, the controls of the tool are controlled by the character's rig.

The tool works well on standard rigs, whether in the *active* mode (on top of the rig, which main controls are *parent constrained* to those of the tool) or in the *passive*

mode (being *parent constrained* to the rig controls). However, when attached to complex rigs intended to be customized and applied to any biped character, it does not work properly in the *active* mode, but only in the *passive* mode. It was tested in two different customizable rigs, such as HumanIK (included in Autodesk Maya), applied to the Nguy character (which was created for this research – see page 327), and Morpheus (character and rig v1.0), with undesirable results whenever they were *parent constrain*ed to the 3D Pose Tool – *active* mode. In the case of HumanIK, the *parent constrain* took no effect when applied to the top of the torso (*ChestEndEffector*) or head (*HeadEffector*) controls; and in the case of Morpheus, the procedure broke the connections to the forward kinematics controls. Due to the high number of connections in each of the rigs, probably only the authors would be able to correctly establish the connections between them and the 3D Pose Tool (the author of Morpheus was contacted on this topic but no reply was received about a possible solution). It was also tested with the Police character, which has a simpler, more or less normal rig, and worked well in both modes.

The option for the user to choose the *active* or the *passive* modes appears in the Attaching Window of the 3D Pose Tool (see Figure 73), displayed at the beginning of the attaching process, and the user is requested to choose between them.

As mentioned before, the *Bottom* control of the tool is controlled by the feet's controls of the character's rig in both the *active* and the *passive* modes, except for the lateral adjustment, towards one foot or the other, which is controlled manually through the *Slide* attribute, accessible in the *Channel Box*. In fact, two things must be done manually: the lateral adjustment (sliding) and also the adjustment of the orientation of the line connecting the two feet in a more accurate way – between the ankle and the ball of the foot, or even the tip of the toe, perhaps, depending on where the supporting point is located. As discussed in section 5.1.3, for example if one of the feet is off the ground, there is no doubt

that the other foot is bearing all the body weight. If one heel is up (rotation of the ball of the foot), probably the other foot is bearing most of the weight (in most cases), BUT there may be situations when that bent foot may even support most of the body weight. Therefore, the sliding and orienting process is only be partially automatized and must be fine-tuned by the animator in the end. The animator may have full control of the *Bottom* control, if needed, by unlocking the *Lock To Feet* attribute, in the *Channel Box*.

When working in the *active* mode, the animator also has the *Pelvis Hierarchy* control, which allows the manipulation the *Top of the Torso* and the *Head* controls together with the pelvis control. It is manipulated by selected by clicking on the semi-transparent grey triangle shapes that surround the *Pelvis* sphere control. When clicking on the sphere, through the open areas of the hierarchy control, the *Pelvis* control is selected, instead.

The *X-ray effect* is turned on or off through two buttons located in a Maya shelf, as described in 5.1.4, and the tool may be hidden using the Maya Display Layers option.

The *Power Centre* symbol may be moved to any position, and parented to any control of the tool or of the character's rig, to remind the animator of where the source of energy is in each pose. It could work in several other ways, involving predefined poses and different degrees of customization to a particular character, as discussed in section 4.3.

The *gravity line*, which helps to double check if the body is correctly organized and balanced according to the intended pose, is completely depending on the *Bottom* control position.

The tool could also be partially manipulated through a sketch-based solution, as suggested in section 4.3, page 149, if the complexity of the character's rig allows it

to work on top, i.e. in the *active* mode. That way, the animator would draw the *line of action,* defining the thrust of the body, in the initial phase of the posing process. However, after that all the precise rotations and translations related with the *contrapposto* and *serpentine line* must be done directly on the tool, by manipulating the specific controls.

As stated before, one of the goals of this tool was the condition of being easy to use, giving freedom of control to the animator, which has been achieved in both operating modes.

5.4   Summary

The development of the 3D Pose Tool involved a long process of trial and error. Overall, the design was kept very simple, favouring the functionality – easy perception of the nuances in its shape and form, and easy selection and manipulation – and the 3D model was made accordingly, because in the end the tool is not to appear in the rendered images. Due to the required behaviour of the cord, in terms of smoothness of the curvature and the twist, the rig solution created to control this tool was only successfully achieved after having explored several options. The final display solution is not exactly as imagined initially, although it allows a satisfactory visibility through the character's geometry, and the automatized colour behaviours also have a few limitations when the tool is used in the *passive* mode.

The process of attaching the tool to the character's rig also required a lot of planning and testing in order to find the best solution. The connections between the tool and the character's rig work well in the *passive* mode but, unfortunately, was not possible to make the connections work properly in the *active* mode with all character's rigs, due to the complexity of some of the rigs.

The functionality of the tool was tested with different character and rigs, and it is easy to operate, whether in *active* or *passive* modes. When in *active* mode, besides the visual guidance, it also works as a high level control interface to manipulate the controls of the main axis of the character's body, but that mode may not be possible with some complex character's rigs. The results of some tests have shown that in some of those cases the tool may need to be controlled by the rig controls – the *passive* mode – in order to work properly without breaking the existing character's rig connections. The manipulation of the *Bottom* control and the *Power Centre* locator is the same in either mode, as well as turning the *X-ray effect* on and off.

In the end, this version of the tool fits the main purpose – providing visual feedback, according to the approach – in a satisfactory way, in spite of the limitations in the display mode through the character's body. The plugin solution is still a work in progress and the coding work required to implement the tool as a Maya plugin is being developed by D. Kravtsov (personal communications).

6 Approach Applications, Demonstrations and Discussion

This chapter presents simulations of the proposed posing approach and its complementary 3D pose tool being applied to some great works of art, as well as to some problematic poses of animated movies and animation related tutorials, by using some pictures as references to recreate those poses.

The aim is, on one hand, to demonstrate that the rationale of the new approach can be identified in the poses of some famous sculptures that are well-known for their expressive and naturalistic postures; that the 3D Pose Tool that embodies it fits perfectly when superimposed on the images of those masterpieces, and also matches when transferred into a virtual character. On the other hand, the purpose is to demonstrate that some problems identified in section 2.6.2 would be avoided if the new approach was applied when creating those poses.

6.1 Depicting poses from masterpieces

The sculpture of Doryphoros created by Polykleitos, which is considered the illustration of his canon, is famous for its lifelike expression, as discussed in sections 2.3.3 and 2.4.1. Taking images of one of the roman copies as reference (Figure 75-a and b), its pose is replicated with a 3D character – NGuy – which has the 3D Pose Tool attached to it, as shown in Figure 75-c and d. When transferred from the virtual character and superimposed on the images of the sculpture, the *expression cord* with its amplifiers – as a visual representation of the approach – matches with the imaginary structure of that pose, confirming the identification with the rationale in both poses.
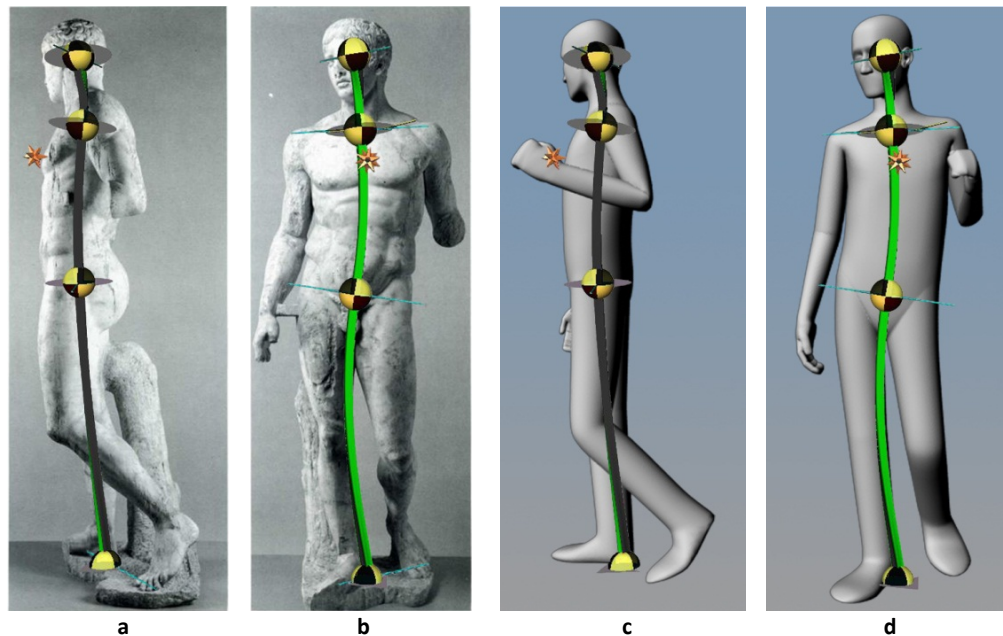
Figure 75 – *Doryphoros* **with 3D Pose Tool** (amended from Meyers 1995, pp. 66-67) **(a and b) and NGuy with 3D Pose Tool, replicating the** *Doryphoros'* **pose (c and d).**

The *power centre* on the chest, suggested by the slight projection of the chest forward, as the origin of the source of energy that leads the body, is consistently expressed by the curvature of the *expression cord*, as seen in Figure 75-a and c. That curvature is also coherent with the slight tilt of the pelvis forwards, counterpoised by the top of the torso tilting backwards, as can be noticed in the corresponding controls orientation. The arching of the torso and expanding the chest are consistent with the expression of dominance (Argyle 1996, p. 208) of a proud winner. The counterpoising of the body parts, typical of the *contrapposto*, as discussed in section 2.3.3, is even more evident in the coronal plane (Figure 75-b and d), as expressed by the reversed *S-curve* shape of the *cord* modulated by the position and orientation of the controls, and enhanced by its amplifiers. It matches the lateral tilt of the pelvis to his left side and of the top of the torso to his right, in a process of distributing the weight of the body conditioned by the supporting leg, bending the torso by flexing his right side and extending the opposite side, thus, producing a particular rhythm of the whole body shape. The opposition relationship also exists in the rotations around the vertical axis (Y) and is expressed

by the torsion of the *cord* and can be more easily identified in the transverse plane, especially with the controls amplifiers, as shown in Figure 76. Besides the orientation of the pelvis opposed to the shoulders, producing the twist of the torso, the alignment of the feet is crossed with the pelvis and the head is crossed with the top of the torso.
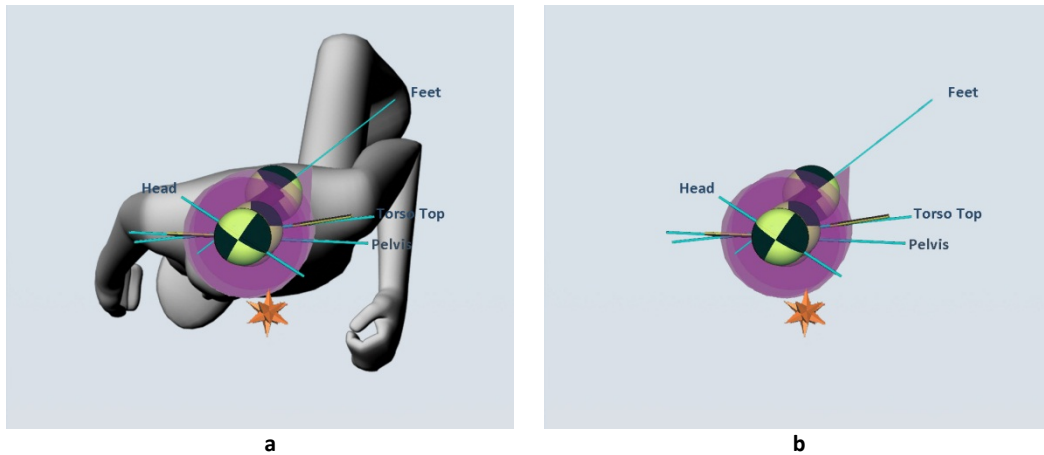
Figure 76 – Top view of NGuy with 3D Pose Tool, replicating the *Doryphoros'* pose (a), and just the 3D Pose Tool (b).

This may seem obvious and easy to do but, even when replicating the pose from an existing reference image, the animator may leave some parts/controls untouched, if he is not careful enough. Taking the example of the sculpture of David, created by Michelangelo, shown in Figure 77-a and the pose created after it, shown in Figure 77-b, at first sight the overall pose may look similar but a closer look reveals that the torso is stiff. The pelvis and the top of the torso are not tilted laterally to express the weight distribution in a similar way to the sculpture, which can be more easily noticed through the amplifiers, as shown in Figure 77-c, when the pose tool is displayed.

| a | b | c | d |
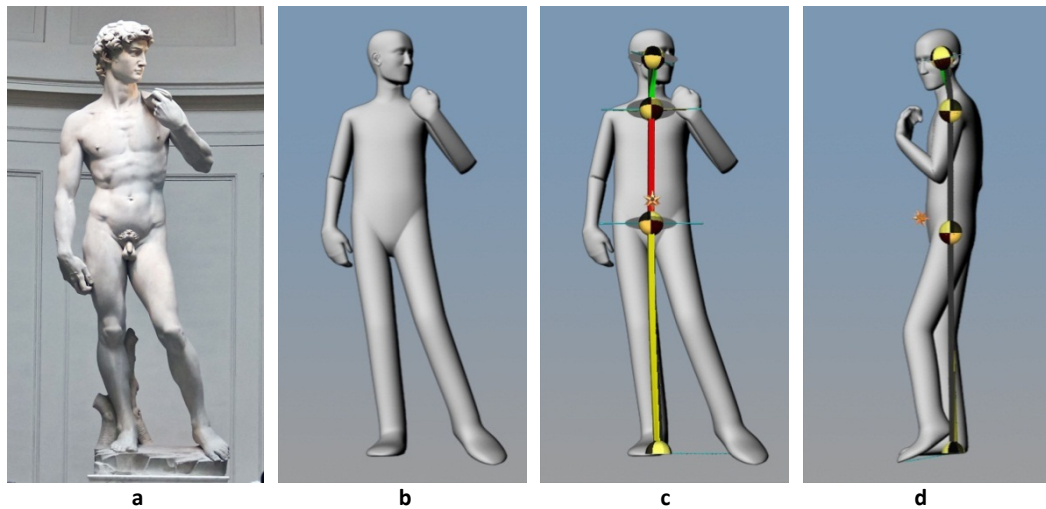
Figure 77 – Example of bad pose (b) after Michelangelo's David (Galleria dell'Accademia di Firenze) **(a), being revealed through the 3D Pose Tool and of the visual feedback it provides (c and d).**

There is also no torsion along the vertical axis, and no translation either, resulting in the stiffness of the torso, which is easily noticed if compared with the pose in Figure 78-b. When observed from the side view, the pose seems to express a fearful attitude (Figure 77-d) rather than a confident and defiant one, as in Figure 78-c.

This example shows that the axis that comprises *pelvis, shoulders* and *head*, which influences the posture of the entire body, may be easily neglected in 3D computer animation, possibly leading to a lack of expressiveness of the character, as referred earlier. This also shows that it can be avoided if the animator follows the rationale of the proposed approach when arranging the body parts of the character. Furthermore, the example shows the usefulness of the pose tool to give visual feedback, and even to alert the animator to the situation of some unchanged axes values, by showing a not green colour (red in this case, because the two controls have no rotation or translation) in that problematic segment of the *cord.*

Michelangelo's David is another example of the *contrapposto* and, therefore, a similar counterpoising rationale and opposition relationship can be identified, although with different orientations from the Doryphoros, due to a different attitude being expressed by that pose (as described in 2.4.1). The *power centre* is

in the belly, as in a confident pose, which pulls that part of the body forward, and the torso leans slightly backwards and to his right side, as in a preparation for the strike. The suggestion of the tension of the moment is complemented by the position of the left foot and of the arms and hands. The *expression cord* behaves accordingly, displaying the corresponding curvature and torsion, in a direct correlation with the arrangement of the body parts of the main axis, as shown in Figure 78 and Figure 79.
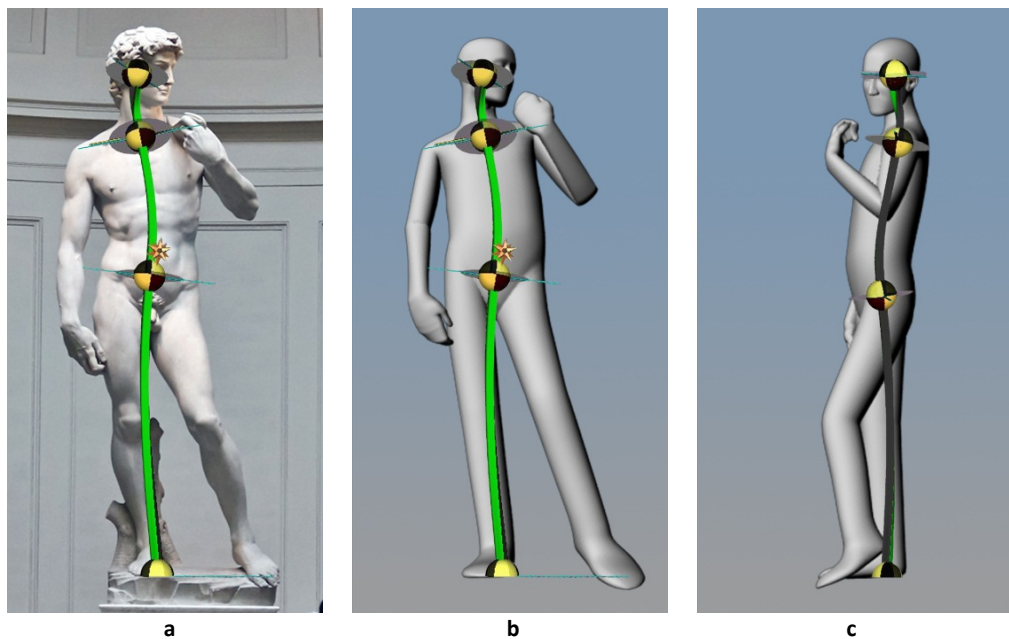
Figure 78 – Michelangelo's *David* with the 3D Pose Tool (amended from Galleria dell'Accademia di Firenze) **(a) and NGuy with 3D Pose Tool, replicating the *David*'s pose (b and c).**
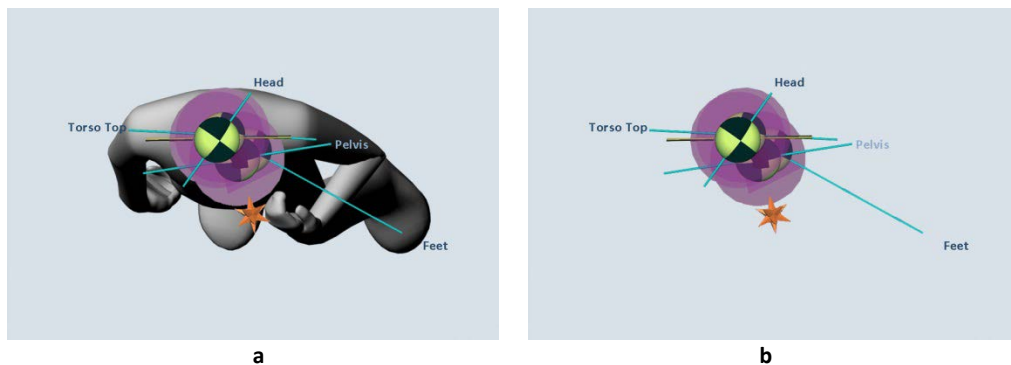
Figure 79 – Top view of NGuy with 3D Pose Tool, replicating the Michelangelo's *David* pose (a), and just the 3D Pose Tool (b).

In a more dynamic pose, like the *David* created by Bernini, the rationale of the *serpentine line* is evident as the main defining element of the pose, as shown in Figure 80.

| a | b |
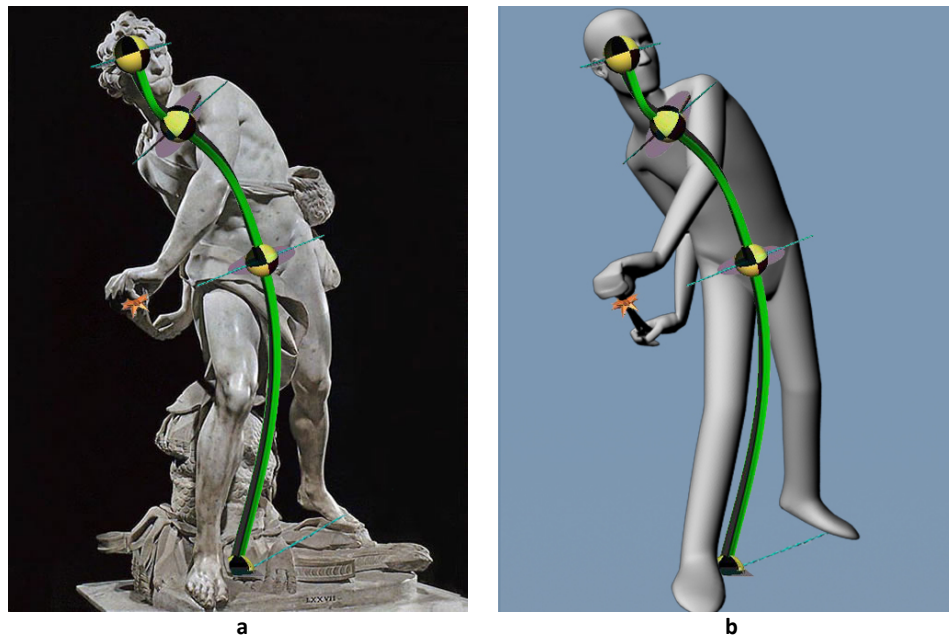
Figure 80 – Bernini's *David* with the 3D Pose Tool (amended from The Culture Concept Circle) **(a) and NGuy with 3D Pose Tool, replicating the *David*'s pose (b).**

The anticipation of the throwing action is represented by a quite slanting figure, with an accentuated angle of inclination of the body forwards (especially evident if seen from the sagittal plane), while twisting and bending towards his right side. The twisting and bending movement is led by his hands, holding the sling, where the *power centre* is located; more precisely in the left one – that is carrying the stone. Later, during the throwing movement, the *power centre* would be in his right hand – that would drive the sling to throw the stone. In spite of that leaning pose, in an anticipation movement to gather momentum, the body is not out of balance and the *expression cord* helps to confirm that, as discussed in section 4.2. The reversed "C" shape (from the feet to the shoulders) of the *cord* has its bottom point vertically aligned with the centre of gravity of the body. The twisted condition of the whole figure is clearly noticed in the 4 sided *cord*, with black and green colours, and also in the spheres with black and yellow marks of the pose

tool. This can be observed from different perspectives but the controls amplifiers provide a more accurate angle of rotation of the corresponding parts of the body, when seen in the alignment of the cord, as shown in Figure 81 and Figure 82.

a   b
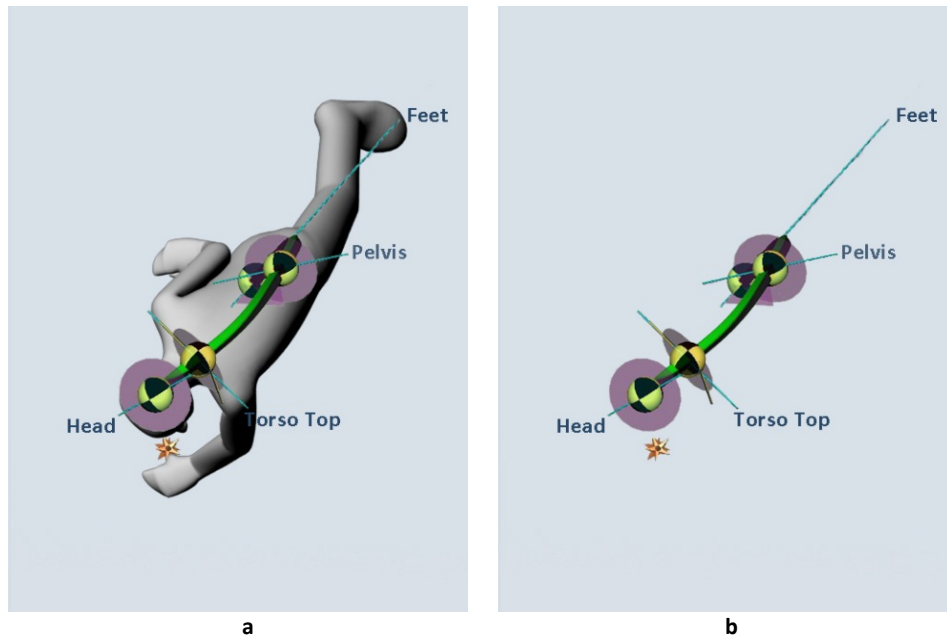
Figure 81 – Top view of NGuy with 3D Pose Tool, replicating the Bernini's *David* pose (a), and just the 3D Pose Tool (b).

a   b
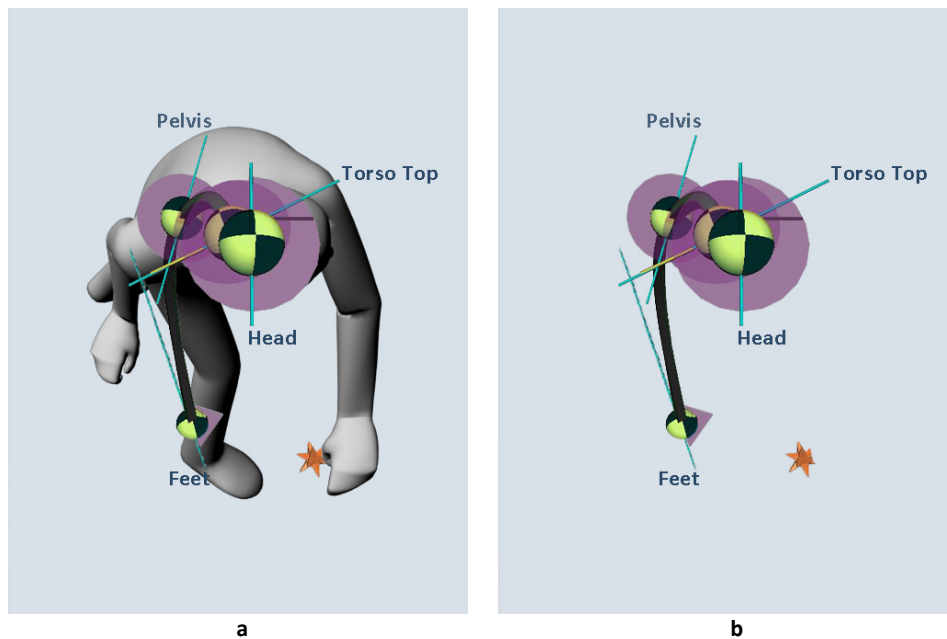
Figure 82 – A different top perspective of NGuy with 3D Pose Tool, replicating the Bernini's *David* pose (a), and just the 3D Pose Tool (b).

The above discussed examples prove that the rationale of the proposed posing approach and its imaginary cord can be identified as structuring elements of the main axis of the body in those famous sculptures, contributing to the definition of the arrangement of the body parts.

Furthermore, the images in Figure 83 show that for the same posture the *expression cord* keeps the same features, whatever the character's body, as it should. Thus, this proves its constancy of synthesis and response, in terms of the quality of curvature and twist, under the same circumstance – pose – independently of the character's design, body proportions and rig as well.
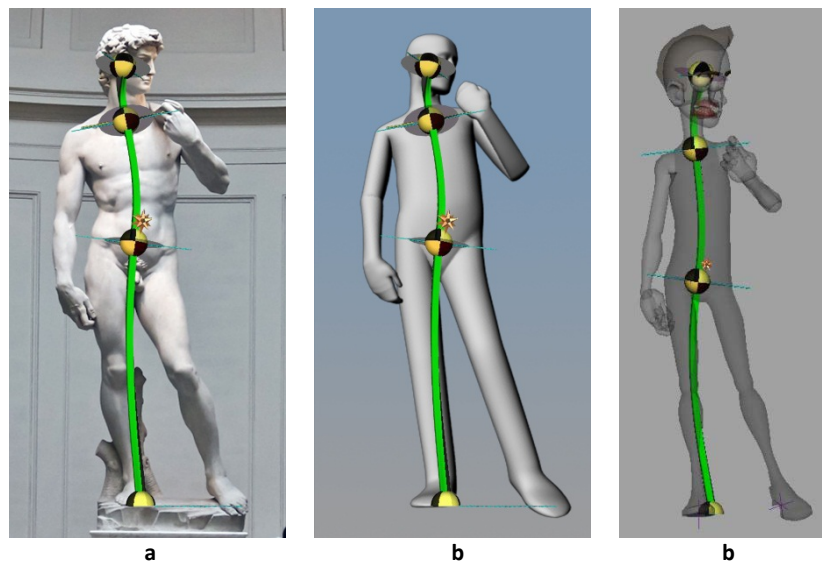
Figure 83 – *Expression Cord* comparison, with NGuy (b) and Morpheus (c) replicating David's pose (a).

Therefore, there is evidence of the validity of this proposed approach as a conceptual guideline for the creation of expressive poses with 3D characters.

6.2   Creating a new pose with a cartoon character

If taking a cartoon character – policeman – and posing him walking on the street, in an entirely new pose created with the new approach, the result is also very

convincing, in terms of expression of weight, rhythm, flow of force and action (see Figure 84-a).
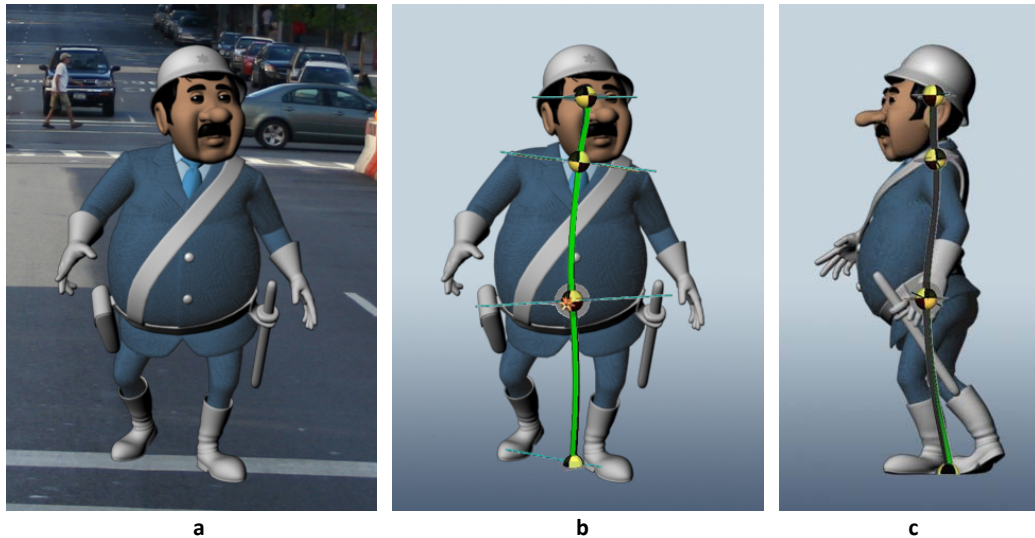
Figure 84 – Police character walking on the street (a) and with 3D Pose Tool (b and c).

He looks at, and walks towards, something on his left side, as suggested by the subtle inclination of the body to that side and the direction of his gaze. The serpentine effect can be easily identified through the whole body and is well synthesized by the *S-curve* and twist form of the *expression cord*, as the structuring element of the pose.

The weight distribution is determined by the engaged foot and also by the momentum of the walk and is achieved by the lateral counterpoise of the torso, producing the flexion of its left side and the extension of the opposite side, as indicated by the amplifiers and by the curvature of the *cord* (see Figure 84-b). This distribution is also complemented by the twist of the body to his left side, from the feet up to the head, which is reflected by the *cord* and its spheres. The twist can also be seen in the orientation of the amplifiers, in the transverse plane (see Figure 85), as well as the spiral displacement of the sphere controls corresponding to the main body parts, being offset from the central axis (as discussed in section 2.3.4).

Besides the expression of weight, the pose shows a particular rhythm and a flow of force that is consistent with the action.

<p style="text-align:center;">a   b</p>
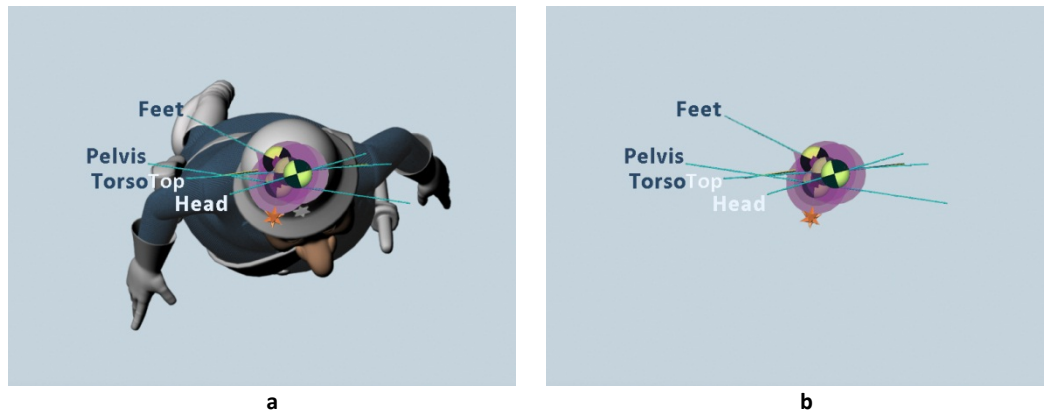
Figure 85 – Top view of Policeman with 3D Pose Tool (a) and just the 3D Pose Tool (b).

The *power centre* is in the belly, as a confident person but also due to his barrel belly condition, that influences his posture, promoting a forward tilt of the pelvis and forcing the spine to arch backwards to balance the body.

This example demonstrates that the *expression cord* and its underlying concepts can also be effectively expressed in a pose of a barrel belly kind of character, making the torso look more organic, natural and convincing (according to the action) and, therefore, more expressive.

6.3   Improving problematic examples from animated movies

Taking some examples of problematic poses of 3D characters from animated movies, which were analysed in section 2.6.2 in terms of body expression –mainly related with weight distribution and stiffness of the torso – and applying the concepts of the new posing approach, will show how the characters' pose can be improved.

In the case of Smurfs, both marked poses have a critical weight distribution problem, with inconsistencies between pelvis and shoulders positions in relation to the supporting leg and also to the shape of the body posture and its flow of energy (see Figure 86-a). In order to correct those poses, while keeping the flow of the general curvature of the bodies, represented by the yellow or red lines in Figure 86, several steps need to be taken.

<div align="center">a   b</div>

Figure 86 – *The Smurfs*, detail with existing problems (a) and proposed changes (b) marked (amended from *The Smurfs* 2011).

Regarding the Smurf with glasses, in the right side of the image, the orientation of the pelvis and shoulders, in the coronal plane, is not coherent with the weight of the body being supported by his right leg, as the pose suggests and was discussed before. Therefore, to correct that problem, the *contrapposto* concept should be applied, making the pelvis tilt to his left side and the shoulders to the opposite side (as marked in cyan in Figure 86-b), which will make the torso bend to his right side, producing a curvature in harmony with the whole body curve represented by the red line. Moreover, the upper body should translate a bit to the same side, in order to align the centre of gravity with the centre of the base of support (the bottom point of the *expression cord*, near his right foot). The tilt of the pelvis will also produce a subtle bend of the left leg, which will add consistency to weight

distribution of the pose, since that leg is free from most of the body weight. The result of these changes can be observed in the pose of NGuy character, placed next to that Smurf, showing the *expression cord* (green) with a curvature similar to the red line over the Smurf, and the amplifiers marks with similar orientations, too (see Figure 87).

Figure 87 – *The Smurfs*, side by side with the proposed corrected poses applied to NGuy character (amended from *The Smurfs* 2011).

Furthermore, the twist of the torso is similar to the one of the Smurf's pose but the left foot of NGuy is moved slightly backwards, in order to avoid the lateral alignment of the feet that would limit any forwards or backwards movement of the upper body and would make the pose less expressive, as stated by Aubert (2003, p. 17). This way, the pose of NGuy displays a serpentine effect, with a subtle twist from the feet to the shoulders, while the head is oriented towards Papa Smurf and the human character (Patrick Winslow). That solution adds some dynamic expression to the pose and makes it consistent in terms of weight distribution and attitude towards the conversation, which contributes to a more appealing body expression.

The Smurf character on the left side of the image also needs to have the tilt of the pelvis and shoulders reversed, in order to be consistent in terms of weight distribution and for the torso to be in harmony with the general curvature of the body, too. In this case, for the body weight to be supported mainly by his left leg and even keeping that leg bent, with the heel off the ground (assuming that was the animator's intention to have that peeping-like pose), the pelvis needs to tilt slightly to the opposite direction and the shoulders should tilt to his left side. Moreover, his right foot needs to be placed slightly away from his left one, and also backwards, in order to add stability to the body. This way the torso will bend to his left side – in harmony with the flow – the centre of gravity will be vertically aligned with the centre of the base of support (near his left foot) and the body weight will look well distributed and balanced. Furthermore, the stability of the pose requires that the orientation of the different parts of the body, in the transverse plane, is organized according to the *contrapposto* concept, in a sequence of oppositions, from the feet to the head. The pelvis turns slightly to the character's left side, opposing the axis of the feet, while the shoulders turn slightly to the right, producing a subtle twist of the torso; and the head turns to the left, looking at the camera, getting a similar orientation to the pelvis. The resulting pose is portrayed by the NGuy character next to the Smurf on the left side of Figure 87.

The *Power Centre* of these curious creatures is in their heads (noses), which justifies the leaning of the bodies forward, as if pulled by their heads.

Although NGuy character is very different from the Smurfs, in terms of proportions and shape of the body, which does not allow a perfect comparison, it is possible to see how the new posing approach would help the animator to avoid the mentioned posing problems and, therefore, to produce more expressive poses.

The lack of weight in Shrek's body expression, especially in some shots showing him walking, as discussed in 2.6.2, is another good example to demonstrate how the proposed approach can be useful to the animator.

Figure 88 – Scared Shrekless (amended detail with different curves, from Scared Shrekless 2010).

As can be observed in Figure 88-a, the position of the pelvis is not correct in any case because if the supporting leg is the left side one, the pelvis should tilt laterally, lowering the right hip and then the shoulders should tilt in the opposite way (see yellow lines in Figure 88). However, considering just this snapshot and the interaction with the other character (Fiona), the best solution for a more expressive pose would be the curve traced in green (Figure 88-b), which keeps the upper part of the torso and changes the supporting leg to the right, requiring the pelvis to tilt and twist in the opposite direction to the shoulders and the torso to bend and twist, too, producing a clear and expressive *serpentine line*.

Therefore, in this shot the character's body should move from the pose defined by the green lines to the one defined by the yellow lines, in a pendulum cycle. The movement should include, of course, the twist of the torso and also a subtle oscillation of the arms, although he is carrying the children in his arms.

A 3D representation of those two suggested poses is shown in Figure 89, below.

Figure 89 – Shrek, side by side with NGuy in the two suggested poses (amended from Scared Shrekless 2010).

The *power centre* should be below the navel, as a confident, grounded and bossy character, considering also what his body mass suggest. Although, often the way he moves and how his hands and elbows are lifted make him look more like an anxious one, with the *power centre* above the shoulders.

Again, the form of the NGuy's body is different from that of Shrek character, and their proportions do not allow a perfect comparison. For example, if Shrek was that thin (and not so heavy), there was no need to tilt, laterally, the pelvis and the shoulders so much. However, this still allows to show that if the proposed approach is followed in this case, it would easily help the animator to avoid the mistakes and, therefore, would contribute to a more consistent and expressive character.

Therefore, from the above discussed examples, it is evident that the approach can help the animator to avoid problems of weight distribution, or lack of appropriate weight, in the poses of 3D characters. It contributes to ensure consistency between pelvis and shoulders orientation in relation to the supporting leg – the

centre of base of support – and adjusting the body parts according to the inherent flow of energy required for the specific attitude.

6.4 Correcting problematic examples from tutorials

Other problematic examples involving the torso were presented and discussed in section 2.6.2, relating particularly with its key influence to the overall expressiveness of the pose. Bending the torso in the way suggested by Lango (2009c) to pose the character leaning forwards or backwards, besides being susceptible of producing misleading body expressions, tends to look unnatural in a pose intended to portray a character looking down or up. As can be observed in Figure 90-a, it affects the fluidity of the pose, i.e. the way the flow of energy goes through the whole body to structure and sustain the pose, because it implies an inflection point below the pelvis.

a	b	c	d
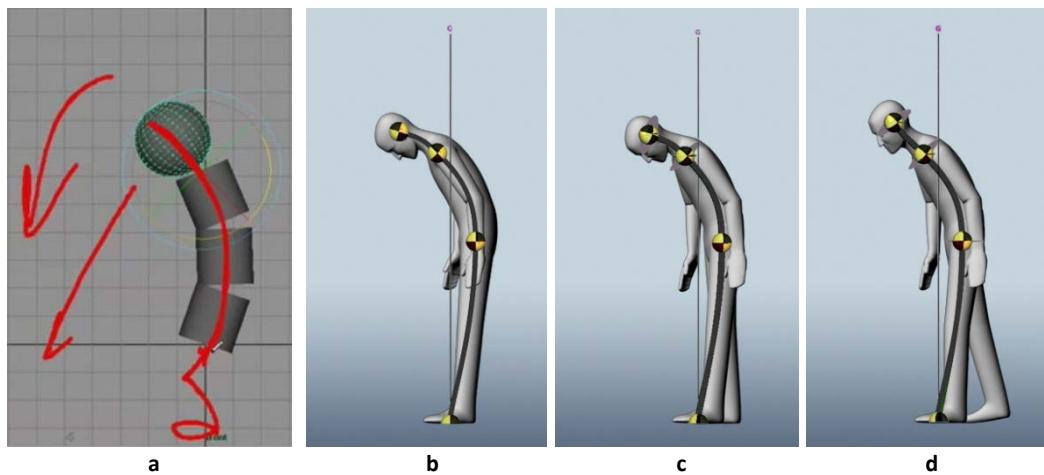
Figure 90 – Example of leaning forwards proposed by Lango (cropped from Lango 2009c) **(a) and NGuy character in some more natural poses of looking down attitudes (b, c and d).**

The solution should aim not just to avoid the stiffness of the torso and keep the balance of the character but to express the driving force behind the attitude. Therefore, differently from what Lango suggests, the curvature should involve the whole body and not just the torso, in order to strengthen the flow of the pose, as represented by the *expression cord* of the 3D Pose Tool in Figure 90-b, c and d.

Likewise, the balance of the body – its weight distribution – is achieved not just by the torso but by the torso in relation to the other parts of the body. The position of the pelvis does not need to be vertically aligned with the top of the torso/chest or with the feet, as suggested in Figure 90-a, and, in fact, the pelvis must move backwards to counterbalance the weight of the upper part of the body that bends forwards, as shown in Figure 90-b, since that is what happens naturally and can be observed in daily life. What needs to be aligned is the projection of the centre of gravity with the base of support on the ground, as shown in Figure 90-b, c and d. In those examples, the centre of that base of support (corresponding to the bottom point of the *expression cord*) is located in the middle of the foot (halfway between the ankle and the toes) but could go till the tip of the toes, if needed – in case the upper body leans further forwards – as discussed on page 136.

Having the two feet laterally aligned and equally supporting the body – meaning that the centre of the base of support is exactly halfway between the feet – as in Figure 90-b, may not look very natural and may also limit the balance of the body in the event of a movement forwards or backwards, as mentioned by Aubert (2003, p. 17). Therefore, the pose looks more expressive and balanced if one foot is placed slightly in front of the other, as shown in Figure 90-c. Furthermore, if the character is posed looking more at one side or the other, changing the leaning direction of the upper body, that adds dynamism and intention to the pose and will also contribute to avoid the twinning effect (if seen in the coronal plane). Such a change in the direction usually involves a twist of the body (the *serpentine* concept) and requires changing the weight distribution, to keep the balance of the body. In the example of Figure 90-c, the pelvis rotates towards the character's left foot, while translating slightly in the opposite direction to counterbalance the upper part. It will also make the bottom point of the *expression cord* to move closer to the left foot, since the character is leaning towards it and, therefore, the body weight is more on that foot.

If considered independently, i.e. taken out of context – out of the entire sequence of the looking down movement – the expression of the pose in Figure 90-c may give the impression of sadness/hopelessness to the audience (although to correctly convey that, the knees would need to bend, too). Therefore, lifting the head slightly, as shown in Figure 90-d, could be a good option to avoid that possible confusion, especially in case the knee(s) bends, since that position of the head, moving against the force of gravity, adds a sense of physical and mental vitality, as discussed by Arnheim (1996, p. 142). Having the feet placed further apart, adds more dynamism to the pose, too. In this last example, the bottom point of the *expression cord* is even closer to the left foot, since the pelvis is translated slightly towards that foot and most of the character's weight is being supported by it.

Even if the animator wants the character to look closer at the floor, bending the legs and lowering the upper body, the pelvis should not tilt backwards the way Lango (2009c) suggests but should instead keep the orientation aligned with the flow of the whole body.

The presented examples show just a few possible ways of creating a looking down pose, as there are many possibilities of doing it and, ultimately, it is up to the animator to decide which suits better the purpose, considering the specific character in a particular scene. Essentially, whatever the way, it should involve the whole body as illustrated with the *expression cord*, in order to successfully convey the intended expression in a believable way.

The solution to avoid the stiffness of the torso, through the dorsiflexion of the torso, with the pelvis tilted forwards, as proposed by Lango (2009c) and Maestri (Lynda.com 2011b), may also raise believability issues (as discussed in section 2.6.2), whether the objective is to create a look up pose or an assertive posture.

Similarly to what was referred in the previous case, in this looking up pose (see Figure 91), the balance of the body should also involve the torso in relation to the other parts of the body. Once again, the pelvis should not be vertically aligned with the feet or the chest but, in this case, it should translate forwards, to counterbalance the upper body leaning backwards, as shown in Figure 91-b. The pelvis should not tilt forward, either, in order to keep the smooth curvature of the flow of force through the whole body.
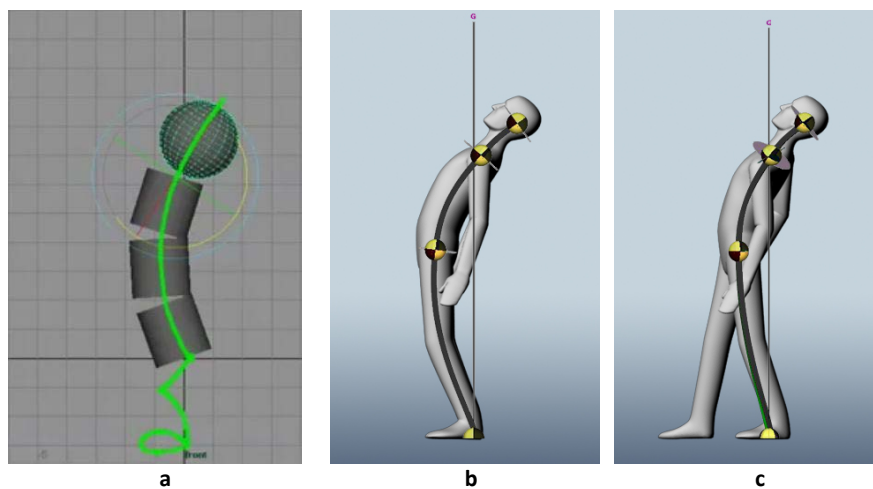
Figure 91 – Example of leaning backwards proposed by Lango (cropped from Lango 2009c) **(a) and NGuy character in some proposed poses of looking up attitudes (b and c).**

Although it is possible to lean the body backwards to a certain degree, while keeping both feet laterally aligned – by bending the knees and moving the pelvis forward (with even a slight tilt backwards) – it requires a considerable effort and, has limited stability, too. Therefore, the placement of one foot backwards, vertically aligned with the centre of gravity, is almost essential in order to provide more stability and reduce the required effort, as shown in the example of Figure 91-c.

The previous two cases give evidence that it is not necessary to tilt the pelvis forwards (to look up) or backwards (to look down), in order to keep the balance of the body. Even the opposite way (tilting the pelvis towards the leaning direction), as Lango (2009c) illustrated as being problematic examples (Figure 40-a), is not

usually required, unless in some extreme situations, like in the example of Figure 91-b. Furthermore, those solutions (reverse tilt of the pelvis and curvature of the torso), *per se,* do not make the poses look more appealing or expressive and may even be misleading. A solution based in a more naturalistic approach, and considering the body as a whole, may contribute to more convincing or believable character expression, which is the main goal in character animation, as stated by many (Thomas and Johnston 1995, pp. 62, 65-66; Williams 2001, p. 34; Roberts 2007, p. 64; Seif El-Nasr et al. 2009; Webster 2012, p. 40; Hayes and Webster 2013, p. 20).

The next example relates to a tutorial on posing techniques (Cooper 2012), showing an attempt to replicate a realistic pose using a Poser 3D model (Figure 92-a) that does not succeed in getting similar body expression to the figure in the reference photo (b), as discussed in section 2.6.2. This provides another good example of how the posing approach proposed in this thesis can help the animator to create natural body expressions of similar patterns to those observed in reality.

a   **b**

Figure 92 – Artistic Posing Techniques for 3D Human Figures (amended with *S-curves* and gravity lines from Cooper 2012).

Considering that the objective is to replicate the pose shown in the reference photo (b), the *power centre* should be in a similar place in both bodies. However, that is not the case, since in the figure from the photo (b) it seems to be in the knees, pulling the body forward and producing a quite unstable pose – in the sense that is difficult to sustain – while in Cooper's 3D model (a) it seems to be in the navel, pulling that area forward.

Although both figures display a similar *S-curve* shape of the body, if we take the traced line over each body and compare them, there is a clear difference since their shapes do not really match, as shown in Figure 93.

Figure 93 – *S-curves* comparison. The green line corresponds to the pose in Figure 92-b and the red line corresponds to the pose in Figure 92-a.

The green line is the one from the photo and it was translated to match the bottom starting point of the red one belonging to the CG model, and it was also resized to the same height.

The forward tilt of the pelvis (rotation in the sagittal plane) is problematic, as it originates the accentuated inflection point on the flow of energy of that pose (discussed in section 2.6.2), which can be noticed in Figure 92-a where the *S-curve* intersects the gravity line. It produces a sense of the upper body being about to

break backwards, or the expression of a quick thrust as in a reaction to avoid something in front of her face, which is not the case of the image in the photo.

When observed and compared in a silhouette mode, that sense of broken flow is even more evident, as shown in Figure 94.

Figure 94 – Silhouette mode of images of *Artistic Posing Techniques for 3D Human Figures*, (amended from Cooper 2012).

Clearly, the author of the tutorial fails to express the force that can be observed in the original picture, by not keeping a fluid and unbroken line, as recommended by Stanislavski (discussed in sections 2.4.4, 2.6.2 and 4.2).

The concept of *serpentine line* would help to avoid that problem, by promoting the smooth curvature of the torso. It would also help to correct the orientation of the pelvis, in the transverse plane (rotation around Y axis), which is not coherent with a progressive twist of the body that is evident in the body of Figure 92-b, as discussed in section 2.6.2 and exemplified with the *serpentine line* marks in Figure 50. A simulation of this is presented in Figure 95, with the *expression cord* representing the spiral effect of the *serpentine line* (a), in which the orientation of the pelvis is consistent with the progressive twist of the body (up to the shoulders).
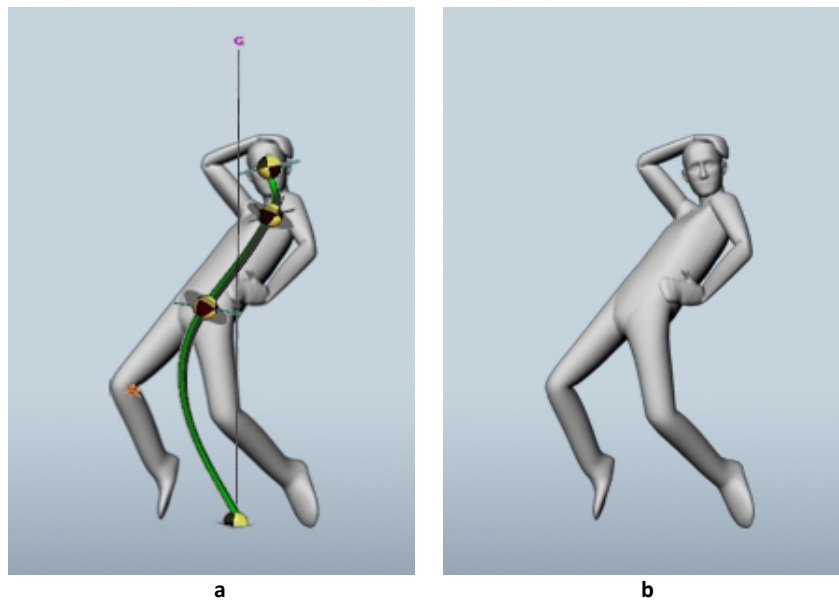
a

b

Figure 95 – NGuy version of the pose shown in Figure 92-b.

The resulting pose expresses the strength of the whole body and gives consistency to that precarious balanced pose – which is inherent to a dynamic pose – making it look more natural, in terms of body expression, and similar to the figure in the photo.

Another example of the need for the *expression cord* of the character to be fluid and unbroken, in order to express the force going through the whole body, is evident from the pushing tutorial presented by Roberts (2007, p. 76), discussed in 2.6.2. In this case the pose needs to portray an action that requires the expression of extreme force, with the whole body taut to produce and project it on the object. However, when the body shows an "S" curve like in pose "Key 9" (see red line in Figure 96-a) it gives the impression of being defeated by the opposed force or the force of inertia. Therefore, any inflection point should be avoided in that pushing moment as it may suggest that the flow of force is being diverted and weakened. Moreover, to keep the flow as straight as possible, the pelvis should not move forward but stay where it was in Key 8, while tilting forward, in order to provide the alignment (in the Y axis) with the flow of force coming from the feet

(mainly the backwards one) and continuing, through the shoulders, to the hands, as shown in Figure 96-b. This gives the torso the appropriate curve and orientation to make the *expression cord* a uniform curve that allows the flow and projection of a strong force on the object, as also shown previously (Figure 53, on page 105).

a	b
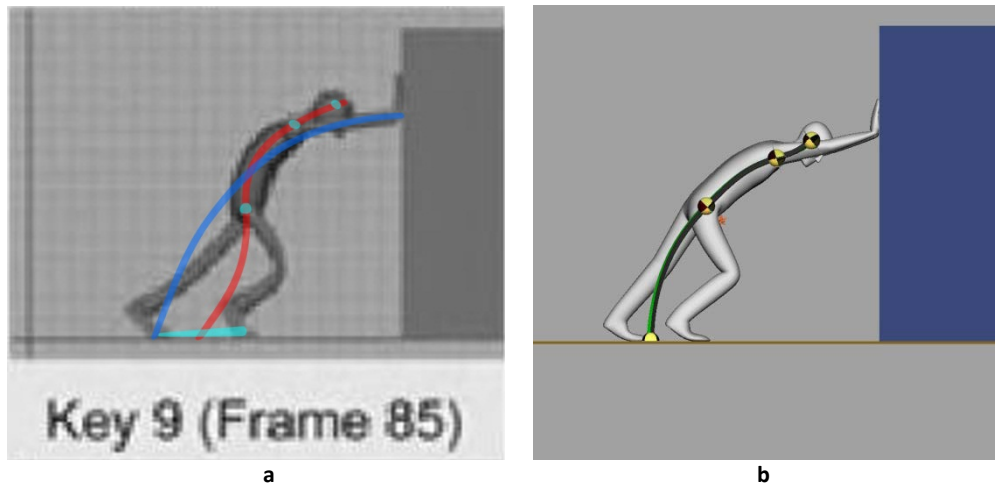
Figure 96 – Key 9 pose, magnified, with *line of action* (blue) and *serpentine line* (red) traced over it (amended from Roberts 2007, p. 76) **(a), and NGuy in the adequate pushing pose (b)**.

On the other hand, if the body bends in a concave up curve, when leaning against the object, while making the effort to push it, then it gives the impression of losing the force, and is probably about to fall down on the ground (see example in Figure 97).

Figure 97 – Body bending in a concave up curve, when leaning against an object.

The previous two examples show that the animator should not break the flow line, or let it bend too much in a way that produces a counter-curve in the torso or in the overall body, if the goal is to show the character delivering a push or projecting a strong force, to move or hold an heavy object, for instance. Otherwise, it will look as if the spine could not cope with the applied effort and the body was defeated in that purpose. Therefore, unless the intention is to animate that behaviour o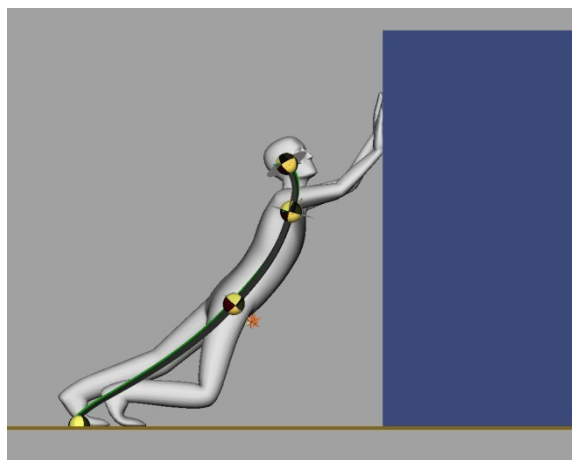f the body being defeated by the opponent force (or resistance), the animator should always keep a fluid arc, from the feet to the top of the body – to the point where the force is being applied to. If not, the force will not be directed in the right way and the expression will not be convincing.

6.5 Summary

Several examples are shown to demonstrate how the approach can help the animator to create the poses and improve their expressive qualities. In a sense, the proposed approach was experimented through the process of applying it to a variety of examples – good poses and problematic ones. It was tested and validated with some famous sculptures (Doryphoros and the two Davids) and also against problematic cases, with the creation of alternative poses that are more expressive of each case, by following its rationale during the process. Its synthesizing imaginary cord can be identified as structuring elements in those famous poses and evidence is given of the constancy of the visual feedback (provided by the tool) in different characters portraying the same pose. Furthermore, it is shown that the approach can be successfully applied to posing 3D characters, even cartoony ones, contributing to harmonize the forces involved in any particular pose and making it look more engaged with the attitude or action, while avoiding the stiffness of the torso. The importance of the torso as the core of the body – where all the dangly parts are attached – and the originator of most body motion (as discussed in section 2.5) and, therefore, as an essential element in the solution to improve the body expression (as discussed in chapter 4), is also

confirmed. Moreover, the configuration of that part of the body is directly influenced by the application of all the four concepts underlying the approach.

The arrangement of the body parts is not arbitrary and, even if merely for the purpose of counterbalancing the body, the animator shall consider the imaginary flow of force going through the body, starting from the centre of the base of support, in order to express the driving force behind the attitude. The way the parts relate to one another is important to define the body configuration and to give a particular rhythm to the pose and, therefore, it shall be done in a logical way, in order to create the correct pattern of body expression and allow the intended interpretation by the audience. Consequently, tilting the pelvis and/or the shoulders to bend the torso just for the sake of avoiding stiffness, without considering its relation with the other parts of the body, will produce misleading patterns of body expression, i.e. the poses will fail to be consistent and believable. For instance, the forward or backward tilt of the pelvis usually affects the expression of personality, mood or status and may even affect the flow of the imaginary *expression cord* – adding inflection points – and, therefore, shall be carefully defined.

The examples presented in this chapter demonstrate that if animators follow the proposed approach when creating the poses, they will get better results, because the poses will look more natural and, therefore, more likely to be convincing i.e. the expression is more likely to be perceived correctly by the audience.

7   Conclusions

This research investigated the problematic of character body expression and particularly the posing process in 3D computer animation, with the aim to improve them, by defining a new approach to the posing process of animating 3D characters and developing a 3D pose tool. It was led by the hypothesis that using a conceptual guideline based on the concepts of *Power Centre*, *Line of Action*, *Contrapposto* and *Serpentine Line* when posing a character, would help the animator to structure the pose, improving the body expression of the 3D character and making the process more efficient.

This chapter summarizes the thesis and the achievements of this research. The first section revisits the research questions initially stated in section 1.3, which directed this research in the pursuit of the objectives established in section 1.4, showing how this thesis answers to those questions. The second section highlights the contributions of this study, and the third section outlines possibilities for future work.

7.1   Overview

The research process undertaken to achieve the stated aim started by investigating the research topic and other subjects intersecting it, to find the answer to the question of how the posing process could be improved and made more efficient. The analysis of the relevant literature and other material, such as films and video tutorials about posing practices, provided useful insights into the quest for a better solution to the posing process of 3D characters and helped to shape the proposed approach and tool.

Body expression was investigated, with the objective of identifying implications of body language and its visual interpretation and representation to the posing

process. A good understanding of body expression is essential for the animator to achieve expressive results when posing the character, as explained in section 2.1. The animator needs to understand how body language is perceived and interpreted by the audience, in order to create the best representation of the character's body expression in each pose and make sure that the audience get the correct interpretation from the resulting body motion. A good pose must convey the intended expression of emotion, attitude or intention of the character, revealing his particular characterization, while dealing with the given situation. By successfully interpreting the expression of emotions, the audience can empathize with the character and get engaged with the situation and the story. Thus, it is important to arrange the body parts in a logical way, according to the force that holds the posture, in order to create the pose with the shape of a particular rhythm which is characteristic of a specific body expression.

Current practice of posing in animation was analysed, in general in section 2.2 and specifically regarding 3D computer animation in section 2.6. This was part of the process of questioning what procedures can be added to (or changed in) the posing phase in order to help the animator to improve the body expression of a character in animation. Some posing issues affecting character body expression were discussed, such as the stiffness look often displayed by 3D characters, mainly due to a deficient (or absence of) manipulation of the torso, as referred in section 1.1 and discussed in section 2.6. The lack of expression of weight (i.e. incorrect distribution of the weight among the body parts) was also discussed as a common issue in 3D character animation. These are consequences of focusing on animating forms instead of forces (not arranging the body in a logical way, according to the driving force). Character rigs with superfluous controls, especially in the torso, are often another issue, which makes its manipulation confusing and distracts the animator from the expression of the body as a whole.

In order to find a solution to help the animators to overcome the stiffness problem this research looked at other arts, to analyse how the problem has been dealt by different artists when representing the human body. The quest went back to the first references of the problem and of the solution that was found when the sculptor Polykleitos invented the *contrapposto*, in Classic Greek Art period. The use that was made of it since then, by so many famous sculptors, painters and illustrators, as shown in section 2.4, proves to be the best solution to distribute the weight and express life in the representation of a standing body, particularly in a static and relaxed pose. In the case of more dynamic poses, the solution usually involves also the *serpentine line* concept. Two more concepts were identified and investigated in section 2.3 – *line of action* and *power centre* – with the objective of studying and evaluating their potential contribution to improve the posing task.

Evidence of the rationale of these concepts can be identified in images of poses created in different art forms – sculpture, painting, drawing, acting and dance – which deal with body expression and its representation, as discussed in section 2.4. This suggests the usefulness of these concepts to guide the animator in the process of creating poses of similar expressive quality. The analysis of several images of famous poses also contributed to shape the new approach solution.

Besides lending the *power centre* concept to character animation, acting is also important for preparing the animator to create expressive performances with the character, as highlighted in section 2.4, too.

The importance of anatomy knowledge for the creation of the pose is also object of analysis (section 2.5), especially in what concerns the structuring elements of the body that are more involved in holding the pose or producing body motion – skeleton and muscles. The particular role of the torso in body expression, as the hub of the body and originator of most actions, due to its flexibility properties, makes it crucial to avoid the problem of the stiffness look of 3D character's body. Section 2.5 shows that the torso bends in a smooth curvature, with no sharp

breaks and, therefore, there is no anatomical reason for the existence of several rig controls for different sections of the torso, as discussed in section 4.5. Furthermore, it also shows that the torso bends and twists simultaneously – not just one or the other – which points to the advantage of adopting the rationale of the *contrapposto* and *serpentine line* concepts in a combined way, when posing a character.

Anatomy knowledge is also important for the creation of better rig solutions, with a more accurate placement of the controls and without superfluous controls (like the example of the torso), which also affects the efficiency of the posing process.

Considering the whole body when posing is a decisive factor in creating expressive and believable poses, because animation is more than just moving arms and legs up and down or in other directions, like pulling up and aside the strings of a puppet, as discussed extensively in chapter 2. Body movement often originates from the main body, which adjusts itself in order to enhance the ability to produce and support the movement, even if it is just an arm gesture, for example. Likewise, the representation of the character's movement must be coherent with the main body shape (especially the arrangement of the torso parts), in order to be convincing. There must be a correlation between the intended expression and the visual configuration (or pattern of body expression) that allows the correct interpretation by the audience. This is often neglected, not only in animation practice but also in research related to computer animation. This study pays particular attention to the torso and the axis comprising the *pelvis,* the *shoulders* and the *head*, along with the position of the feet, which are fundamental in determining the pose of a character because the position of those body parts are interconnected and influence the posture of the entire body. The importance of this axis is also often neglected in 3D computer animation, as referred in sections 2.3.4 and 2.6.2, and is decisive to solve the possible lack of expressiveness of some 3D animated characters, as discussed in 4.5. Furthermore, it must be noted that

character expression is not just about the mechanics of motion but about the expression of what is happening – attitudes or actions – led by emotions and modulated by personality.

This led to the formulation of a new posing approach, which is presented in chapter 4, devised to answer the research questions stated initially (section 1.3). It proposes a solution to structure the pose of the 3D character and improve its body expression, by integrating the aforementioned concepts in the process. Thus, this approach is based on an imaginary line with the properties of the concepts of *line of action* and *serpentine line*, as well as the *contrapposto* and *power centre,* to provide not only the orientation and inclination or bending but also the twisting of the body as a whole and the peculiar rhythm of the body expression. From the *line of action* we get the orientation and the angle of inclination of the body which are more suitable to the action or attitude – to give dynamics and tension – and the curve that structures the main body and the way it bends – to give fluidity to the pose. The *serpentine line* adds the twist, which accentuates the tension and the dramatic effect, by giving the animator the ability to create the torsion of the body through a gradual change of orientation of its different parts, from the feet to the head. The *contrapposto* helps to distribute the weight and promotes the variation of each part of the body in relation to its counterpart. The *power centre* and its imaginary spot works as a conceptual synthesizer of the components of characterization – the character's personality, his/her state of mind (or mood) and emotions – whose synthesis is an imaginary centre of energy that drives the posture, thus, influencing the imaginary line.

The variation in the angles of orientation of the parts of the body, generated by the *contrapposto* and *serpentine line,* also help to produce variation to the rhythm of the whole body. This promotes the asymmetry of the pose (preventing the *twinning* effect) and helps to avoid the stiffness look, while contributing to define

the flow of energy of the posture. Thus, it makes the character look more natural and more appealing.

The imaginary line proposed in this approach – *expression cord* – also facilitates the perception of the character's pose, since the *serpentine line* promotes the twist along the entire figure, which produces different angles of orientation between the feet and the shoulders. Consequently, this, along with the counterpoising from the *contrapposto*, influences the position of the arms and hands, too, originating more explicit body forms and shapes. Furthermore, the rationale of the flow of force behind the *expression cord* allows the animator to establish a hierarchy of movement of those body parts, i.e. a logical sequence in time for the change of position of each part to occur – the unfold effect (discussed in section 2.6.1) – and for the corresponding keyframes to be registered. This determines the way the transition of each part, or transformation from one body configuration to the next one – usually best represented in the breakdown poses – is expressed, improving the consistency of body expression, not just of the key-poses but of the resulting animation. This rationale also helps to avoid the string puppet effect – stiff torso and body parts not arranged into a meaningful way – discussed in section 2.6.2, which is usually the consequence of keeping the focus on animating forms instead of the force that structures and holds the body (which produce those forms), as discussed in section 2.2.1. Hence, the rationale underlying the *expression cord* helps to strengthen the believability of the pose, by contributing to make the body look more engaged in the action or attitude.

This logical way of organizing the order of the unfold makes it easier for the animator not to forget the manipulation of each of the parts involved in the movement (besides the order of its manipulation), as explained in section 4.6. That section presents a suggested posing workflow, to help the animator to apply the rationale of the proposed approach in a more efficient way.

Although this approach promotes a naturalistic arrangement of the body parts of the character, it can be applied to different styles of animation – from the more realistic to the more cartoonish ones – as long as the character is an orthograde biped or anthropomorphic one, as discussed in section 4.4 and demonstrated in chapter 6. It does not limit the aesthetic options or constrain the use of the 12 Principles of Animation, even of those that have more influence in defining the animation style of a character, like *timing*, *anticipation, stretch and squash* or *exaggeration*. These principles and other concepts used in posing remain essential to the process, being led by the high-level conceptual guideline of this approach. The purpose is not to reproduce real postures and movements (for that purpose there are Motion Capture solutions), but to assist the animator in creating unique poses, that look natural, i.e. believable and, therefore, susceptible of producing more convincing body expressions. Thus, it is not for the sake of creating naturalistic poses but as an intuitive solution for the arrangement of the body parts in order to express a convincing flow of force through the body that produces (and justifies) a specific pose in each particular moment. As demonstrated with several poses in chapter 6, this solution helps the animator to keep the fluidity of the character's body, even in very extreme poses. This fluidity can be more efficiently achieved if the torso and neck sections of the rig are built with a solution based on progressive influences (without additional controls in the middle of the torso), as discussed in section 4.5.

Regarding that proposed simpler rig to overcome the issue of excess of controls mentioned in sections 1.1 and 2.6.2 and to make the posing process less time-consuming, as discussed in chapter 4 (page 121, besides section 4.5), this variable of efficiency can only be tested in a future experiment with a significant sample. However, the characters used in the examples presented in the case studies (chapter 6) have just two controls for the torso – at the bottom and at the top – and another for the head, as discussed and recommended in section 4.5. This demonstrates that, as long as the spine section has a significant number of joints

to allow a smooth deformation and is rigged properly, the torso, neck and head can be arranged into expressive and natural poses without extra controls in between. Thus, by having fewer controls to manipulate that critical axis, the animator naturally tends to spend less time arranging those parts of the body into a pose and, later, there will be fewer keyframes to adjust the *timing*, as well. This evidence suggests that the new approach makes the process less time-consuming, independently of having additional rig controls in the middle of the torso (although less controls means less time spent setting and adjusting keyframes, obviously). Moreover, the complementary pose tool can still provide its valuable visual guidance when the character rig has several controls in the middle of the torso, like the one used in the exploratory posing experiment. As seen in that case, the tool was applied to the rig in the passive mode, which means that the manipulation of the character was done using the character rig controls, and yet the displayed behaviour of the tool was of the same kind, as shown in appendix A.3.2.

The proposed approach helps the animator to think structurally when creating the poses, taking the focus of his/her attention out of all those rig controls and on to the flow of force that holds the character's body and determines the way it manifests. Hence, it helps to improve the animation process since the beginning, through the creation of more meaningful key-poses, which will reduce the heuristic tendency of adding multiple keyframes to define and control the motion, later. When following this approach, the animator is naturally led to overcome the stiffness problem and gets better results in terms of the characters' body expression and, therefore, more effective poses (and corresponding animation, since the key-poses are determinant in generating the animation).

The approach can be applied at a conceptual level, in the animator's mind, or embodied in a visual tool, which immediate feedback contributes to make the posing process more efficient. Such a tool – the 3D Pose Tool – which is

complementary to this approach and aims to provide visual guidance to animators, is presented in chapter 5. This virtual tool is integrated in a 3D animation software (e.g. Maya) and may also allow the animator to directly manipulate the main axis of the character, whenever the active mode of the tool is possible, as imagined initially. The vertical tube of the tool represents the *expression cord,* as a visual metaphor of the flow of force that goes through the main body and energizes the pose. Initially, that cord serves as a representation of the *line of action*, and then evolves to a representation of the *S-curve* or of the *serpentine Line*. The feedback about the twisting is given by the torsion of the *expression cord* – a line is not enough to express it and, therefore, a 3D form is required. The rationale of the *contrapposto* is also represented by the marks on the control spheres and by the horizontal amplifiers. Hence, the 3D Pose Tool synthesizes all those concepts, visually, in a virtual display. The usefulness of this pose tool was tested and demonstrated by its application in all the examples presented in chapter 6.

All those procedures proposed in chapter 4, along with the pose tool presented in chapter 5, help the animator to improve the character body expression and make the posing process more efficient, as demonstrated in chapter 6. A better efficiency is achieved through the creation of more expressive poses and a less time-consuming process. The expressiveness is improved through the arrangement of the body parts in a believable way, creating a particular rhythm and harmonizing the whole figure around a flow of force that drives the body in a specific attitude, according to a given situation and a particular personality. The time consumed in the process can be reduced through the use of the conceptual guideline (allowing to keep the main focus on the body as a whole), the visual guidance provided by the 3D pose tool, and with simpler character rigs.

Evidence of the contribution of the new approach to improve the practice of posing 3D characters is given in chapter 6. Several examples are provided and discussed, as visual evidence of the contributions of this approach to the creation

of expressive poses with 3D characters. It was tested in two ways: against images of famous art works (sculpture, cinema, animation) and images of real life examples, through the replication of good examples and the correction of problematic ones; and for its capability to guide the process of creating new and original poses with virtual characters.

Regarding an evaluation by other practitioners, the exploratory experiment – although based on an incipient sample, which does not allow generalization – provided some hints, at least on the local ambit, regarding the state of character animation education at university level, particularly on the posing process and involving body expression. The participants' results and the questionnaires corroborate some previously identified issues about the practice of posing in 3D character animation, as discussed in appendix A.4.4. They seemed to be more focused on animating forms instead of forces (discussed in section 2.2.1), and use a heuristic way of posing (discussed in section 2.6.1), instead of adopting a clear approach, applied in a systematic way. Moreover, maybe the students should be more effectively exposed to body expression and acting, and its importance for character animation. The results of the exploratory experiment, in fact, reinforce the need of such a new approach to posing, to improve the process and the resulting character body expression.

7.2 Contributions

This research aims to contribute to knowledge on the creation of 3D character body expression, particularly in the posing process of 3D computer animation, as mentioned initially. There are two main conceptual contributions to practice methodologies of animating characters: the New Posing Approach and the 3D Pose Tool based on its rationale.

The introduction of a novel approach to posing a 3D character is based on a combination of concepts – *Power Centre, Line of Action, Contrapposto* and *Serpentine Line*. Such combination is synthesized into a whole body pose by the imaginary line – *expression cord* – and its associated amplifiers of the body key points, expressing the flow of energy through the body that holds the pose, defines its rhythm and guides the arrangement of the body parts around it. Furthermore, this imaginary cord can be used by the animator as a symbol to graphically represent the imagined poses, when sketching preliminary studies, thumbnails, etc. The proposed approach presents a solution to involve the whole body – including a meaningful use of the torso – in the creation of 3D characters' poses, in order to overcome the problems that affect the believability of the character's body expression. Therefore, this approach allows the animator to improve the poses of a character, by helping him/her to arrange the body parts in a convincing way according to the intended body expression to be conveyed. Although this solution is conceived for orthograde bipeds it may be adapted to other kinds of characters, as discussed in section 4.2. The same rationale can even be applied to quadrupeds, as long as the anatomical differences are taken into account.

The design and development of the 3D pose tool, integrated into the animation software Autodesk Maya, which behaves as a three-dimensional *Bezier curve* and provides visual guidance and feedback, allowing the animator to apply the rationale of the proposed approach in a more efficient way. This 3D Pose Tool also constitutes a good solution to extract poses from images in storyboards, thumbnails, photos, etc. imported into the animation software; by hiding the 3D character, the animator can adjust the *expression cord* and its amplifiers over the body in the image, capturing the essence of the pose. It can also work as a high-level graphical user interface, when the character's rig allows it to be attached on top (in the active mode) and control the manipulators of the main axis of the character's body, thus, giving total control over its manipulation to the animator.

In the end, with the approach and pose tool proposed in this thesis, the initial *line of action* becomes something more comprehensive, in order to deal with the complexity of a meaningful pose in a more complete, efficient and naturalistic way. It is no longer just a 2D line, but something with three-dimensional properties, encompassing several concepts – the *expression cord*. Furthermore, the proposed tool makes it logical and, therefore, easier and more intuitive to identify each section of the cord with the corresponding part of the body, delimited by the control points located between each section of the tool.

The initial position of the *power centre* locator, as a virtual label attached to each character, contributes to keep the consistency of the character's performance, either when there are different characters being animated in the same scene or when the same character is animated by different animators in each scene, as discussed in 4.3.

The introduction of a specific workflow (section 4.6), suggesting an efficient sequence in time for the concepts to be applied by the animator, while ensuring that the essential steps of posing are not forgotten in the process.

The presentation and discussion of applied examples, with several poses specifically created to illustrate the cases, which provide evidence of the advantages of using the proposed posing approach and tool, demonstrating how it can help the animator to improve the characters body expression, by intervening on the pose creation phase.

The conceptual guidance of this approach is also useful for practitioners of other visual art forms, such as comic artists and illustrators, when dealing with the creation of characters in expressive poses.

This thesis demonstrates that the fine arts concepts of *contrapposto* and *serpentine line* and the acting concept of *power centre* can contribute to improve

the posing process in 3D character animation when combined, in a systematic way, with *line of action.*

Some professionals have said, in informal talks, that this approach is more important for students because professionals already know about this. Indeed, all the professional animators should know about *this* already but the issues shown in section 2.6.2 and discussed in chapter 6, are just a few examples of this being often forgotten by many of them.

Therefore, it is recommendable that, once the plugin solution is finalised, the 3D Pose Tool should be made available for full testing by a significant sample of professionals and students, in advance of the possible production of the tool.

7.3   Future work

There is always room for improving an approach, and certainly that is also the case with this one. However, in the near future, the effort shall be on finishing the complementary 3D pose tool as a plugin solution, so that it can be easily applied by the user to any 3D character. The visual guidance solution provided by the tool could be improved if access is granted to Autodesk Maya source code or if future versions support richer *viewport* real time rendering functionality. This would allow to further develop the display mode, as discussed in section 5.1.4. Potentially, an experienced Maya plugin developer could find another solution to overcome this limitation. Besides the limited visibility, further developments could be made to the pose tool:

The alignment of the *bottom* control (half sphere) and amplifier with the feet could be automated, taking also into consideration the possible bending of the feet, although leaving the ultimate control to the animator (as should always be), to decide exceptional cases.

The *power centre* control spot could be manipulated through a pop-up lever, sliding vertically along a power intensity scale, following the rationale of the force of gravity, as explained in section 4.3 (page 147). A visually more intuitive solution to manipulate the *power centre,* also based on the association of the position of its control spot with a cluster of controls of the parts of the body involved in each *power centre* representation, could be the idea suggested in section 4.3 (page 148). Such a solution would require a system of coordinates in the 3D space, around the character, influencing certain joints of areas of the rig and, that way, making the body automatically react to the manipulation of the *power centre* spot. To achieve this, it might be necessary to go deeper into psychological studies related to the problematics of audience perception of attitudes and emotions based on displayed body postures. This, through a reverse process, could help to develop a framework describing which joints contribute to specific postures of the body, similar to that discussed by Coulson (2004), which could be very useful to the development of this *power centre* solution. The goal should not be to create a collection or library of actions/reactions to be applied as in Behavioural Animation but to provide a base posture (corresponding to a particular *power centre*), especially involving the main axis of the body, from which the animator would start building the specific pose.

Regarding the manipulation of the pose tool, besides the earlier mentioned control points of the *expression cord*, a sketch-based solution, similar to those discussed in sections 2.6.3 and 5.3, should be tried and integrated into the plugin solution, as suggested in section 4.3 (page 149). That would be useful for the second step of the approach (mentioned in section 4.6), when the animator, following the *line of action* concept, needs to define the orientation and inclination of the body, which is led by the thrust that impels the action. The stroke would be fine-tuned afterwards through the control points, in the subsequent steps of the approach, because the sketch tool is not sufficient to completely define the pose. First, the animator needs to characterize the character and determine which part of the

body leads the thrust (through the *power centre* concept). Then, after having defined the *line of action*, he/she needs to distribute the weight (by applying the *contrapposto* concept) and add torsion to the body, defining the expression of dramatic intensity of the pose (with the *serpentine line*). For example, whenever a change occurs in the tilt of the pelvis or in the top of the torso, it will affect the *line of action* or the *serpentine line*, and the head and the feet have similar kind of influence. However, such a sketch-based solution is conditioned by the complexity of the character's rig, similarly to what happens now to the tool in the *active* mode, and therefore further research is needed to find a solution that allows it to work on top of complex rigs (i.e. in the *active* mode).

In terms of user validation, the pose tool and its underlying rationale should be tested with a significant number of users – students and professional practitioners. The exploratory posing experiment (see appendix A) confirmed that the validation of an approach which involves the adoption of new practices by the users will have to consider the learning curve with the new approach and the use of the tool, before conducting the test. In terms of students, for example, the more feasible strategy would be carrying out the experiment in two different universities, in order to avoid ethical issues for teaching students differently. The approach and tool would be taught to animation students, in one of the universities, in a normal class, for the entire term and, at the end, the test would be conducted, as an assignment, with those students and also with students in another university. After being practiced extensively by a larger number of users, a new experiment may point to possible refinements of the posing approach and tool.

The process of attaching the tool to the character's rig through the Attaching Window (section 5.2), should also be tested (and not just the use of the tool), maybe in a first stage of a future experiment.

The use of the proposed approach may be extended to a simple notation system for posing, allowing the directors and other elements of the producing team to

express their ideas about a specific pose, in a meeting/daily or other discussion moment. This could be done either on paper or virtually, using a tablet or other mobile device, using a specific application or a plugin, having the pose tool integrated in a stylized 3D character, such as NGuy (Figure 110, on page 327).

This solution could also work as a virtual pose generator for comic artists or illustrators, helping them in the process of creating expressive body postures, according to the rationale of the proposed approach.

Moreover, this solution could be explored as an identifier of postures captured from photos or video clips, for nonverbal communication studies or even to be used by people with Asperger syndrome. It would be combined with the advanced *power centre* solution mentioned earlier, this time working in a reverse way – the user would adjust the control points of the *expression cord* over the image and the application would prompt the corresponding body expression label.

In conclusion, this thesis demonstrates the importance of applying the concepts of *Power Centre, Line of Action, Contrapposto* and *Serpentine Line*, systematically, to work the body as a whole, when posing a character, in order to create expressive poses, as hypothesized. Moreover, it shows the importance of using the rationale of an imaginary flow of force, along with these concepts – *expression cord* – not only to define the specific rhythm of body configuration but also to determine a logical hierarchy for the changing of the body parts to occur in time and space. The proposed posing approach and its complementary tool contribute to improve the process of animating the character's body expression in 3D computer animation, by guiding the animator through the complex process of posing, with a new method of thinking and creating the poses.

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Appendices

A - Exploratory Posing Experiment

This empirical study had the purpose of seeking feedback from other practitioners about the posing approach being developed, especially on its contribution to improve the body expression (mainly regarding the torso stiffness) and also the efficiency it adds to the posing process. It had also the purpose of testing the 3D Pose Tool as a visual guide to assist animators in the process of posing a character following the same rationale. At the same time, this exploratory experiment served to test the feasibility of a future validation of the pose tool, and the underlying rationale of the approach it is based on, under similar circumstances.

This experiment focused on posing a 3D character expressing two attitudes – confident and insecure – that reveal different traits of personality, and then doing the action of throwing a bowling ball, modulated by two qualities of performance – professional and amateur – and, in the end, expressing two emotions – happiness and anger (or frustration) – produced by the result of a bowling throw.

The main aim was to produce evidence of better results achieved by the proposed new approach when compared to the ones achieved with previous approaches, in terms of expressiveness of the poses. Additionally, allowing to compare and verify the expected advantages and possible disadvantages of the new approach, in terms of efficiency, i.e. creating expressive poses in a less time-consuming process. Since the tool was not used in the active mode – as a manipulator of the main axis of the character´s body – for the reasons explained in section 5.3, the usability of that active mode could not be considered in this experiment as a possible contribution to the efficiency of the process.

The requirements for each pose had specific aims, in order for each participant not to repeat the poses for the exact same actions or attitudes in the two sessions/exercises of the experiment. This prevented the work done by them in the second session from being biased by what they already did in the first session. For that reason, in each session the participants also had to start from scratch, with a provided new Maya file. The fact that the file for the second session included the 3D Pose Tool attached to the character also helped preventing the possibility of using the poses created previously. The only exception, to a certain extent, was the first pose, which had similar requirements for both sessions – posing the character in his normal, relaxed posture, according to the given definitions of his abilities and personality – but those given personalities and abilities were different for each session and, therefore, the resulting poses should not be exactly the same. There were two reasons for this exception: the aim to give the participants the opportunity to show how to create different characterizations of a 3D character, while keeping the variable of a standing relaxed pose; and the aim to verify what differences could the new approach produce in the pose created in the second session, especially in terms of the shape and position of the torso, of the legs and also of the head, and the controls used to manipulate them.

A.1 - Preparations

This experiment was designed to use a reduced number of poses and interactions with props and its complexity, in order to make the experiment more feasible in two sessions, each lasting 2 to 3 hours.

The preparations involved the recruitment of the participants, the logistics and the creation of the necessary materials, as described below.

A.1.1 - Participants

The participants were recruited within the National Centre for Computer Animation (NCCA), at Bournemouth University, and all of them were 3rd year students (Level H), from Computer Animation Arts (CAA) and Computer Visualization & Animation (CVA) courses. One is female and three are male students, with ages between twenty to twenty one years old.

The fact that the participants were all from the same academic level (Level H) would, in principle, guarantee an even level of animation knowledge and abilities of the participants. Curiously, their self-assessment expressed in the questionnaires suggests that they had different levels of expertise in 3D character animation. On a scale from 1 to 10, the average level was 6.5, with the lowest being 5 and the highest being 8. This is, of course, a subjective matter, since it depends on their perception of themselves in terms of that expertise, and could also be because they were studying in slightly different courses.

A.1.2 - Materials

The posing experiment required the preparation of several materials to be used by the participants and also in the introduction and practical instructions to the approach. Furthermore, some specific equipment was needed for the participants to use during the experiment – a place, computers with animation software, and a video projector for the presentation.

The experiment took place in a classroom (the W115 animation studio), habitually used by the students for their animation classes, equipped with Linux OS computers, with Autodesk Maya (version 2012), among other software usually required for computer animation classes.

A Maya scene was created and the character and the props were placed in the initial composition, as seen on page 301 (appendix F). A fixed shot camera was created and blocked, to make sure that all participants would have the same view through the camera that would capture/render the final images of their work, later. The chosen composition of the scene, by staging the character placed on the left side of the screen and seen from a perspective of ¾ in front, has the main aim of giving the character enough space to perform his actions while moving forward. That perspective allows showing the character's side and front at the same time, leading the animator/participant to present all the poses from an interesting angle. Moreover, with that perspective there is no need to show and manipulate the ball hitting the pins, thus playing with the imagination of the viewer, as done in films. However, that would not limit the participants' freedom of manipulation of the character, since they were free to use any of the other available camera views when creating the poses, in order to allow them to manipulate the character as they please. The shot camera – which was fixed and could not be changed – would be used just to check that the poses they were creating would be seen the way they wanted.

Giving all the participants the exact same conditions and the same instructions to follow, was very important to guarantee that the outcome would not be biased by any possible different shot camera that they might create or inadvertently change. The reason is obvious, because perception of image, either still or moving, is influenced by the perspective from which it is seen by the viewer. This is why *staging* is so important in theatre and cinema and, of course, in animation, along with the silhouette concept, to provide clarity of the characters' shape and to guarantee the audience get a good perception of the overall image, as discussed in chapter 2.

The character used in this experiment is the *Morpheus* (morpheusRig_v01_00, courtesy of J. Burton – www.joshburton.com, personal communication, 26

February 2013, see appendix H), a fully rigged solution that can be customized to different humanoid bodies. The choice for using this particular character in the experiment was due to the familiarity of the participants with that rig, since it had been used by them in their animation classes. Thus was decided to use the same rig, in order not to introduce another conditioning variable to this experiment, because being requested to use a different approach is already demanding enough for the participants.

Two variants of the Maya scene were created – one for each session of the experiment. For the first one was the Maya file *Posing_exercise_3Y_Alfa,* with the Morpheus 3D character exactly as provided by its original author (see image in appendix F, page 301). For the second session (animating with the new approach), was used the Maya file *Posing_exercise_3Y_Beta*, with the 3D Pose Tool attached to the Morpheus 3D character (see image with normal view – with *Xray off* – on page 302, and image with Xray view activated – *Xray on* – on page 303).

Two briefs were produced, one for session 1 (see Brief-1, on page 290, appendix B), where the participants were requested to create the poses the way they normally do; and another for session 2 (see Brief-2, on page 291, appendix B), where the participants were requested to use the new approach that had been presented to them. Each brief included specific instructions for the task and had a different character description and also a different short script, defining the situations.

A semi-structured questionnaire was developed, divided in two parts, one for each session. The first part of the questionnaire sought information about the participants' approach to posing. In the second part the participants were asked their opinion about the proposed approach and tool and how it could be improved.

A presentation was prepared to introduce the new posing approach to the participants, before beginning Exercise 2 – second session of the experiment. A

Maya file with several poses already created, was used to demonstrate how the approach theory and tool work in practice, during the introduction to Exercise 2.

Some video files of people playing bowling were previously collected and made available to the participants before they begin both sessions of the experiment, with the purpose of helping them familiarize with the actions of that game (see links in appendix D, page 297).

A.2 - Experiment sessions

The posing experiment consisted of two sessions or exercises, the first requiring the participants to use their usual approach and the second requiring them to use the proposed new approach, as mentioned before.

Before beginning the first exercise (Exercise 1), the participants were informed about the experiment and a consent form was presented to each of them to sign.

For each exercise, the participants received an assignment Brief with all the instructions they should follow and the requirements to fulfil, as described in section A.1.2. A few video clips of people playing bowling were also provided (transferred to their computers), at the beginning, in case the participants wanted some reference on bowling.

The participants were given the same Maya file, with the character and the props already in place and seen through the fixed *shot_camera*, specifically created for this experiment, as described in section A.1.2. Moreover, they were told that the *shot_camera* was blocked (as mentioned before) and would essentially serve to check that the poses they were creating would be seen the way they wanted, since the final images of those poses would be rendered from it.

At the beginning of Exercise 2, the participants were introduced to the new approach, in terms of concepts involved and the rationale behind it, through a

short presentation on the screen. Two video clips of the film "The Last Laugh" were also shown, as examples of different *power centres* portrayed by the same character in different moments and under different circumstances, giving evidence of how it affects the body posture (see Figure 7). The presentation was complemented with images of some examples of problems in animated movies that this approach proposes to solve. They were also given some practical suggestions in terms of workflow, according to what is mentioned in section 4.6. Then, the 3D Pose Tool was also introduced, showing them how it works with the Morpheus character in Maya and how to turn on and off the X-ray effect, in order to see the tool inside the character. Several examples of poses (see page 298, appendix E) created in a Maya file, using Morpheus with the tool and following the proposed approach, were shown to them to demonstrate how to apply the theory in those practical examples. After the introduction, the participants were given some time (around 15 minutes) to try and familiarize with the pose tool before they begin creating the poses.

In each exercise, the students were requested to save the Maya file as Pose_0 (see briefs) immediately after opening the file, and then as Pose_1, Pose_2 and Pose_3 after finishing each pose, in order to assess the amount of time each pose took them to create. However, some of the participants forgot to do it, in spite of having been reminded several times during the sessions, and at the end some of them made a note in the back of their questionnaires, stating the approximate duration for each of the poses they had failed to save as at the right time.

The first section of the questionnaire (Section 1), about the usual approach of the participants, was supplied to them after finishing Exercise 1 and the Section 2, asking their feedback about the proposed approach and pose tool, was supplied to them at the end of the second session.

During the experiment the researcher tried not to interfere with the participants work. Therefore, besides the information/project framework, all the

recommendations and suggestions regarding the use of the proposed approach and the tools were given at the beginning of Exercise 2.

A.3 - Results

This section presents visual evidence of the poses produced in the experiment and quantitative information about the time consumed in each session. The poses created in Exercise 1 are presented in section A.3.1 and those created in Exercise 2 are presented in section A.3.2. For the purpose of better viewing the poses, the images were cropped to frame just the figure (the full scene images are included in appendix G, page 304). Section A.3.3 presents some quantitative data of the time consumed by the participants to create each pose.

Additionally, section A.3.4 provides the author's version of the poses created from the same experiment briefs, to serve as examples of expected poses in the discussion.

A.3.1 - Poses created in Exercise 1

The following poses were created by the participants in the first exercise, where they were requested to pose the character following their usual approach. The character, Robert, was supposed to be a very confident person and a good bowling player, as described in **Posing Experiment Brief – 1** (page 290).

The aim of situation 1 – *Robert is standing, in a relaxed position* – was for the participants to work the characterization of the character, defining his normal posture in accordance with the given abilities and personality, by showing him in a relaxed position, before picking the ball.

| 1.1 | 2.1 | 3.1 | 4.1 |
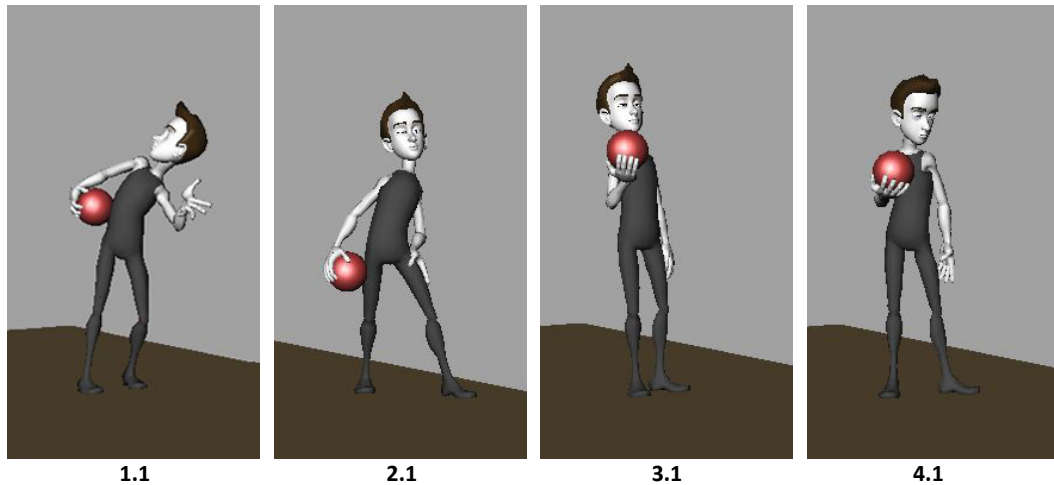
**Figure 98 – Poses of a confident person and good bowling player, standing in a relaxed position.**

All the above poses (Figure 98) express a somehow confident attitude, as required, although in pose 1.1 the character looks more like pretentious or even exhibitionist and in pose 2.1 looks like he is targeting something (maybe the pins). Poses 3.1 and 4.1 look like the character is concentrating. However, none of them look relaxed.

The second situation was the throw of the ball, in a very professional style, by the same character.

| 1.2 | 2.2 | 3.2 | 4.2 |
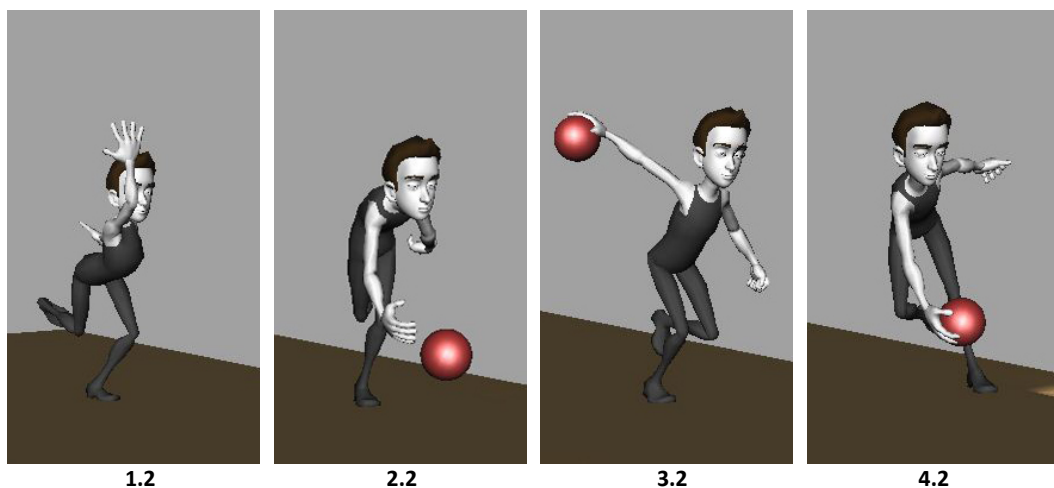
Figure 99 – Poses of a confident person and good bowling player, throwing the ball in a very professional style.

Generally, all the poses shown in Figure 99 suggest more or less the intended action.

In situation 3, the character is frustrated and sad, because he failed to knock down most of the pins.

| 1.3 | 2.3 | 3.3 | 4.3 |
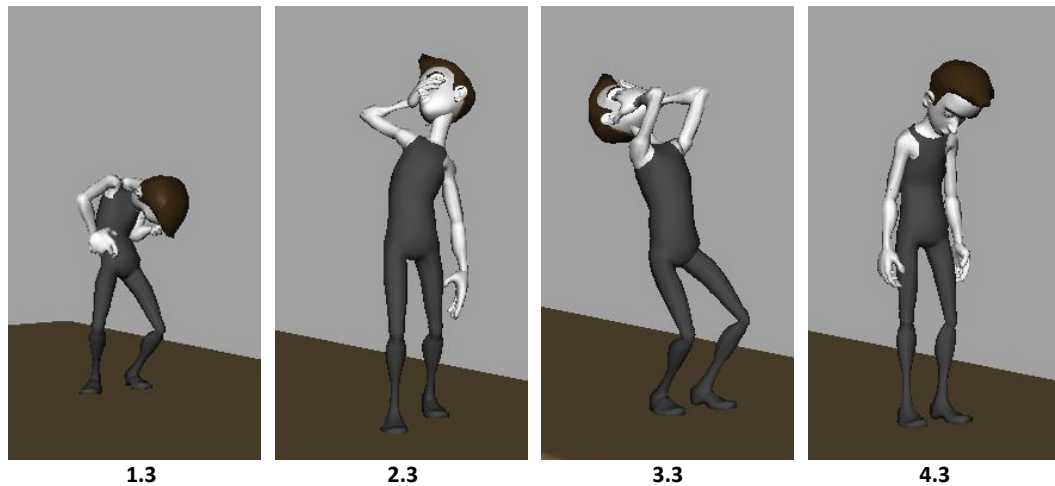
Figure 100 – Poses of a confident person and good bowling player, feeling frustrated and sad, because he failed to knock down most of the pins.

Most of the poses shown above (Figure 100) could be interpreted as expressions of frustration or sadness but pose 1.3 looks more confusing.

A.3.2 - Poses created in Exercise 2

The following poses were created by the participants in the second exercise, where they were requested to pose the character following the new approach they had just been introduce to. This time the character, Jack, was supposed to be an insecure person and lacking skills as a bowling player, as described in **Posing Experiment Brief – 2** (page 291).

Similarly to exercise 1, in this case the aim of situation 1 – *Jack is standing, in a relaxed position* – was for the participants to work the characterization of the character, defining his normal posture in accordance with the different given

abilities and personality, by showing him in a relaxed position, before picking the ball.

5.1   **6.1**   **7.1**   **8.1**
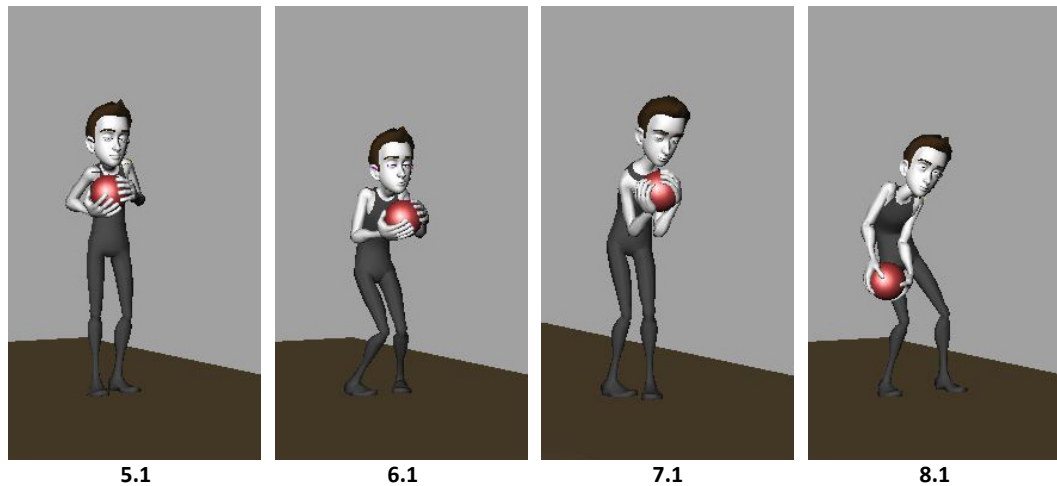
Figure 101 – Poses of an insecure person, who lacks skills as a bowling player, standing in a relaxed position.

5.1-PT   **6.1-PT**   **7.1-PT**   **8.1-PT**
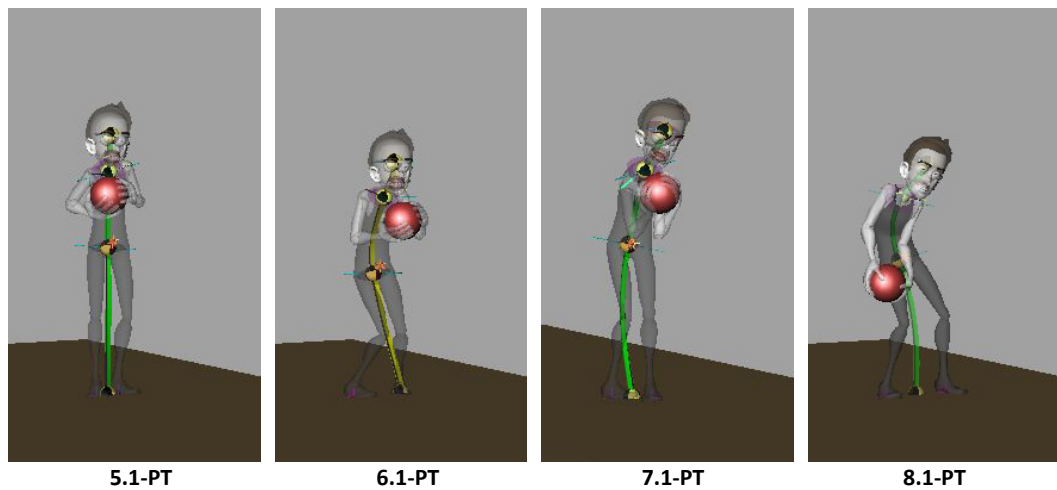
Figure 102 – The same poses in X-ray view, revealing the 3D Pose Tool inside each character.

In the poses shown above (Figure 101) the characters look fairly insecure but, again, do not look that much relaxed.

The second situation was the throw of the ball, in a not very professional style, by the same character, and the results are shown in Figure 103, below.

5.2   **6.2**   **7.2**   **8.2**
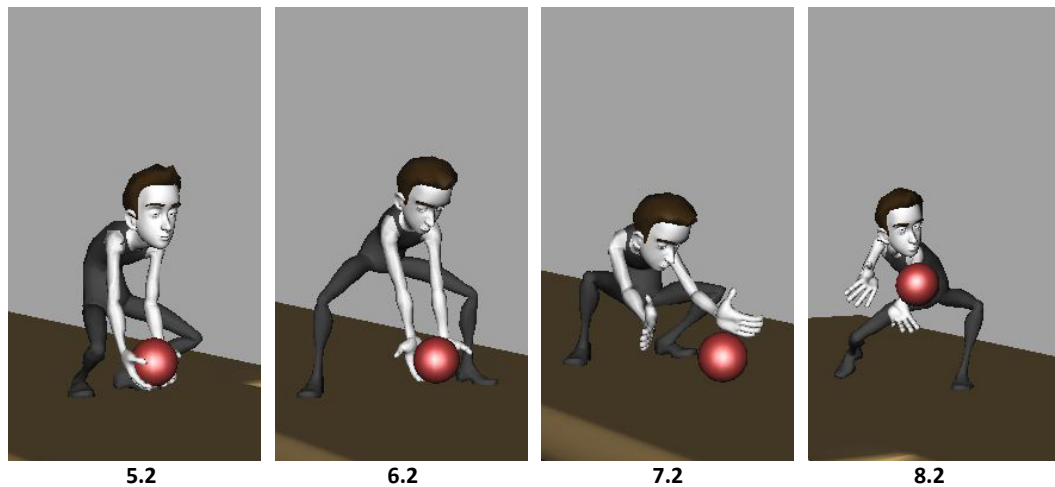
Figure 103 – Poses of an insecure person, who lacks skills as a bowling player, throwing the ball in a not very professional style.

5.2-PT   **6.2-PT**   **7.2-PT**   **8.2-PT**
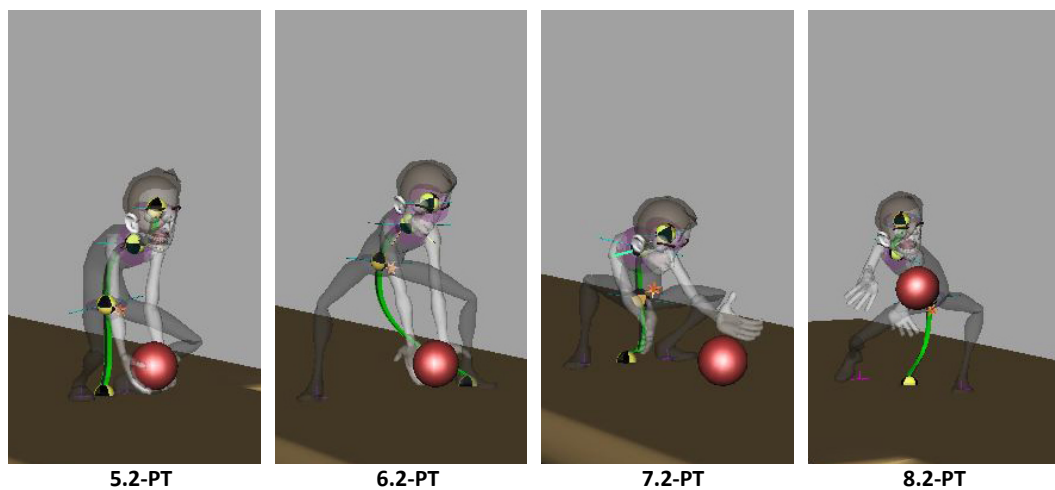
Figure 104 – The same poses in X-ray view, revealing the 3D Pose Tool inside each character.

Although the ways of throwing the ball seem quite unprofessional, none of the characters look that much insecure.

In situation 3Figure 104, the character is happy, because luckily he knocked down all pins. The corresponding poses are shown in Figure 105, below.

5.3   **6.3**   **7.3**   **8.3**
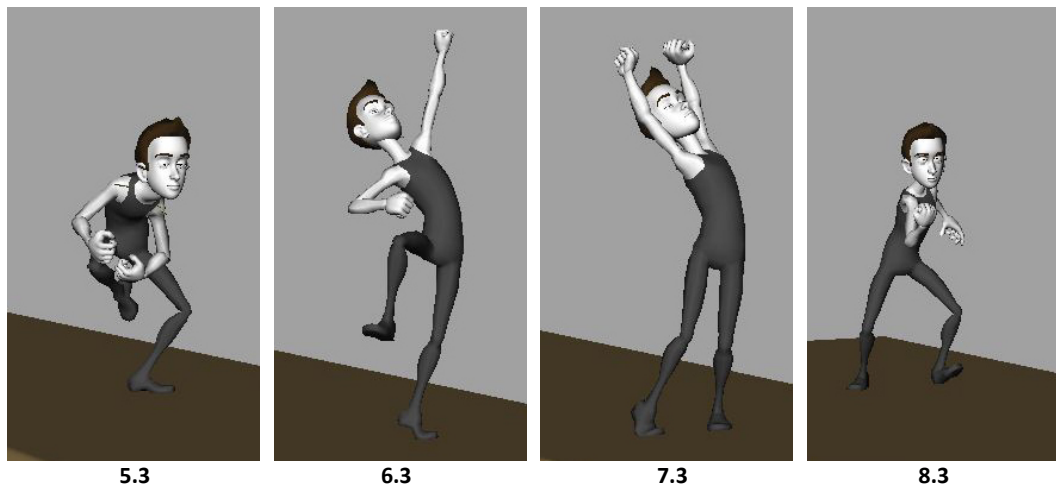
Figure 105 – Poses of an insecure person, who lacks skills as a bowling player, feeling happy because luckily he knocked down all pins.

5.3-PT   **6.3-PT**   **7.3-PT**   **8.3-PT**
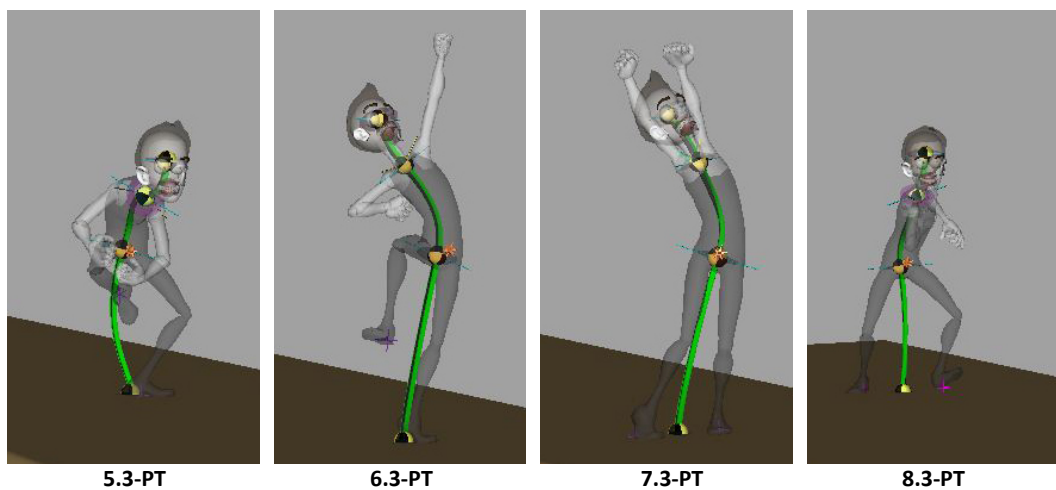
Figure 106 – The same poses in X-ray view, revealing the 3D Pose Tool inside each character.

The expression of two of the poses (6.3 and 7.3) look happy but in the other two (poses 5.3 and 8.3) the reaction is not very explicit.

A.3.3 - Time consumed by the participants

The purpose is to discriminate among the time consumed by each participant to create each pose, in the two exercises, and verify if the new posing approach and tool would influence the time consumed in the process. However, the gathered data is not accurate, because some of the participants forgot to save the scene

with a new number after finishing each pose (in Maya) and later provided an estimated time, as mentioned in section A.2. It should also be noted that participant C created more than just the 3 required poses in each exercise. The data related to Exercise 1, corresponding to their usual approach, is presented in Table 1, below.

Table 1 – Time spent by the participants creating each pose in Exercise 1.

Participants' code	Pose 1	Pose 2	Pose 3	Total
A	18 min.	42 min.	17 min.	**1h17m**
B	N/A	N/A	14 min.	**1h24m** (estimated)
C	13 min.	38 min.	27 min.	**1h18m**
D	12 min. (estimated)	24 min.	29 min.	**1h05m** (estimated)
	a)	a)	87 minutes	**304 minutes**

a) Impossible to calculate, due to insufficient data.

The data related to Exercise 2, corresponding to the new approach, is presented in Table 2, below.

Table 2 – Time spent by the participants creating each pose in Exercise 2.

Participants' code	Pose 1	Pose 2	Pose 3	Total
A	10 min. (estimated)	29 min.	14 min.	**0h53m** (estimated)
B	20 min. (estimated)		34 min. **(Pose 2 + 3)**	**0h54m** (estimated)
C	5 min. (estimated)	14 min.	36 min.	**0h55m** (estimated)
D	13 min.	16 min.	4 min. (estimated)	**0h33m**
	48 minutes	a)	a)	**195 minutes**

a) Impossible to calculate, due to insufficient data.

Participant A took 1 hour and 17 minutes to complete Exercise 1 and 53 minutes (estimated) to complete Exercise 2, i.e. the latter took him 24 minutes less. Participant B took 1 hour and 24 minutes to complete Exercise 1 and 54 minutes (estimated) to complete Exercise 2, i.e. the latter took him 30 minutes less. Participant C took 1 hour and 18 minutes to complete Exercise 1 and 55 minutes (estimated) to complete Exercise 2, i.e. the latter took him 23 minutes less. Participant D took 1 hour and 5 minutes to complete Exercise 1 and 33 minutes (estimated) to complete Exercise 2, i.e. the latter took him 32 minutes less. Strangely, this participant mentions in the questionnaire that Exercise 2 took him more time!

All the participants took less time to create the poses in Exercise 2 – on average, 27.25 minutes less, which corresponds to around 35.85% less time. When discriminated by pose, Pose 1 took them less 5 minutes to create, in Exercise 2, on average (34.89% less); Pose 2 took them less 15 minutes to create, in Exercise 2, on average (43.27% less); and Pose 3 took them less 6,33 minutes to create, in Exercise 2, on average (26.01% less). The only exceptions are: Pose 2 created by participant D, with an estimated time of 1 minute more; and Pose 3 created by participant C, with an estimated time of 9 minutes more.

A.3.4 - The same experiment made by the author of the thesis

The following poses (Figure 107, Figure 108 and Figure 109) are the author's version, based on the same experiment briefs. The intention is to show that if the concepts of the approach are applied systematically, by someone with deeper understanding of the approach and experience of the tool, the produced results are more expressive than those usually achieved with a standard approach, as used by participants in Exercise 1.
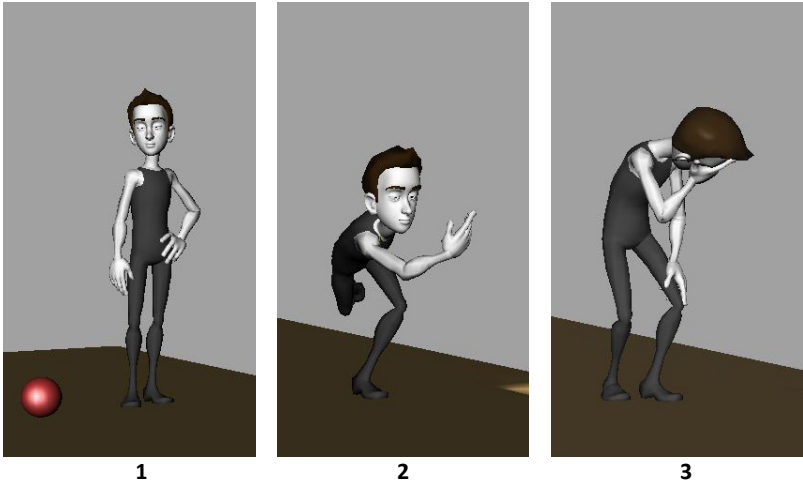
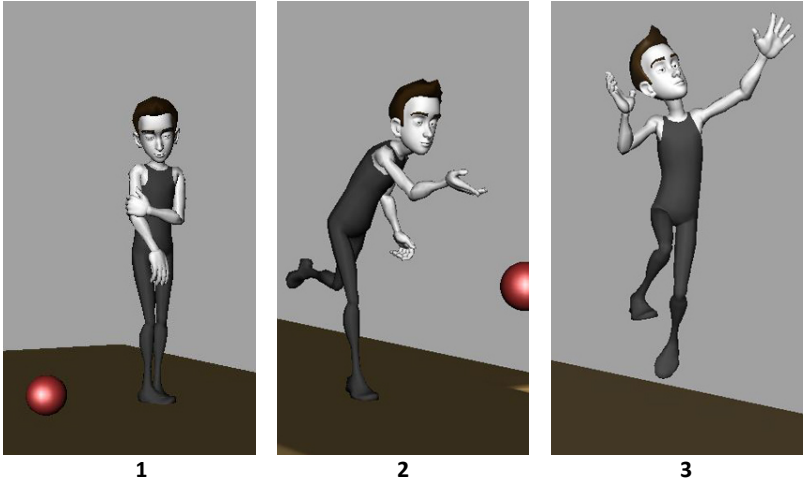**Figure 107 – The poses created according to Exercise 1, portrayed by a confident character.**

Figure 108 – The poses created according to Exercise 2, portrayed by an insecure character.
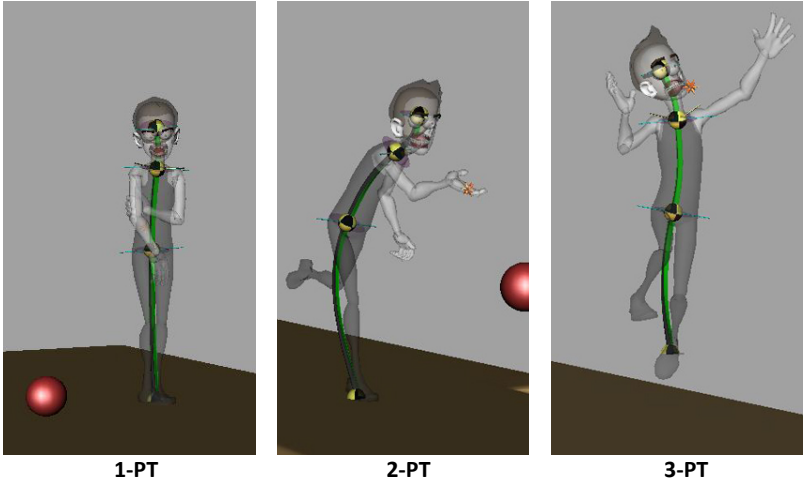

Figure 109 – The same poses of previous figure, in *X-ray* view.

The poses shown above demonstrate a strong application of the approach rationale and its complementary pose tool and are intended as examples in the analysis which follows.

A.4 - Discussion

In character animation, a pose should be assessed on its expressive quality only if regarded with the situation the character is dealing with (not just the present moment but also what happened before and what will happen next), as mentioned in section 2.1.2. It should also be regarded with the action, attitudes and behaviour the character is supposed to convey in the scene. In order to be convincingly expressive, there must be a correlation between the intended expression and the configuration or pattern produced by the arrangement of the body parts according to an implied force, as discussed in section 2.2.1. Therefore, a pose is more or less expressive depending on how successfully the character expresses a particular and intended attitude – by appropriately conveying the emotions behind it, being modulated by a particular personality – while performing a specific action in a convincing way. Hence, the results of this posing experiment are analysed and interpreted according to the situations provided to the participants.

Evidence of the new posing approach being applied in Exercise 2 was also under evaluation, in order to verify its hypothesized advantages in terms of effectiveness – expressive poses – and efficiency, considering the time consumed in the creation process.

It should also be noted that, initially, the plan was to use two groups of participants doing the same exercise, with one group following their usual approach while the other would follow the proposed new approach, to guarantee that there would not be any influence or contamination. Later, due to the lack of participants, was decided to use just one group, doing two different exercises as

described in the briefs. Whether both exercises should be done by the same group of participants or each exercise by a different group of participants, arguments could be found to justify one option or the other. The advantages of the first option were that there would be no bias in the results. The advantages of the second option were, besides a larger number of created poses, the guarantee that both exercises were done by participants with exactly the same skills. This way each first pose of both exercises, done by the same participant, could be also compared to see the differences in the results and try to find out if it was due to the new approach, since the requisites were the same. Well, not exactly the same – the characters´ personality and abilities were different, which introduced another variable to the experiment. Therefore, that comparison cannot be established in exact manner; however, as the characters' situations and tasks are comparable so are the results.

A.4.1 - Poses 1 – The relaxed posture

The first pose of each exercise was intended to give the participants the opportunity to work the characterization of the character, defining his normal posture according to the given abilities and personality, by showing him in a neutral and relaxed position, before picking the ball. For example, the expected poses would be something like the poses 1 in Figure 107 and Figure 108. Curiously, all the participants created the first pose, in both exercises (Figure 98 and Figure 101), with the character already holding the ball, which does not add much to a relaxed pose, considering the weight of a bowling ball. This means that probably the instructions for the first pose, provided in each brief, were not clear enough.

So, the intended relaxed poses (1.1, 2.1, 3.1 and 4.1) portrayed by the confident character (produced in Exercise 1, with the participants' usual approach) shown in Figure 98 do not look that much relaxed, although they look confident, as mentioned in section A.3.1. In fact, all the poses presented in Figure 98 show some

tension in the body, even if just because of holding a heavy ball, as in the case of pose 3.1. Inevitably, their body configurations reveal that they are doing more than just standing in relaxed positions. For example, in pose 1.1, the character seems to be interacting with someone else off-screen.

In terms of perception – readability – of body configuration, most of the poses in Figure 98 display good silhouettes, except for pose 3.1 in which the ball is overlapping the body, making it a less clear body shape. However, the attitude of poses 1.1 and 2.1 are not very explicit, in spite of their *C* and *S* body shapes, which is due to the inconsistent arrangement of the body parts. All the poses in Figure 98 show evidence of problems because some parts are not arranged in a logical way, i.e. in harmony with the flow of force that should be holding the body, as discussed in section 4.2. For example, pose 1.1 has the same kind of weight problem as the Smurf in the left side of Figure 45 (as discussed on page 96), i.e. the pelvis should be tilted laterally to the opposite side, because his left leg is supporting most of the body weight. Furthermore, the torso does not bend gradually (actually it has an accentuated inflection in the middle), which makes it look artificial. Pose 2.1 has a similar problem: in this case the pelvis should tilt to the opposite side, because most of the weight is supported by his right leg, and then the shoulders should tilt to his right side, producing a reversed arc in the torso, too. Pose 3.1 seems to be slightly out of balance, leaning to his right side, but in spite of that it is closer to a relaxed standing posture (except for the arm holding the ball) or at least a less dynamic one. The arrangement of the parts looks quite consistent with the force holding the body – the tilt of the pelvis according to the supporting leg and the shoulders counterpoising it. Pose 4.1 also shows a consistent counterpoising in relation with the supporting leg – pelvis tilting to the character's left side and shoulders tilting to the right – but the torso should also twist, pulling his right shoulder forward and the left backwards. The way it is, the shoulders and the pelvis have the same orientation in the transverse plane and the shoulders also have a weird translation – too much to the character's right side – which is not

accompanied by the gradual bending of the rest of the torso.

In spite of the problems, all the poses show confident postures, exposing or projecting the ventral area (where the *power centre* is supposed to be) and also projecting the chest forward, with the torso straight or slightly backwards (as defined by Argyle and Trower 1979, p. 15), and the feet apart and pointing outwards. This means that the patterns of body expression have enough characteristics related with confidence but lack those related with relaxation, like, for instance, the arms drooped or with the hands on the hips, and just one leg carrying the weight, as shown in the example of pose 1, in Figure 107.

Regarding the insecure character portraying the relaxed poses (5.1, 6.1, 7.1 and 8.1) shown in Figure 101, they were created in Exercise 2, supposedly, using the new posing approach. The problem of misinterpretation about the relaxed condition persisted and, as can be observed, no one looks relaxed when carrying a heavy bowling ball. Indeed, most of the poses express insecurity, with the shoulders raised (except pose 7.1), which is associated with the lack of confidence (Aubert 2003, p. 38), the torso slightly bent, the arms close to the body, the knees and the feet pointing inwards (Navarro and Karlins 2008, p. 81) (except pose 5.1), and the knees bent, too (except pose 5.1, again). Wisely, most participants used the ball against the body (poses 5.1, 6.1 and 7.1), like a shield to protect the chest. That fashion of holding an object is also associated with insecure behaviour, since people usually tend to put their arms and hands in front of their chest (sometimes holding an object) when they feel uncomfortable, insecure or fearful, as stated by Navarro and Karlins (2008, pp. 92-93). Of course the characters were not supposed to hold the ball but just stand in a relaxed posture (as relaxed as an insecure person can be), like for example the pose 1 in Figure 108. That pose shows a variation of the "fig leaf" gesture (when the crotch area is covered by one or both hands, or even by an object), which expresses insecurity (Alberts 1997, p. 104) or emotional weakness. Likewise, crossing the arm(s) in front of the body is

considered a self-protective gesture. The *power centre* is in the back side, in the lumbar region, pulling the buttocks out and tilting the pelvis forwards.

Again, several inconsistencies can be observed in the arrangement of the body parts in each pose shown in Figure 101. In pose 7.1, the lateral tilt of the pelvis is not consistent with the leg supporting most of the weight (his left leg), which is clearly evidenced by the pelvis amplifier shown in the X-ray version (7.1-PT), in Figure 102. Pose 8.1 has a similar kind of problem with the pelvis, which should tilt in the opposite direction (see 8.1-PT in Figure 102), since the right leg is supporting most of the weight. In that case, the force comes up from the right foot and for that reason the *bottom* control of the tool should also be closer to his right foot. There is no torsion through the body, or counter-rotation, in pose 6.1, which is clearly revealed in the X-ray version 6.1-PT (Figure 102) by the cord of the tool displaying the yellow colour. This means that the Y axis was left untouched and shows the usefulness of the tool, as a visual guide, if used properly. The absence of twist in the torso does not look so problematic in this pose because it shows a crouching posture, with a quite tense expression.

There are also some *twinning* problems – the limbs of one side of the body are mirroring those of the other side (as discussed on page 33) – in poses 7.1 and 8.1, shown in Figure 101, because the characters' arms are parallel to each other and doing exactly the same thing.

Although pose 5.1 looks the least dynamic, the body shows a subtle *contrapposto*, with a slight lateral tilt of the pelvis to his left side and the shoulders tilting to the opposite side (maybe too much, considering the look of the amplifier – see pose 5.1-PT in Figure 102). This produces a subtle *serpentine line* effect, with a slight twist to his left side, as shown in Figure 102, and may suggest some influence of the new posing approach. However, the fact that the *bottom* control of the tool is not properly placed (in poses 6.1 and 8.1) according to the centre of the base of support, as mentioned in section 4.2, and the *power centre* locator remains

unchanged in all the poses, gives evidence that the use of the tool was neglected or not correctly understood by the participants.

As noted above, there are also some inconsistencies related to the insecure posture: in pose 5.1, the character's feet and knees are pointing outwards instead of inwards and his right knee should also be bent; in pose 8.1, the left knee should also not point outwards; and in pose 7.1 the shoulders are too drooped – should be raised, instead. Moreover, having the pelvis pulled forward and tilting backwards (poses 5.1 and 8.1) is also not an insecure feature (it is more of a *macho man* or even a confident person). When a person feels insecure or uncomfortable he/she tends to protect the ventral area, not to project and expose it, as stated by Navarro and Karlins (2008, pp. 92-93).

The readability of the poses shown in Figure 101 is not ideal because the characters hold the ball in front of the body, which does not favour good silhouettes.

Overall, the poses 1 created in both exercises express the traits of personality – confident or insecure – as required in the briefs, but fail to express the relaxed attitude. As discussed above, the existing issues in the poses, related with the arrangement of the body parts and the consequent configurations, do not allow a clear distinction in terms of the quality of the results of one exercise over the other.

A.4.2 - Poses 2 – Throwing the ball

The second poses of each exercise were intended to express two different ways of throwing the bowling ball, by the two different characters – confident and insecure. During the throw the *power centre* should move to the hand that is applying the force to the ball, as discussed in section 4.1.

The poses expressing a professional style of throw (1.2, 2.2, 3.2 and 4.2), shown in Figure 99, are portrayed by the confident character and were produced in Exercise 1, with the participants' usual approach.

Although all these poses can be identified with the action of throwing a bowling ball, poses 1.2 and 3.2 have the pelvis tilted forwards, which is not characteristic of a confident person but of an insecure one. A confident character would show, for instance, the backward tilt of the pelvis, the knees and feet pointing outwards, and a more expansive arrangement of the body parts, as the example shown in pose 2 in Figure 107. Moreover, the configuration of pose 1.2 is a bit ambiguous – without context could be easily interpreted as some kind of dance, for example. The way the character holds the ball (the position of the fingers), in pose 3.2 does not look very professional, too.

There are some inconsistencies in the arrangement of the body parts. In pose 1.2, the spine looks like broken in the middle, with an inflection point (discussed in sections 2.6.2, 4.2 and 6.4) producing an exaggerated bend backwards, which does not look natural. The orientation of the shoulders should rotate more to his left side (the right shoulder should be pulled more forward), in order to be consistent with the extended movement of the hands and arms. Pose 3.2 represents the anticipation of the throw – the beginning of the action – but it lacks the twisting effect in the body typical of this kind of movement, as discussed in sections 4.1 and 4.2. The shoulders should accompany the movement of the right hand, rotating to that side (left shoulder should be pulled more forward), producing the gradual twist of the torso required in that kind of action. Moreover, the pelvis orientation – there is no lateral tilt – is not consistent with the supporting leg because the left hip should be lowered, due to the suspended leg, and consequently the right shoulder should also be lowered, as discussed in section 4.1 about the *contrapposto*. This pose is actually an example of a stiff torso, which clearly contrasts with the more twisted and counterpoised bodies in poses 2.2 and 4.2.

Although the representation of dynamic movements requires poses more or less unbalanced, pose 4.2 seems to be too much out of balance, considering the position of the supporting foot and the orientation of the body in relation with the direction of the throw. The perception of the body shape of this pose may also be a bit confusing, with the position of ball in front of the left knee and the right arm and hand partially hiding the right leg and foot.

The poses intended to express a not very professional style of throwing the ball (5.2, 6.2, 7.2 and 8.2), shown in Figure 103, were created in Exercise 2, with the new posing approach. Indeed, the results shown in Figure 103 are quite different from those with the professional style produced in the previous exercise (Figure 99) – so much so that, if considered without the context, they could generate different interpretations. For example, pose 5.2 looks like the character is placing the ball very carefully on the floor and not expressing a clear intention to throw the ball forward towards the pins. It could also be the opposite: he has just caught the ball and is lifting it off the floor with some effort, since the heels are on the floor (and should be up, in this kind of position). Pose 7.2 looks more like a goal keeper, about to catch the ball, and pose 8.2 looks as if the character is moving from an *anticipation* moment (discussed in section 2.2) and about to bat the ball back with his hand. Pose 6.2 is the less ambiguous about the action, but the character does not look insecure, with the legs wide open and the knees pointing outwards.

Thus, as key-poses – the poses that show what is happening in a shot (as discussed in section 2.2) – these poses shown in Figure 103 are not very successful in the purpose, although knowing the context, one can imagine how these poses could fit in such an action. In this sense, these are more like *breakdown* poses, showing some particular ways of doing – the *how* the character moves from one key-pose (or extreme) to the next one (as discussed on page 31), instead of clearly illustrating *what* is happening. Particularly, poses 5.2 and 6.2 also serve as

examples to illustrate problematic results that may occur when the key-pose does not represent the end or the beginning of the movement, as discussed on page 27.

In general, these results (Figure 103) are another example of the problem of animating forms instead of forces, as discussed in section 2.2.1. Just because the required action is an amateurish throw, that does not mean the body does not need to project some force (coming through the body) on the ball, in order to make it move and hit the pins placed several meters away. In fact, the torsos are not arranged according to a clear flow of energy. In pose 5.2, the torso is not bending in a fluid curvature – looks like there is an inflection point in the middle of it, suggesting a hunchback character – due to the middle controls of the torso not having been manipulated according to the rationale of the flow of force. In pose 7.2, the torso is arching a lot and also suggests an inflection point. Particularly, poses 7.2 and 8.2 show no clear thrust of the body in the direction of the throw.

Besides expressing an amateur style of throw, the poses shown in Figure 103 were also supposed to keep some characteristics of an insecure character, like for example the forward tilt of the pelvis, the inwards direction of the knees and feet, and a sense of somehow constrained movements, as shown in pose 2 in Figure 108. However, the arrangement of the body parts fails to represent patterns of expression consistent with the intended action and with the trait of personality of the character, in order to allow the audience a clear interpretation.

There are also some twinning problems affecting the poses 5.2 and 6.2 – the legs and arms are mirroring each other – and the pose 7.2 – just the arms – which do not help to a natural look.

Generally, considering the correlation between the intended body expression and the configuration of the poses, under the defined situations, the poses created in Exercise 1 (Figure 99) express the specific action in a slightly more convincing way.

In Exercise 2 (Figure 103), it seems that the participants took the "unorthodox" way of throwing the ball to such a level of exaggeration that the poses, *per se*, do not convincingly express the intended action. That is, if seen in isolation – without the contextual information about throwing the bowling ball – none of the poses 2 of the second exercise (Figure 103) is very clear about the action, because they lack enough reference to allow the audience to recognise it, as discussed in section 2.1.2.

A.4.3 - Poses 3 – The reaction

The third poses were intended to express the reactions led by two different emotions, triggered by the different results of the throw, performed by the two distinct characters.

The poses 1.3, 2.3, 3.3 and 4.3, shown in Figure 100, were supposed to express a frustrated and sad character after having failed to knock down most of the pins, while keeping some characteristics of body expression of a confident character. For example, the backward tilt of the pelvis, the knees and feet pointing outwards, and a bolder arrangement of the body parts, as shown in pose 3 in Figure 107. In this example, the *power centre* is on the floor, pulling the body down, or not providing enough energy to pull the body straight up (according to Arnheim's rationale mentioned on page 147).

Poses 1.3, 2.3 and 3.3 (Figure 100) express somehow frustration, but the body configuration of 1.3 looks a bit confusing – it is too tense and forceful (accentuated by the raised shoulders) for a frustrated and sad posture. Pose 4.3 expresses sadness mainly by bowing the head, which accentuates the curved shape of the body, showing little tension and lack of energy, as described by Arnheim (2004, p. 449).

The arrangement of the body parts of pose 1.3 produce inflection points in the

middle of the torso and at the base of the neck, which make a much exaggerated bow of the torso, as if it has some kind of deformity. This is another example of the problem of having multiple controls in the middle of the torso which are not coherently manipulated according to the flow of energy and considering the torso as a whole (as discussed in section 2.6.2). Moreover, the pose could suggest some sort of inner conflict if it was accompanied of a more accentuated twist of the torso – it only twists a bit. In pose 3.3, the pelvis should be pulled forward, not just because the character is a confident one but because that would allow a smooth arc backwards, from the feet up to the top of the head. It also lacks a more accentuated twist in the torso which would help to avoid the twinning problems of this pose – arms and legs mirroring each other.

The happy reaction is portrayed by the insecure character after having knocked down all pins, as shown in poses 5.3, 6.3, 7.3 and 8.3 (Figure 105). This kind of expression is expected to include insecure characteristics like for instance the forward tilt of the pelvis, the inwards direction of the knees and feet, and a sense of somehow constrained movements, as in the example shown in pose 3 in Figure 108. In this example, the *power centre* is in front of the head, pulling the body up.

Poses 6.3 and 7.3 (Figure 105) express happiness more effectively, due to the stretching of the torso, which predicts joy, as stated by Gross et al. (1989, citing Meijer) and discussed in section 2.1.2. They show the shoulders raised and the arms raised and stretched, although, the fingers are not stretched, strangely. It seems that the character in pose 6.3 got so happy that… he became confident – that is how he looks – and pose 7.3 is the only that keeps some insecure characteristics – knees and feet pointing inwards. Pose 7.3, in fact, looks more like a manifestation of pride (a self-conscious expression), in front of an audience, than of happiness, and if taken out of context, could be confused, for example, with the stretching movement just after getting up (especially because of the rotation of the forearms/wrists).

Poses 5.3 and 8.3 (Figure 105) do not seem to portray a common expression of happiness but one more related with "triumph in agonistic contexts", as discussed by Matsumoto and Hwang (2012), with hands in fists, suggesting a punching motion, commonly portrayed immediately after winning/beating the opponent in a competition. Pose 5.3 may also suggest negative emotions, like fear or anger, due to the bowing of the torso (Gross et al. 1989). Its shape is indeed very confusing, with the hands overlapping the hips, legs and even part of a foot – failing the silhouette test – which does not help to the perception of the action.

In fact, pose 5.3 has several issues related with the arrangement of the body parts. In this kind of body expression, the torso usually bends towards the leg that is being simultaneously lifted, but the whole body must be balanced according to the supporting leg, otherwise it will fall. In this case it looks out of balance because the centre of the base of support is on his left foot and the *bottom* control of the tool (see X-ray version 5.3-PT, in Figure 106) should be placed there, too. For this reason, the pelvis (and the upper body) should translate to the character's left side, to be vertically aligned (or almost) with the supporting foot. The shoulders should tilt to his right side, reversing the orientation of the amplifier (seen in the X-ray version 5.3-PT), to counterpoise the pelvis and the head should also be oriented to his right leg. The unbalanced situation could be acceptable if it was the initial phase of the movement of the character to his right side. However, that does not make sense in this case because no one projects the upper body downwards when moving to the side, as he would dive in to the ground, since the body is unbalanced and has no sustaining point on that side.

The pose 6.3 would look better if the body was completely off the ground – jumping – because that kind of stretch suggests it.

In pose 7.3, the pelvis is not tilting to the correct side (see amplifier in the X-ray version 7.3-PT in Figure 106), since the body is supported by his left leg. Although the heel of the right foot is up, that is not part of the primary action (as discussed

in section 4.1) and therefore there should be no effort from the pelvis to lift that leg (contrary to what happens in pose 6.3, for example).

Likewise, in pose 8.3, the pelvis is not tilting to the correct side (see 8.3-PT in Figure 106) since the left foot is up and the body is entirely supported by his right leg. In this pose, the position of the right arm overlapping the torso shape also affects the interpretation of the body expression.

Once again, it is not easy to distinguish between the quality of the body expression of the poses 3 produced in Exercise 1 (Figure 100), with the participants' usual approach, and the poses produced in Exercise 2 (Figure 105), with the new approach. However, in general, the poses 3 created in the second exercise (Figure 105) show less stiff torsos and more twisted bodies.

A.4.4 - Evidence of applying the new posing approach

Before further discussing possible evidences of the new approach, it is important to know about the participants' usual approach. The answers given by the participants in the section 1 of the questionnaire (before having been introduced to the new approach) reveal that only one of the underlying concepts of the new approach was usually considered by them in their posing process – the *line of action*. This is no surprise, as discussed in chapter 2.

In terms of their main concerns with the posing process, three of the participants mention the silhouette to make sure the pose is readable, and one of those adds the weight, balance and *line of action*, while another says that the key-poses are vital, and another emphasizes the relation to reality. The other participant says his main concern is with the mesh deformation to show a natural look and express the intended emotion, having the human pose as reference. This seems a similar panorama to what is discussed in section 2.2.1 about the issue of animating forms

instead of forces, with no clear mention to the expression of force and the arrangement of the body parts according to it.

Regarding their workflow, one starts from real life reference and then exaggerates the pose, two of them act out the action (with one also using reference material), and only one draws thumbnails. As to the sequence for the character manipulation, two of them mention the hips (or centre of gravity), followed by the torso (or spine), the head and the legs (or feet), with the arms and hands being the last. One starts with the torso and arms and then the legs. Another starts from the feet, then hips, shoulders, arms, hands, and then the neck and head. Strangely, two of them manipulate the arms before the head, which may mean that the flow of force through the axis of the main body is not considered in their usual approach.

Overall, although most of the participants consider that their approach is not unique but similar to others or standard, the other answers about their usual approach reveal that they do not all follow one systematic approach. Their choice is based on what gives them better results, which corroborates the heuristic way adopted by many 3D computer animators, as mentioned in section 2.6.1.

This is a summary of their working habits regarding posing and one conclusion that can be drawn from this experiment, after analysing the poses, is that established practices or habits are not easy to change. In fact, according to Lally et al. (2010), on average it takes 66 days for people to form a new habit, but it may vary from 18 days to 254 days, depending on the person and the behaviour. It takes time to assimilate the new concepts and their rationale, and to adapt to new procedures required by a new approach, even when people are open to changes which they clearly see as very useful ones – hence, willing to try new ways of doing things.

Evidence of this is the fact that the simple procedure of saving each finished pose as a new file name, as requested in the Briefs, was forgotten by the participants in

many occasions – every participant forgot about it at least on one occasion and several did it on two occasions or more, in both sessions. There is also evidence of that adaptation issue in the manipulation of the 3D Pose Tool, for example on some occasions when the position of the *bottom* control – which depends on the feet position – was not adjusted in relation with the supporting foot. For instance, being left in the middle position between the feet, instead of moved closer to the foot that is supporting most (or all) of the weight of the body (e.g. poses 8.1-PT, in Figure 102, and 8.3-PT, in Figure 106). In other cases, being placed close to one foot when the body is clearly being supported equally by both feet (e.g. poses 6.1-PT, in Figure 102, and 6.2-PT, in Figure 104). Even the example in pose 7.3-PT, in Figure 106, where the position of the character's right heel suggests that most of the body weight would be supported by his left leg but the *bottom* control is closer to his right foot. The *power centre* also seems to have been neglected in the process, since the position of its locator (orange star) in the pose tool was not changed (adjusted according to the situation) in any of the created poses, as can be seen in Figure 102, Figure 104 and Figure 106.

The above mentioned situations may mean that the participants just forgot about making the adjustments in the tool controls, but it may also mean that they did not understand or assimilate properly the new approach. For example, they may have not understood that the *bottom* control should mark the point where the line of gravity meets the ground, i.e. the point around which the character's pose is balanced or unbalanced (depending on the action), being also crucial to determine the shape of the bottom section of the *expression cord* (from the feet to the pelvis). Furthermore, in the case of the *Power Centre* spot, it may mean that they did not understood the benefit of thinking of its position and how it could help defining the curve of the *expression cord* and organizing the parts of the body in the pose.

It could also be the case that the participants did not agree with the visual guidance provided by the pose tool but, from their answers to the questionnaires, the new approach and tool were considered, by all of them, very useful to the posing process (see appendix G, page 325). In their answers, they do not separate the approach from the tool, i.e. in the same answer they also include references to the tool as a reminder, due its visual feedback. They use sentences such as: "Being able to see the line of action is great" (Participant A); "it got me thinking specifically about how the shoulders and hips are working" [...] "a very useful and improved method of thinking" (Participant B); "a very useful reminder of the principles of animation" (Participant C); "a good learning tool" (Participant D). Three of them consider that it helps them getting more expressive poses and the other one gives a peculiar answer: "It didn't particularly make the poses more expressive, but it helped to correct certain curvatures of the shape of the characters in some camera angles" (Participant D), which means... it helped to correct the pose, after all. The same three participants consider that it makes the process of creating the poses easier or faster. The other one says it took him longer because the tool showed him what was not correctly done and made him spend more time amending it. This is not exactly bad because efficiency is firstly about doing it well and then faster – if the pose is not correct, it is better to correct it earlier than later when it will probably have more implications.

Moreover, regarding the virtues of the pose tool, all the participants mention the immediacy of the visual feedback, with one mentioning the ability to see the *line of action* reacting to the posing and other emphasizing that it helped developing strong *line of action* and balancing the poses. As to the flaws, two of them refer to the visibility problem ("hard to see through the control" and "needs X-ray visualization"), as discussed in section 5.1.4, with one adding that it slightly decreases the performance. Another participant says that it would be easier if the control manipulates the character's rig (active mode).

A first glance at the poses produced in Exercise 2 (Figure 101 to Figure 106) may suggest that the tool is not enough to guarantee a convincing pattern of body expression, in order to allow the correct perception and interpretation of the pose. However, a closer look, for example at pose 5.3, reveals that the *contrapposto* was not properly followed, as can be seen in the X-ray version 5.3-PT (Figure 106) – the amplifiers of the pelvis and shoulders have a similar lateral tilt. If the shoulders were counterpoising the pelvis, the torso would bend to his right side and the position of the hands and arms would change as well, along with the realignment of the upper body, as discussed in previous section. Moreover, if the *serpentine line* was also applied, then the twist would have changed the position of the hands and the arrangement of the arms even more – improving the silhouette. The green line of the tool, representing the *expression cord* and the flow of force driving the body, shows a sinuous sequence of tight curves instead of a single *S-curve* with the upper part pointing to the camera (for this kind of body expression).

It must be stressed that the purpose of the pose tool is to provide an immediate visual guidance to the animator and not to automatically adjust the body parts, removing the artist skills from the decision, as mentioned in the initial aim of this thesis. The tool gives hints, like in the case of pose 5.3, and if the user/participant had paid attention to its feedback, he would have noticed that the *expression cord* is showing a lack of fluidity, with two accentuated inflection points diverting the flow of force, produced mainly as a result of an inadequate rotation/displacement of the pelvis, middle and top of torso controls. This case constitutes further evidence that the new approach to posing requires more time of practice and guidance, in order to be well assimilated by the participants, before testing the benefits of applying it.

As mentioned before (page 251), another variable to be tested and analysed was the time consumed in the creation of each pose, by each of the participants. However, since all of them forgot, at least once, to save the Maya file as new file

with the pose number, after finishing each pose (as explained in section A.2), it is not possible to accurately determine the time consumed in each pose – some could only be estimated and a few could not be determined. Moreover, it should be noted that the data gathered from both exercises shows the time consumed by the participants working on the Maya files (since they started until they finished) but they may have spent some time studying/preparing the poses, before opening the Maya file and saving it for the first time (as Pose 0). Actually, they did not start and finish working on the Maya file exactly all at the same time and some even created more poses than required, as mentioned in section A.3.3. Nevertheless, the duration of each session/exercise was recorded (Table 1 and Table 2, in section A.3.3) and can provide useful and interesting information about which approach was less time-consuming.

As a matter of fact, all the participants took less time to complete Exercise 2, which suggests that the new approach makes the process faster, as corroborated by the answers of two of the participants to the questionnaire (answers of participants A and B to question 3, in appendix G, page 325). One may say this could be just because the participants wanted to finish and leave as soon as possible, although none seemed to be in a rush to leave the room after having finished the experiment. It could also be suggested that maybe this is just a coincidence, for instance because the poses required in Exercise 2 were easier for the participants to create. Or maybe the new approach they had just been introduced to really influenced their process and made it easier for them to imagine the poses, as some of them stated (see answers of participants A, B and C to question 3, in appendix G, page 325). For example, the difference in time consumed in the creation of poses 1, where less variation (between Exercise 1 and Exercise 2) was required to the participants – just the traits of personality were different – was around 27 minutes less in Exercise 2, on average. The available data shows that participant D (who created all the poses with prefixes 4 and 5) was the fastest one in both exercises and also that he spent about half of the time less in Exercise 2

than in Exercise 1. Curiously, when asked if the new approach would have made the process faster, he does not acknowledge the fact and even mentions that it took him longer (answer of participant D to question 3, in appendix G, page 325). He classifies himself with a level 6 of expertise in 3D Character Animation and the quality of his poses, on average, is not the lowest – although pose 5.3 is, in fact, the least convincing reaction, on which he spent just about 4 minutes. Each of the other participants (self classified with levels 5, 7 and 8) spent about 21 minutes more, on average, creating the poses of Exercise 2 than participant D. Some of the most successful (or least problematic) poses (6.1, 6.2 and 6.3) were created by participant C, who created the poses with prefixes 3 and 6. Pose 6.1, with an estimated time of 5 minutes, was the fastest of poses 1 to be created in Exercise 2 (Table 2) and pose 6.2, with 14 minutes, was also the fastest of poses 2 to be created in the same exercise. Only pose 6.3 was the most time-consuming of all. However, it must be noted that this participant C created more poses than the three required in the brief, which means that just these three were certainly completed in less time. This also shows that no evident correlation can be established between the quality of the poses and the total time spent creating them.

The average time difference verified in Poses 2 – the throw – is twice bigger (15 minutes less in Exercise 2) than the verified in Poses 1 (5 minutes) or Poses 3 (6 minutes), which could suggest that the new approach is even more advantageous, in terms of economy of time and effort, when creating more dynamic poses and, therefore, can contribute significantly to the efficiency of the posing process. It could also be considered more efficient, if the poses 2 in Exercise 2 (shown in Figure 103) were more expressive as well, which is not the case, since those poses are not very convincing, either in expressing an insecure character or in throwing a ball even in a non-professional style. The poses 2 created in Exercise 1 (shown in Figure 99) express more convincingly a confident character throwing the ball in a professional style, as required.

One can argue that a naturalistic pose in professional style of throwing is more demanding (requiring more accuracy) and therefore takes more time for the animator to create it than if the style is not so professional. However, just because one character is required to convey a poor style or not very professional way of doing something that does not mean that the pose and the animation need to be equally poor. On the contrary, often non-standard situations/actions can be more demanding to the animator, in order to achieve believability. The matter is not just about the mechanics of motion but about expressing a convincing attitude according to the character's personality, his mood and the circumstances he is dealing with, as well. It could be also argued that the participants spent more time studying the given reference material for the professional way, but it could also be argued that they might have spent more time searching online for references of unprofessional ways of throwing the ball.

The analysis of the bodies reveals that the poses created in the second session, with the new approach, show less stiff torsos – more use of the twist (except in poses 5.2 and 6.1) and tilt of the pelvis and shoulders. Even if sometimes the arrangement of those two parts is not consistent with the engaged leg and the centre of the base of support of the body, as mentioned before. The question, then, is whether this kind of improvement is because of the approach or because of the tool? From the analysis of the tool in many poses, it seems that the manipulation of its *bottom* control was neglected or forgotten, as described before, probably due to lack of habit or maybe just because they did not understand well how it should be operated. Therefore, it was probably because of the new approach.

Furthermore, the failure to create some poses that more accurately express the requested action could also be due to a possible different understanding of the participants about body configurations associated with the expression of each emotion or attitude, involving different clusters. However, such difference in

understanding was not verified in the poses 1 created in both exercises. Thus, this means that in Poses 2 of Exercise 2 the participants neglected the need to keep the characteristics related to the traits of personality, or maybe they thought that it was not important to keep those aspects but to focus on the action – the throw (and the reaction, in poses 3).

Probably, the participants just thought that, for the amateur style of throw, any weird pose would suffice and, thus, did not care about arranging the body parts in a convincing way, according to the flow of force necessary for the action (as discussed in section A.4.2) and consistent with the insecure trait of personality of the character. If they had followed the rationale of the *expression cord*, they could have arranged the body parts according to the imaginary flow of force, having in mind a clear *line of action*, the *contrapposto* and the *serpentine line*. Moreover, if they had thought of the *power centre* when creating the pose, then they would have started by pulling the pelvis backwards and tilted it forwards, and that would suggest the knees and feet to point inwards.

Independently of these considerations, it seems that poses 2, created with the new approach (Figure 103 and also Figure 104), show more twisting figures and less stiff torsos (except 5.2), in line with the tendency of the rest of the poses produced in Exercise 2. Thus, in spite of the limitations, the experiment provides some hints towards the validity of the proposed approach and to support the hypothesis that such a conceptual guideline would help the animator to define the pose and improve its expressiveness. Likewise in what concerns the time consumed, since, on average, the participants spent around 35% less time creating the three poses, when using the new posing approach.

A.5 - Limitations

This exploratory experiment has several limitations, related not only with the number of participants but also with the changing of their habits and procedures.

Regarding the limited number of participants involved in the experiment, it proved to be very difficult to recruit participants for the posing experiment, as discussed in chapter 3. There are three main reasons: 1) the experiment requires participants with very specific skills (3D character animation students, experienced in using Maya software), and with an even level of expertise; 2) the participants have to work for several hours (4 to 5 hours, at least, in the last design of the experiment); 3) the students were very busy with their academic projects and did not have time to spend with this experiment.

It must be also noted that is not easy for the participants to assimilate the new approach in approximately 2 hours (including 15 minutes to try the tool) and start working that way, following the proposed rationale immediately, without any previous practice and guidance. That fact and the results they produced lead us to conclude that those results are more the evidence of the problem that the approach proposes to solve than the evidence of how the approach can help solving the problem.

So, how could the approach be tested? Probably after a longer training process, where the students/participants would have been introduced to the approach and would have practiced it for the entire term, using it in all their submitted assignments. Then, an experiment similar to the one already carried out, but with two groups at the same time and in different rooms, would provide more reliable results regarding the effectiveness and efficiency of the approach, which would probably be more distinct from the ones produced this time. The results of the two groups could be compared, to see which were the most expressive.

Again, that way would not guarantee the sufficient number of participants (which was problematic this time) and the ideal solution would be to include the experiment as one of the students' assignments. However, that would imply dividing the class in two and teach them differently for an entire term, to guarantee that half of them would not learn the new approach – which would be

difficult to achieve because the students talk to each other – and, furthermore, would raise some ethical issues related to their right to be taught equally. It also would be hardly feasible due to the changes in the course organization that such a solution would require.

Under the circumstances, this was the possible experiment.

A.6 - Summary

The experiment aimed to empirically test and validate the proposed new posing approach and tool with some potential users, as a solution to avoid the stiffness problems and improve the expressiveness of the poses, along with the efficiency it possibly adds to the posing process.

The results confirmed the suspicion that it would not be easy for the participants to switch to a new approach and use it without previous training and practice. This has to be taken into account in the evaluation of these results, which cannot be considered conclusive but just as mere hints towards the validity of the proposed approach. In spite of the limitations, the poses created with the new approach seem to be less stiff, in general, and were produced in less time than those in session 1, with the participants' usual approach.

What is unequivocal is the usefulness of the approach and tool according to the participants' opinions, as attested by their answers to the questionnaires.

B - Posing Experiment Briefs to the 3ⁿᵈ year students

Posing Experiment/Practical BRIEF - 1

Aims: The aim of this session is to study the students' ability to pose a 3D biped character from a given script, using their usual approach.

Working individually, the students will create 3 main poses and timing (blocking stage) for the three moments described in the given scene script. **They shall not animate the facial expressions, just the main body.** Some video clips will be provided for reference.

Duration: up to 10 seconds

Character information: Robert is a very confident person and a good bowling player.

Script to create the 3 poses:

INT. BOWLING CENTRE - AFTERNOON

FULL SHOT (no camera movement).

Robert is playing bowling:

1) Robert is standing, in a relaxed position;
2) Robert throws the ball, in a very professional style;
3) Robert is frustrated and sad, because he failed to knock down most of the pins.

Outcome and submission details:

The students should work on their assignment by making gradual improvements. They should work on their first pose first, and when this is complete work on the second pose, and so on … until they complete all three poses.

Students shall save the Maya file when they start, and then save a copy immediately after finishing each pose. Once a pose is complete, the student should save the Maya scene/file using the following naming convention:

Before starting the first pose: First name_Last name_Pose_0.mb

After finishing the first pose: First name_Last name_Pose_1.mb

After finishing the second pose: First name_Last name_Pose_2.mb

After finishing the third pose: First name_Last name_Pose_3.mb

When finished, all the files shall be put in a folder and then zipped and labelled as **First name_Last name_Posing_1.zip** to be copied to a USB memory stick.

Posing Experiment BRIEF - 2

Aims: The aim of this session is to introduce a new posing approach to the students and ask them to pose a 3D biped character from a given script, using a specific 3D Posing Tool. The ultimate goal is to test both the new approach and the related 3D Posing Tool.

Working individually, the students will create 3 main poses and timing (blocking stage) for the three moments described in the given scene script. **They shall not animate the facial expressions, just the main body.** Some video clips will be provided for reference.

Duration: up to 10 seconds

Character information: Jack is an insecure person and he lacks skills as a bowling player.

Script to create the 3 poses:

INT. BOWLING CENTRE - AFTERNOON

FULL SHOT (no camera movement).

Robert is playing bowling:

1) Jack is standing, in a relaxed position;
2) Jack throws the ball, in a **not very professional** style;
3) Jack is happy, because luckily he knocked down all pins.

Outcome and submission details:

The students should work on their assignment by making gradual improvements. They should work on their first pose first, and when this is complete work on the second pose, and so on … until they complete all three poses.

Students shall save the Maya file when they start, and then save a copy immediately after finishing each pose. Once a pose is complete, the student should save the Maya scene/file using the following naming convention:

Before starting the first pose: First name_Last name_Pose_0.mb

After finishing the first pose: First name_Last name_Pose_1.mb

After finishing the second pose: First name_Last name_Pose_2.mb

After finishing the third pose: First name_Last name_Pose_3.mb

When finished, all the files shall be put in a folder and then zipped and labelled as **First name_Last name_Posing_2.zip** to be copied to a USB memory stick.

Jose Fonseca – NCCA – Bournemouth University – e-mail: jfonseca@bournemouth.ac.uk

C - Questionnaire & Consent Form

Research Project Title:

Character Body Expression in 3D Computer Animation: A New Posing Approach

Description:

The focus of this research is on the posing phase of the animation process of a biped 3D character and the objective of this experiment is, firstly, to assess the students' usual approach and, secondly, to introduce them to the proposed new approach and 3D Pose Tool, asking them to try it, in order to test it and get the students feed-back.

PhD Researcher:

Jose Fonseca, NCCA - Bournemouth University, e-mail: jfonseca@bournemouth.ac.uk

Research Supervisors:

Prof. Jian J Zhang, NCCA - Bournemouth University, e-mail: jzhang@bournemouth.ac.uk

Anargyros Sarafopoulos, NCCA - Bournemouth University, e-mail: asarafop@bournemouth.ac.uk

1

CONSENT FOR RESEARCH PARTICIPANTS FOR QUESTIONNAIRES AND POSING EXPERIMENT

Please read the form carefully to ensure you fully understand it and tick each box to confirm that you have read and understood each section:

I confirm that I have agreed to volunteer to participate in this research by doing the Posing Experiment session and completing this form and the questionnaire provided. The information I provide in this questionnaire will be used for the research purpose stated.

I understand that my work and responses will be completely confidential and the results published will be anonymous.

I understand that the data will be securely stored at Bournemouth University in accordance with the Data Protection Act (1998), will be disposed of after research completion in accordance with the University's research ethics policy.

I understand that I am free to withdraw from the research at any stage by informing a member of the research team named here. I also understand that, as the data is anonymous, it will not be possible to withdraw my data from the research once my contributions have been transcribed.

I understand the analysis will be only used for research and for no other purposes. Any results published will not be available for commercial reasons.

2

Participant Details:

Name:

_____

Age: _____

Gender: Male/Female

Course:

_____

Nationality: _____

On a scale of 1 – 10 (10 being the highest) how would you classify your level of expertise in 3D Character Animation? ____

If you have any questions about the research, or the statements above, please do not hesitate to contact the researcher or his supervisors.

_____	_____	_____
Name of Participant	Date	Signature

_____	_____	_____
Name of PhD Researcher	Date	Signature

THANK YOU!

3

QUESTIONNAIRE

Section 1

(About your approach to posing)

1. Please describe your approach to create the poses of a biped 3D character, in terms of:

   - What are your main concerns in the process of creating a pose, and how important do you think it is to achieve a good pose?

     _____
     _____
     _____

   - Are there any specific concepts that you follow when creating a pose?

     _____
     _____

   - What is the workflow of your approach, while posing?

     _____
     _____
     _____
     _____
     _____
     _____

   - Which part of the body do you manipulate first, secondly, etc.?

     _____
     _____

2. Would you say that your approach is unique or is it similar to the one your colleagues and friends use?

   _____
   _____
   _____

3. Do you use that approach because you consider it is the one which allows you to get better results or/and because it is the only one you know?

   _____
   _____
   _____

4

QUESTIONNAIRE

Section 2

(Your opinion about the new approach and 3D Pose Tool)

1. What do you think of the proposed new posing approach? Do you find it useful?

   _____
   _____
   _____

2. Does it helps you to get more expressive poses?

   _____
   _____
   _____

3. Does it makes it easier/faster for you to create the poses?

   _____
   _____
   _____

4. What are the virtues of the visual tool/3D Pose Tool?

   _____
   _____
   _____

5. What are the flaws of the visual tool/3D Pose Tool?

   _____
   _____
   _____

6. Are there any features that you think would be useful to have?

   _____
   _____
   _____

5

D - Links to the video clips of people playing bowling

As mentioned in appendix A.1.2, some video clips were provided to the participants, for optional reference of bowling actions. They can be found in the links below:

https://www.youtube.com/watch?v=TZ9JbvClnZA (Title: Biggest Hook you will ever see in Bowling ...Tom Daugherty) [Accessed: 06 June 2013].

https://www.youtube.com/watch?v=Wla9JprypLc (Title: Slow Motion 10-Pin Bowling Releases 4) [Accessed: 06 June 2013].

E - Poses shown to the participants

Examples of poses displayed to the participants, when introducing the new approach and showing them how the 3D Pose Tool works with the Morpheus character in Maya (including how it is seen with the X-ray effect).
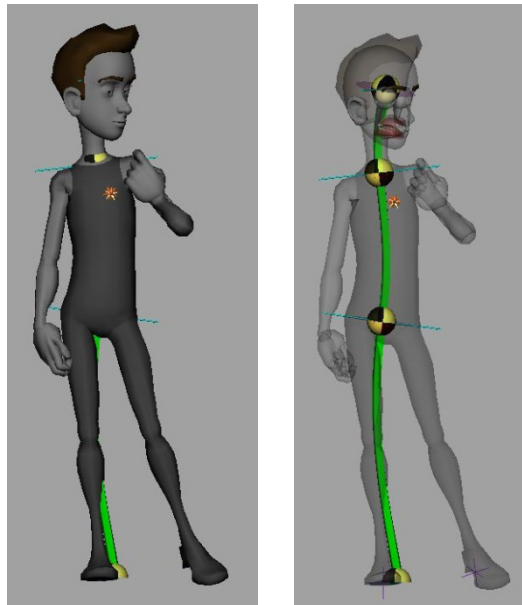
Replicating the pose of Michelangelo's David sculpture.
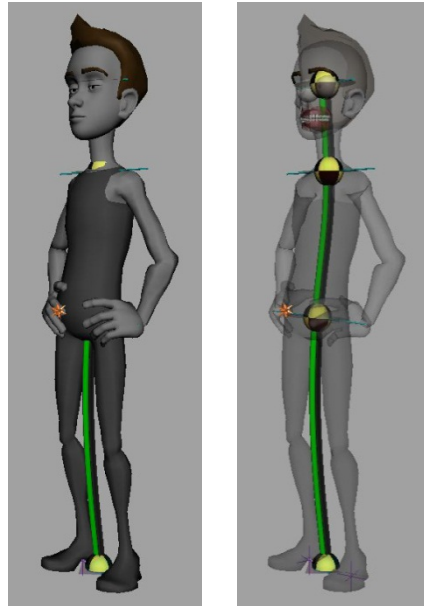
A macho-man pose.
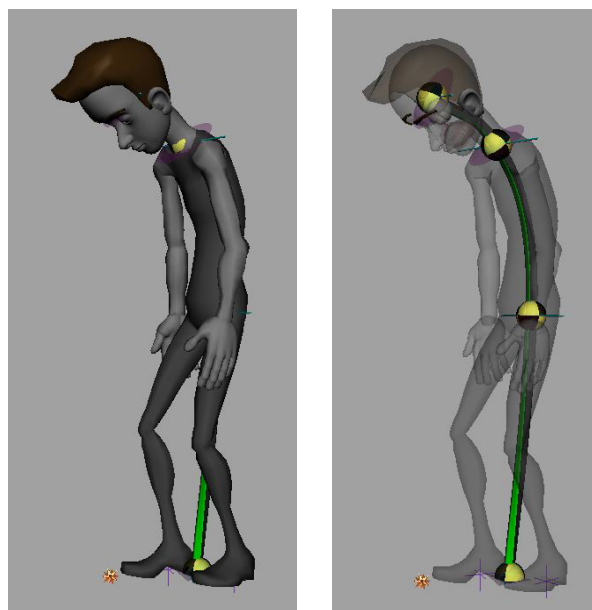
A sad pose.
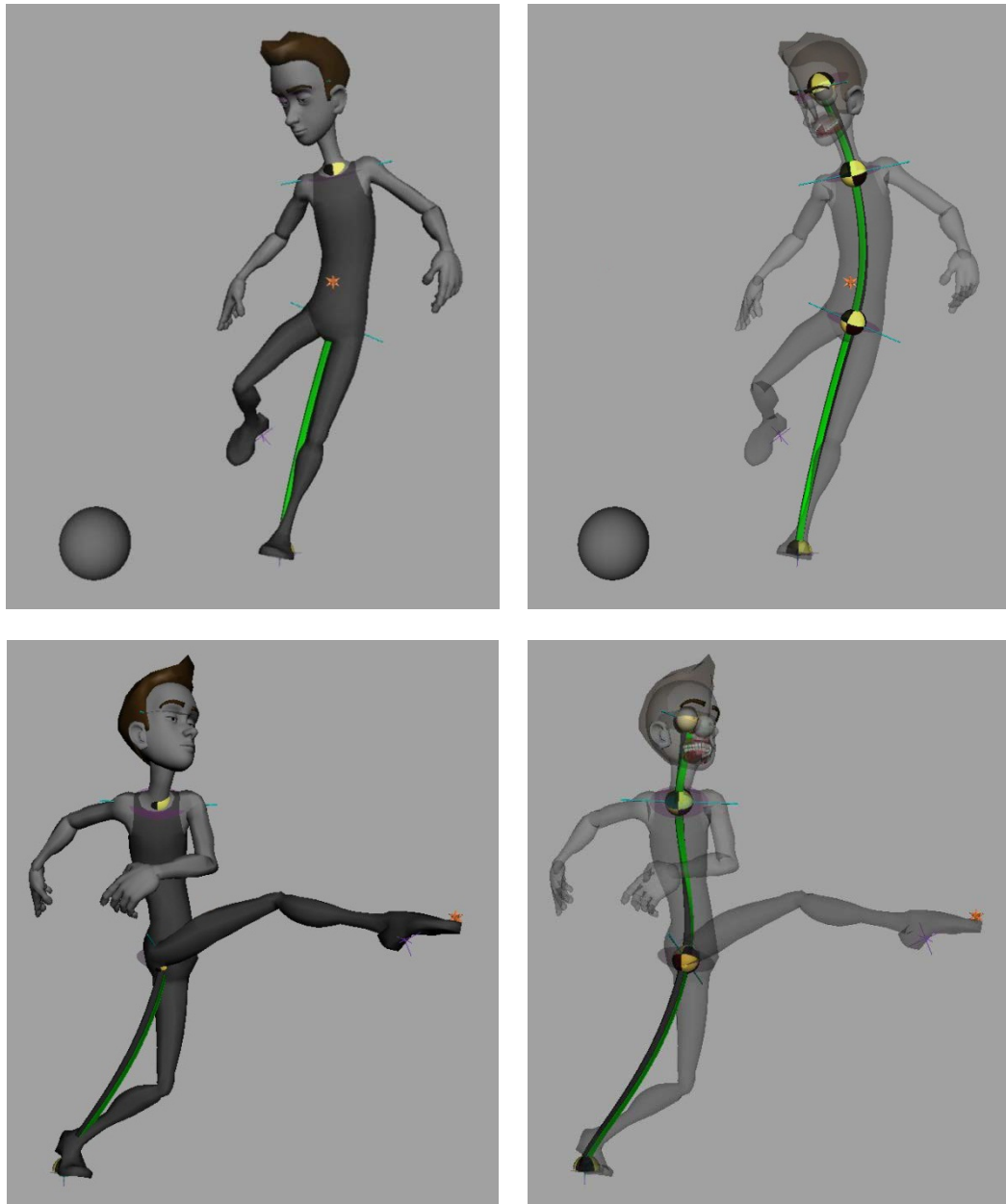
Football player, in two kicking moments.

F - Images of Maya interface with the scenes provided to the participants

F1 - Image of Maya file *Posing_exercise_3Y_Alfa*, for the first session
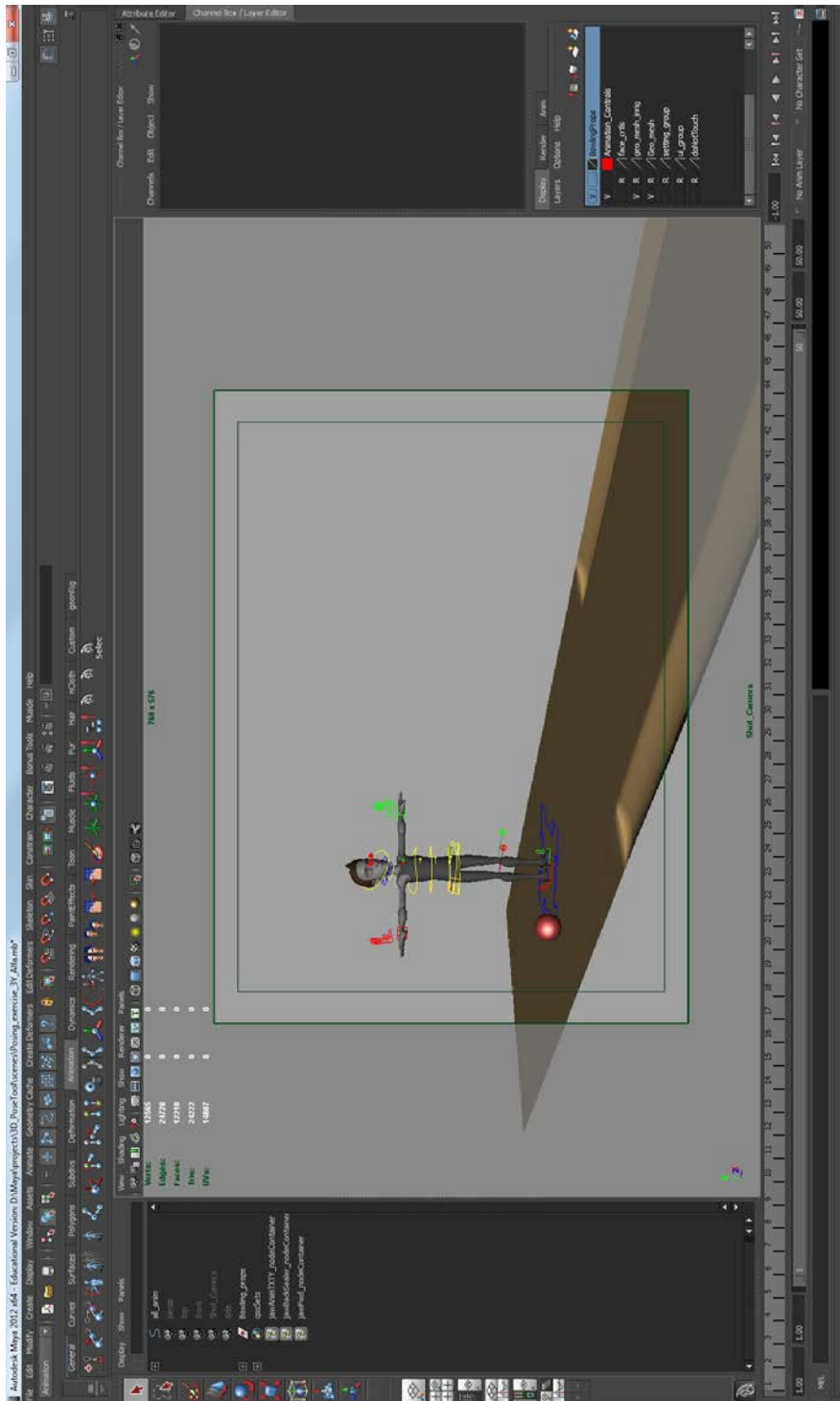
F2 - Image of Maya file Posing_exercise_3Y_Beta - Xray off, for the second session
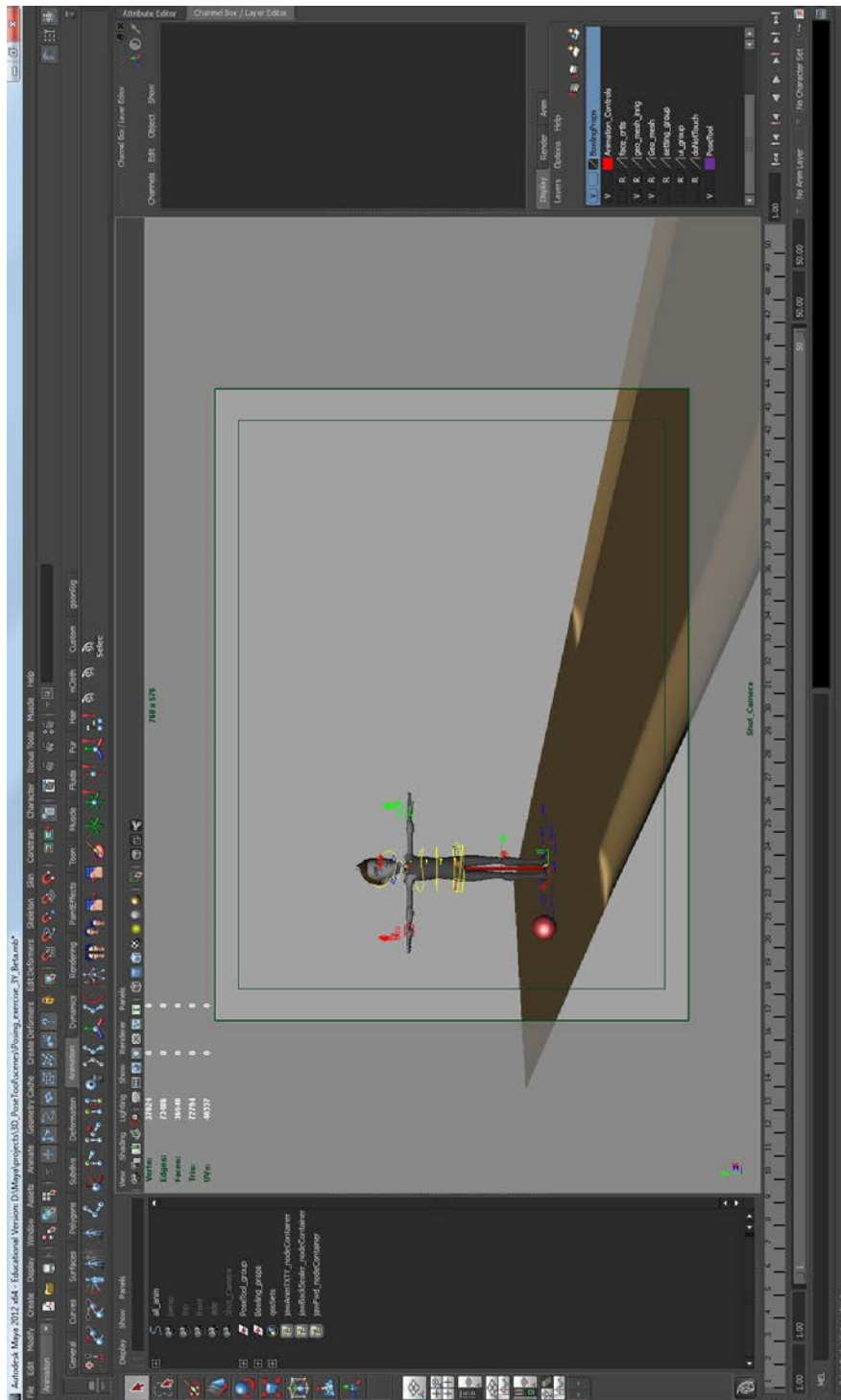
F3 - Image of Maya file *Posing_exercise_3Y_Beta - Xray on*, for the second session, with X-ray view activated
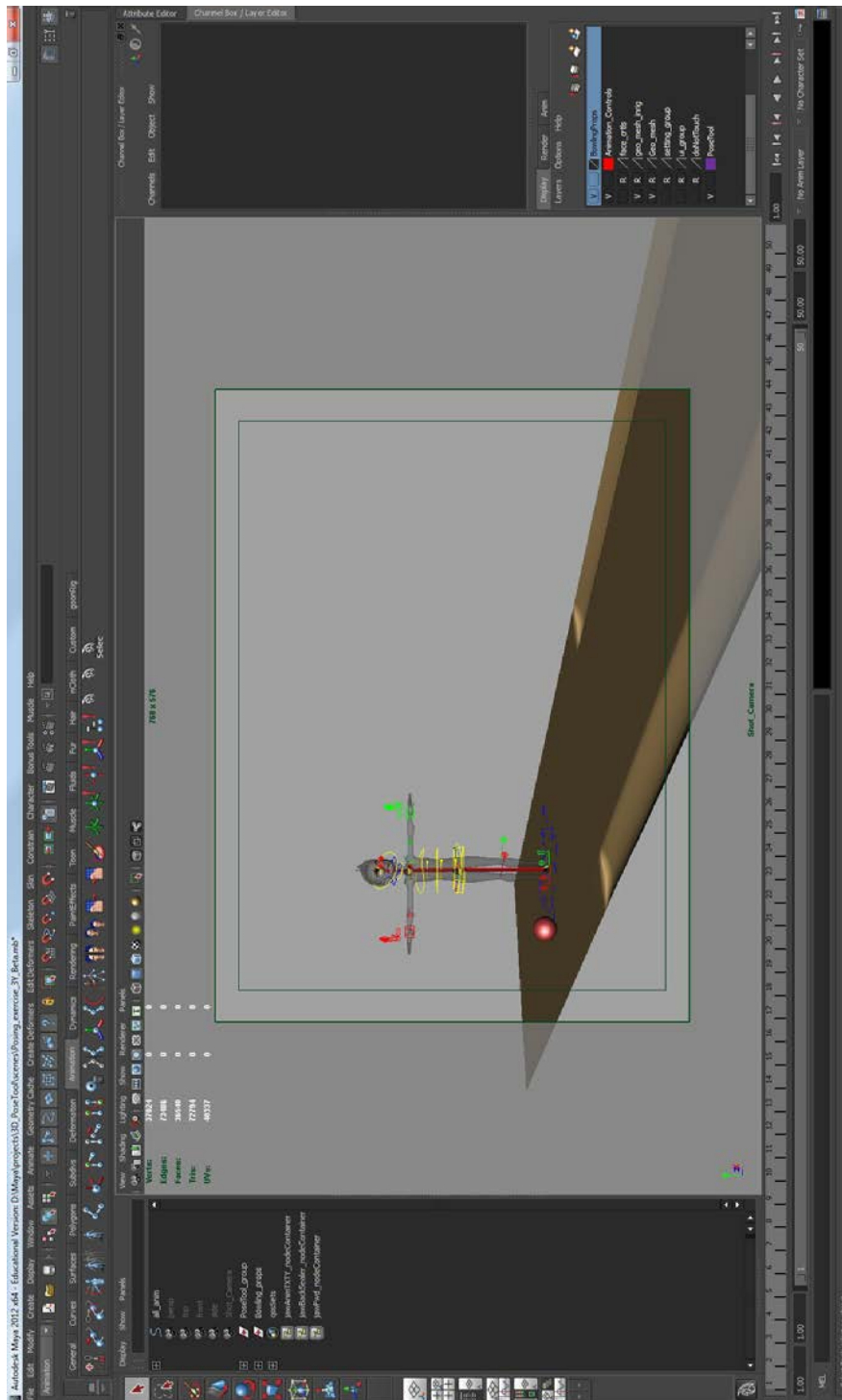
G - Posing Experiment Results

G1 - Poses from Exercise 1 – The usual approach
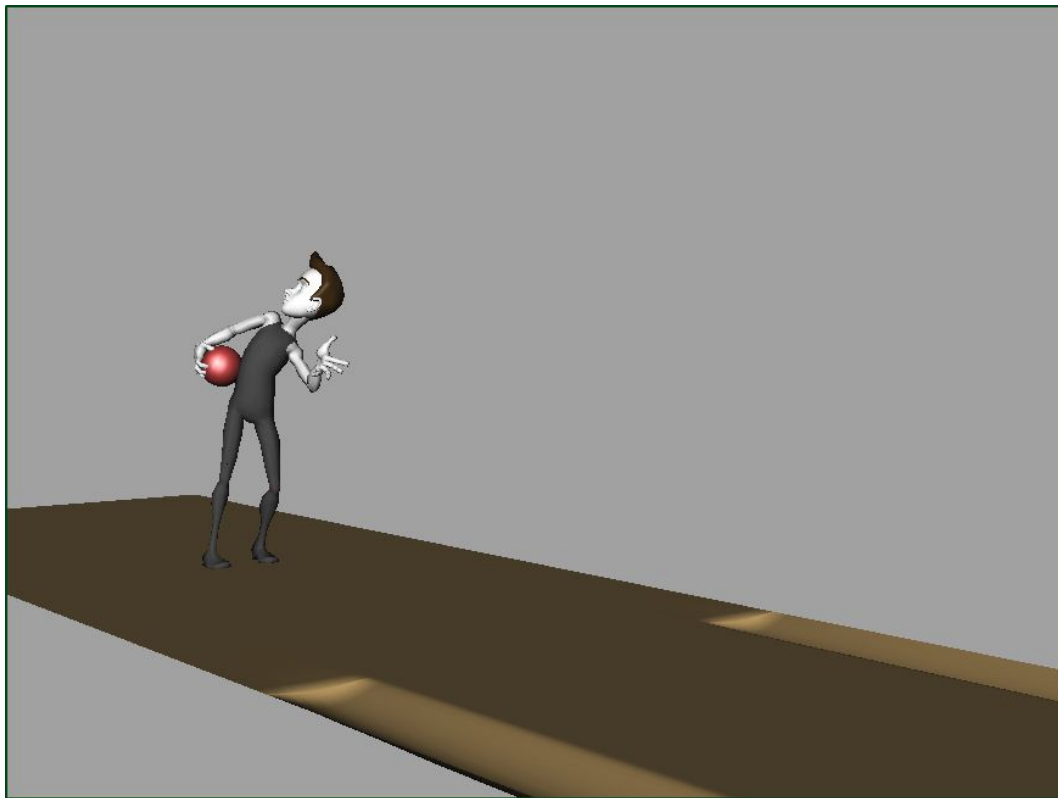
1.1
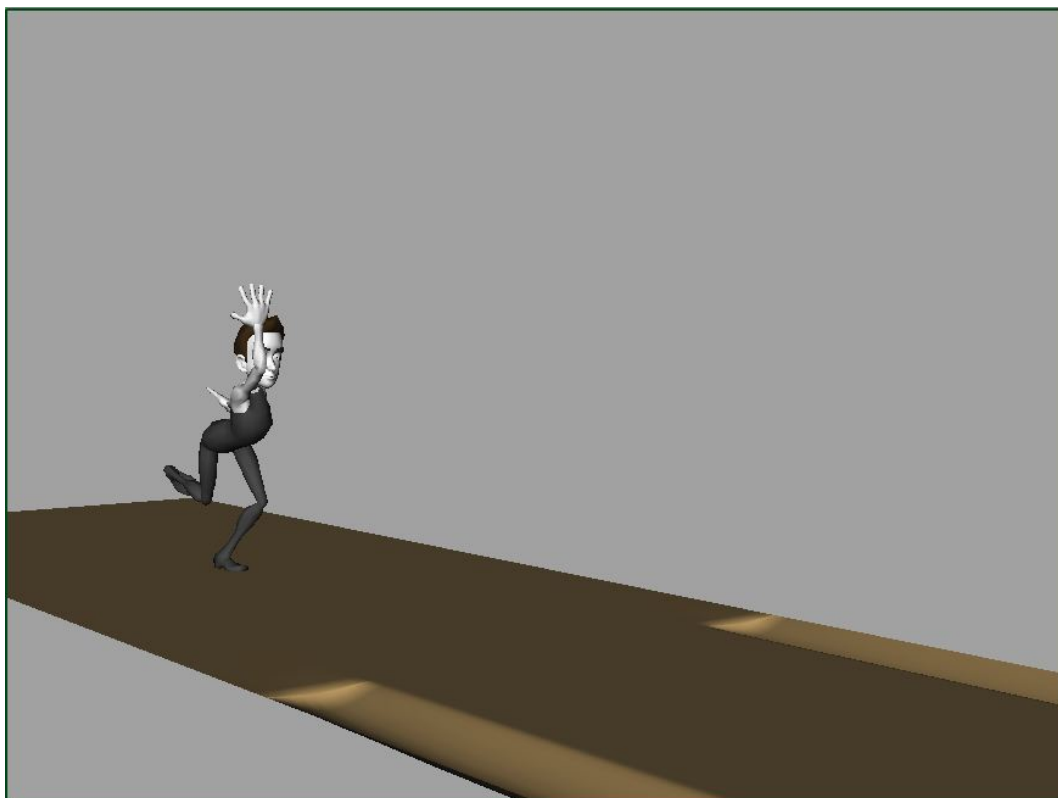
1.2
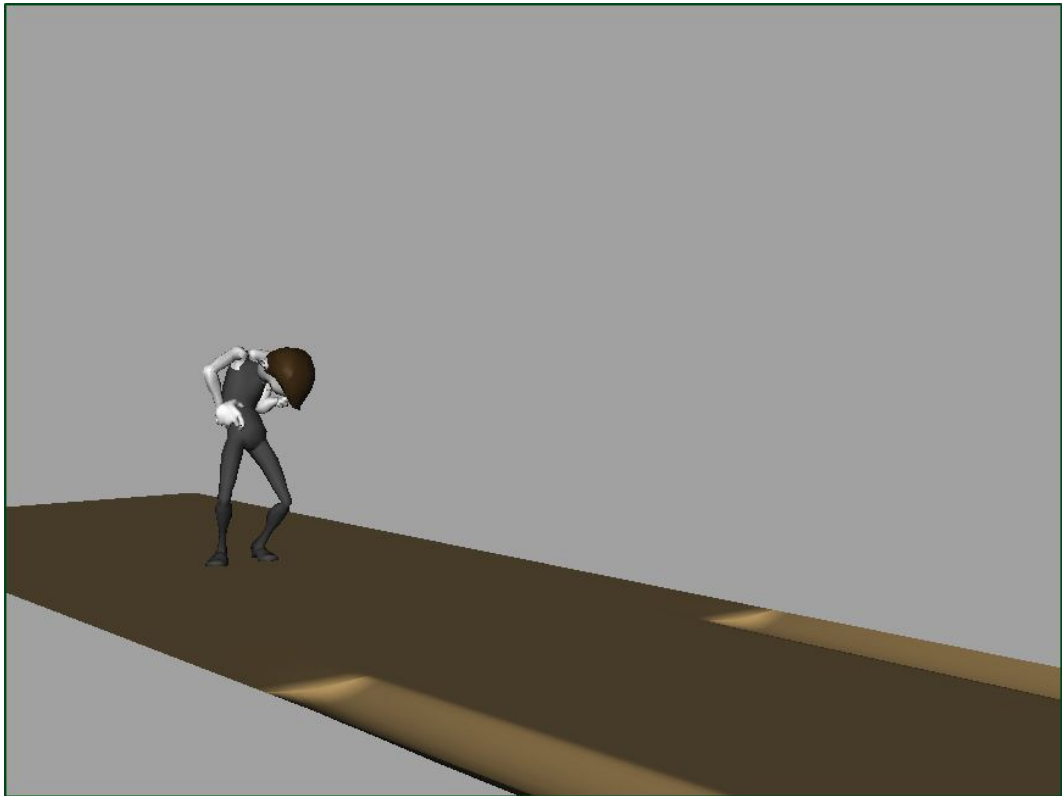
1.3
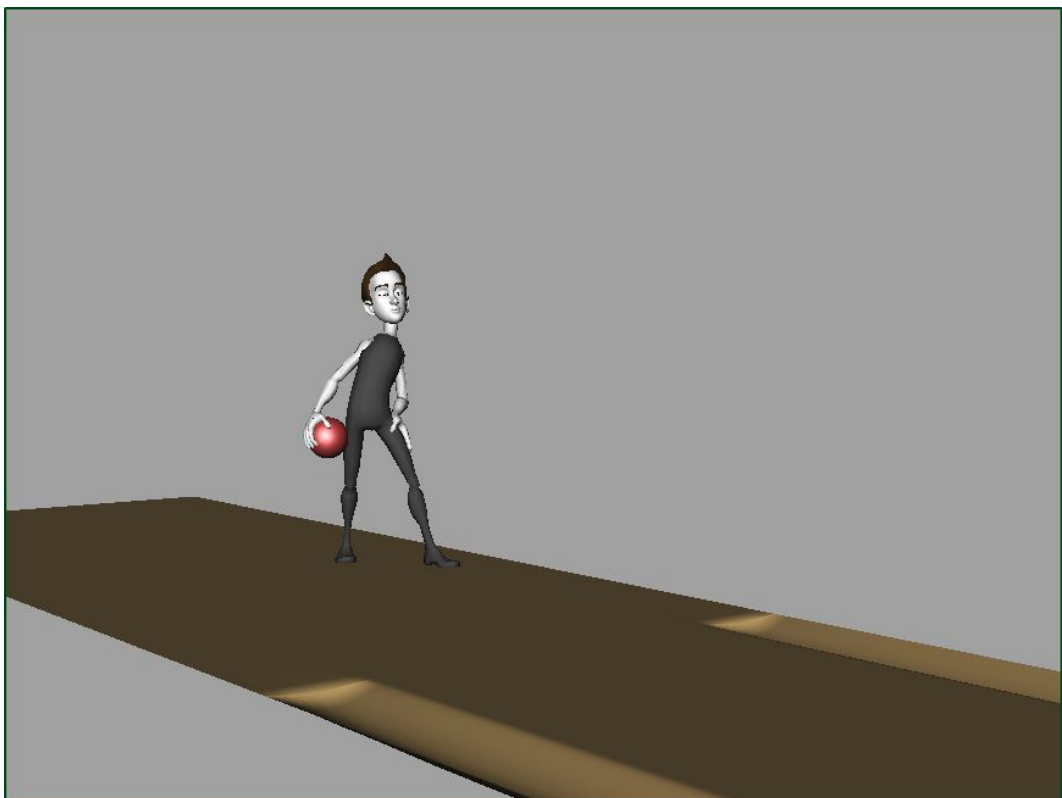
2.1
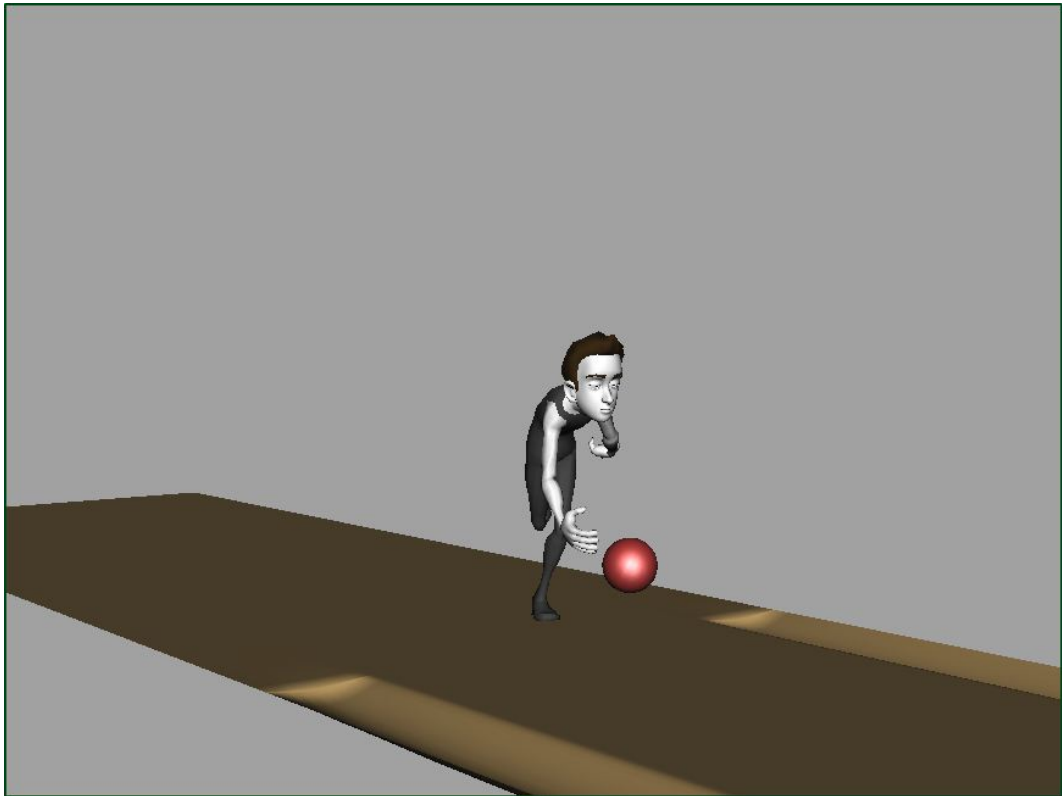
2.2
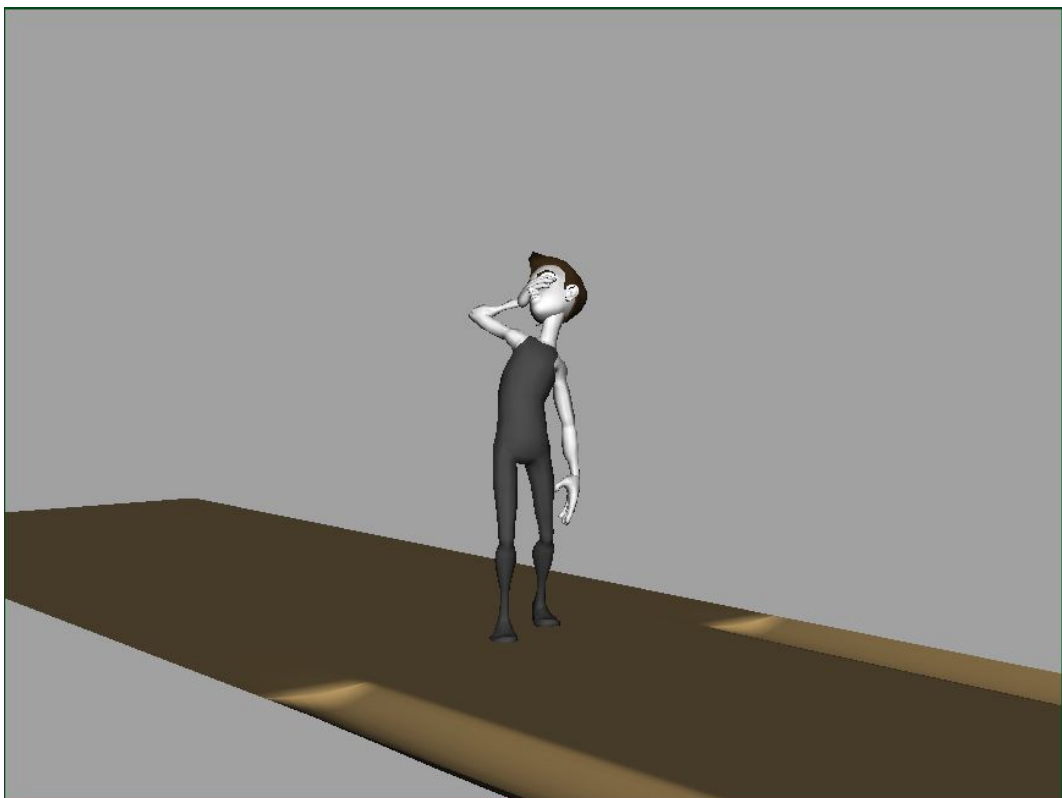
2.3
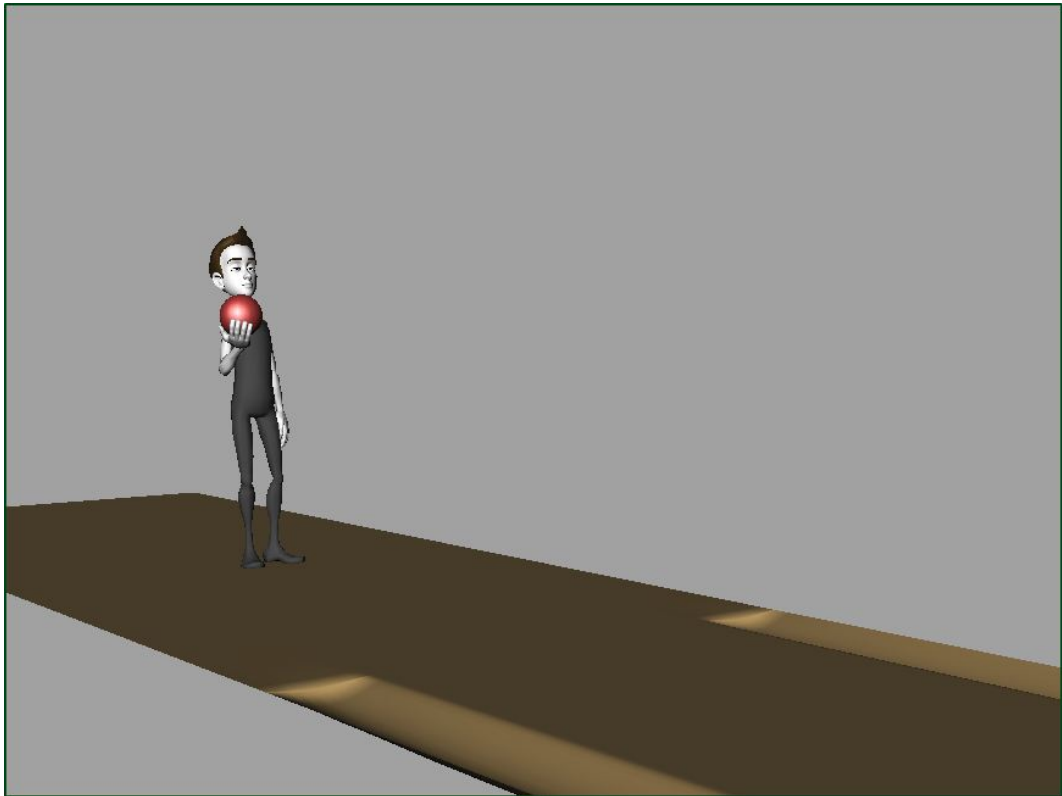
3.1
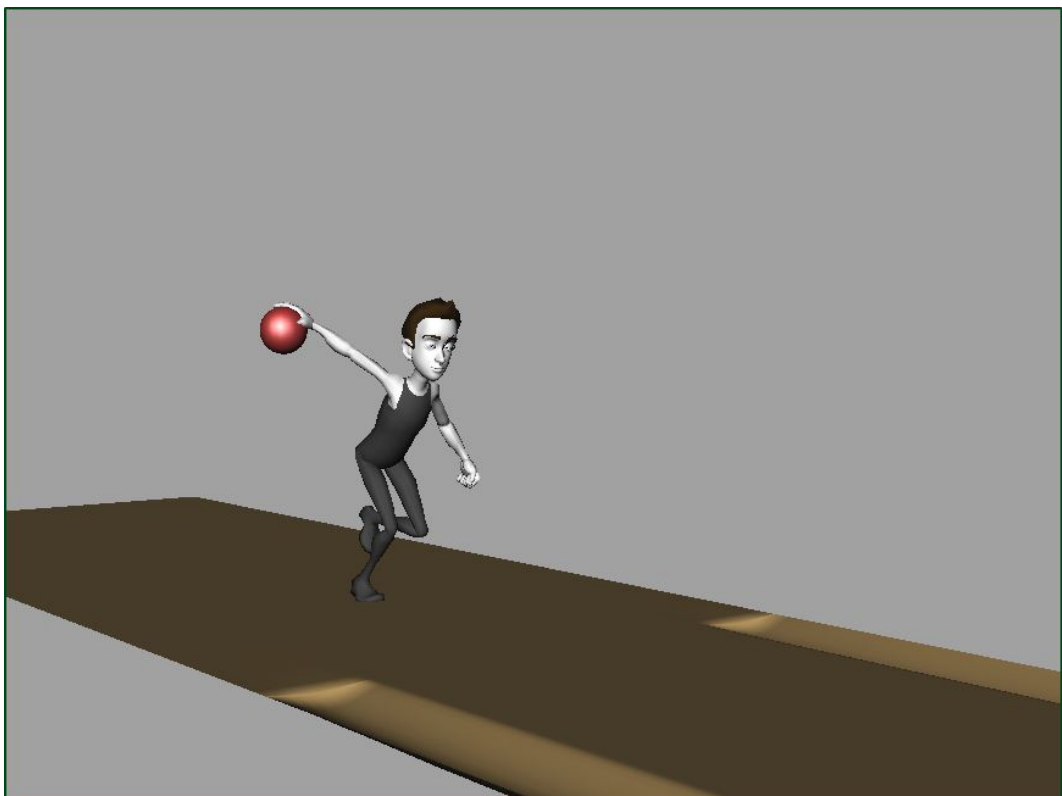
3.2
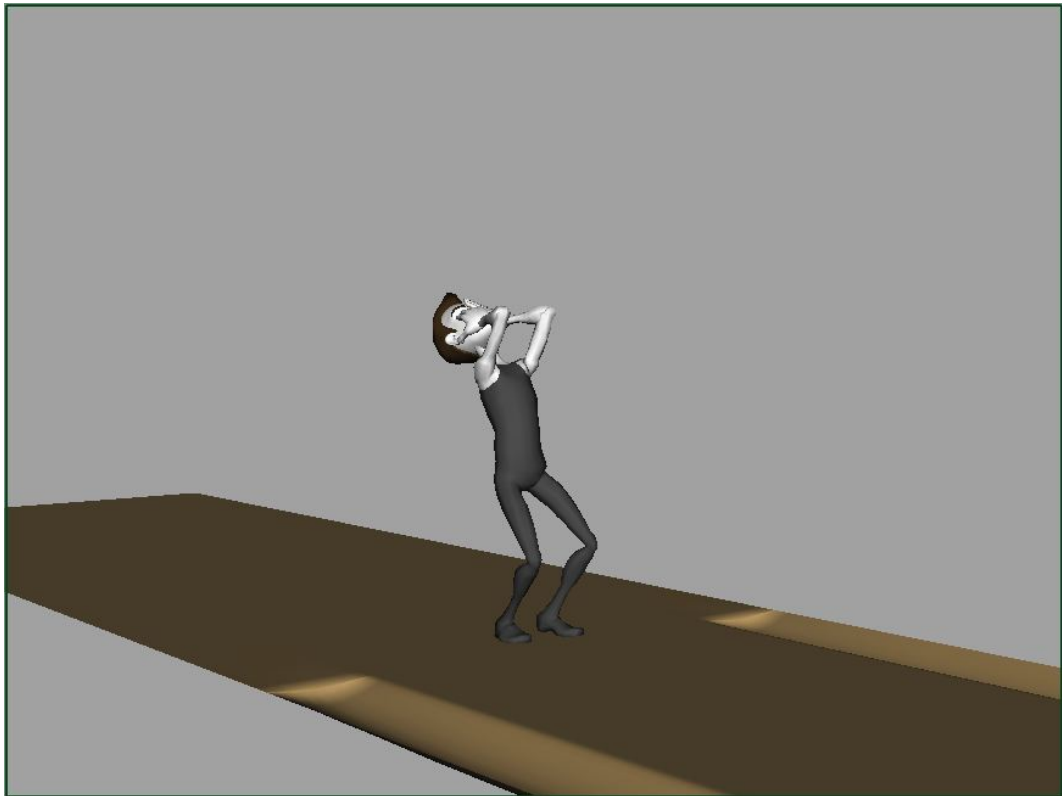
3.3
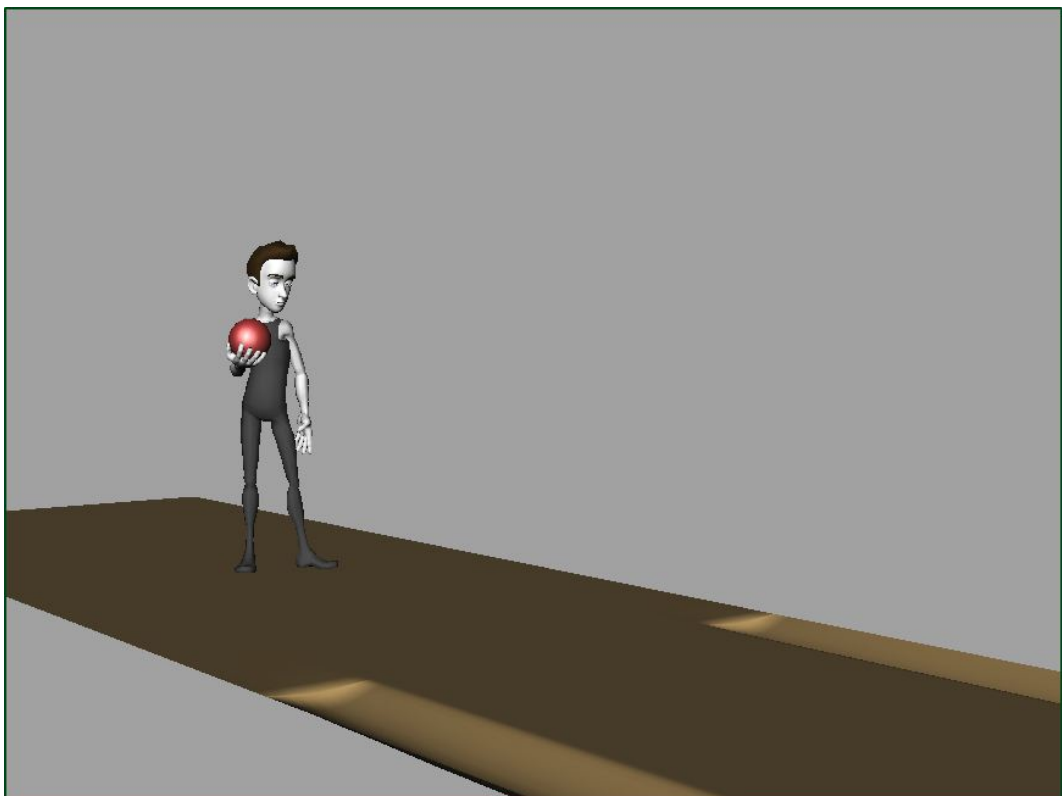
4.1
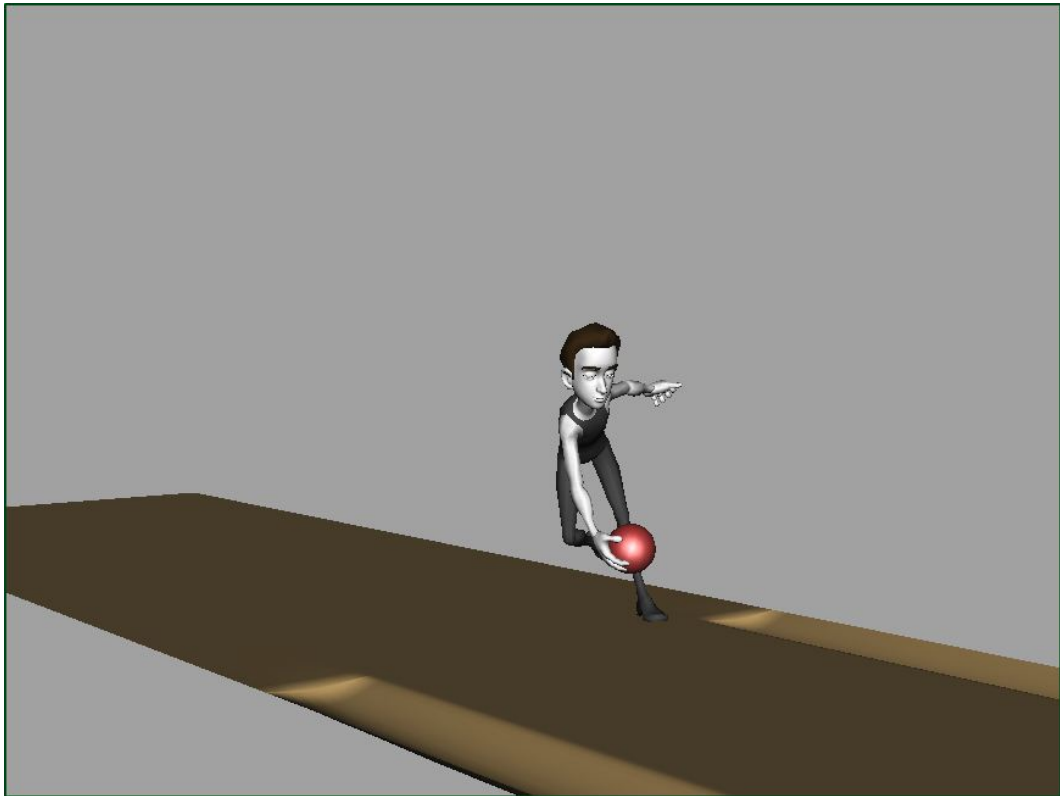
4.2
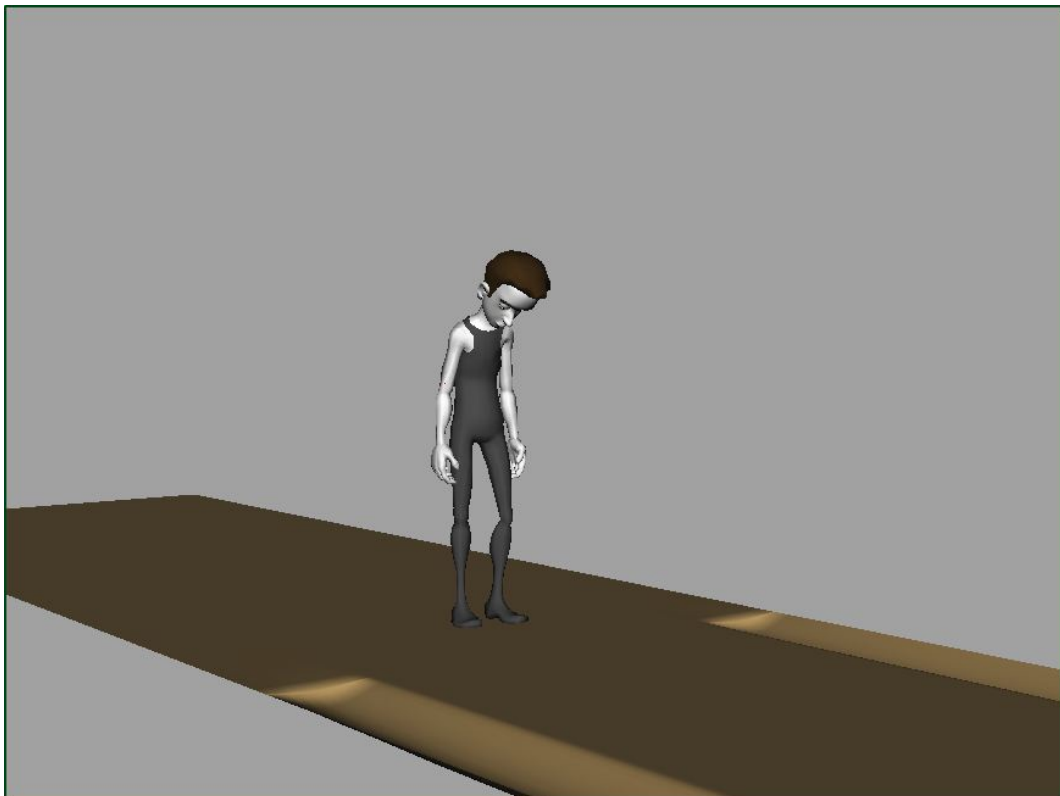
4.3

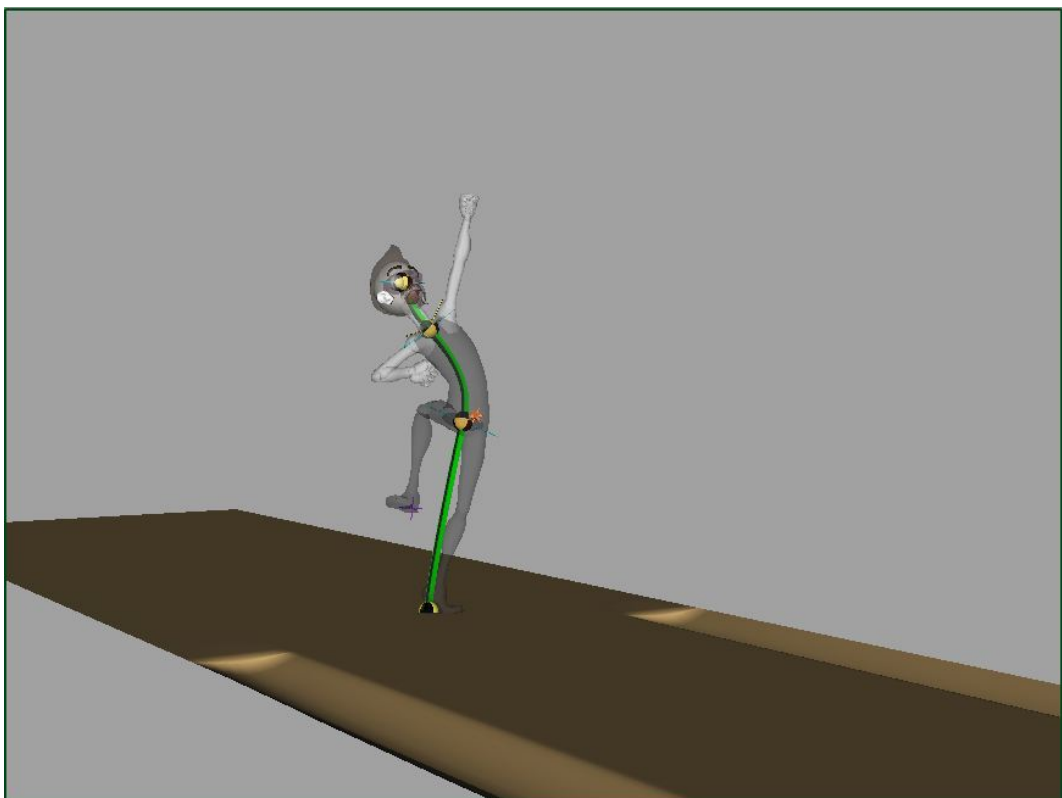**G2 - Poses from Exercise 2 – The new approach**
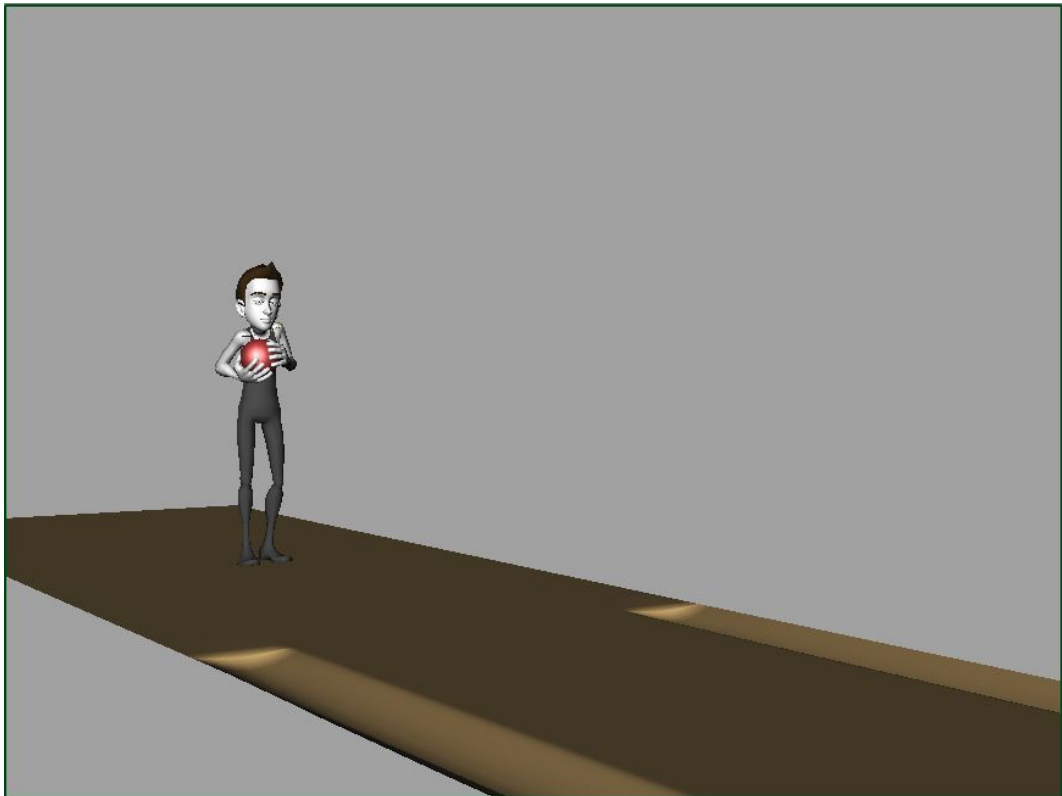
5.1
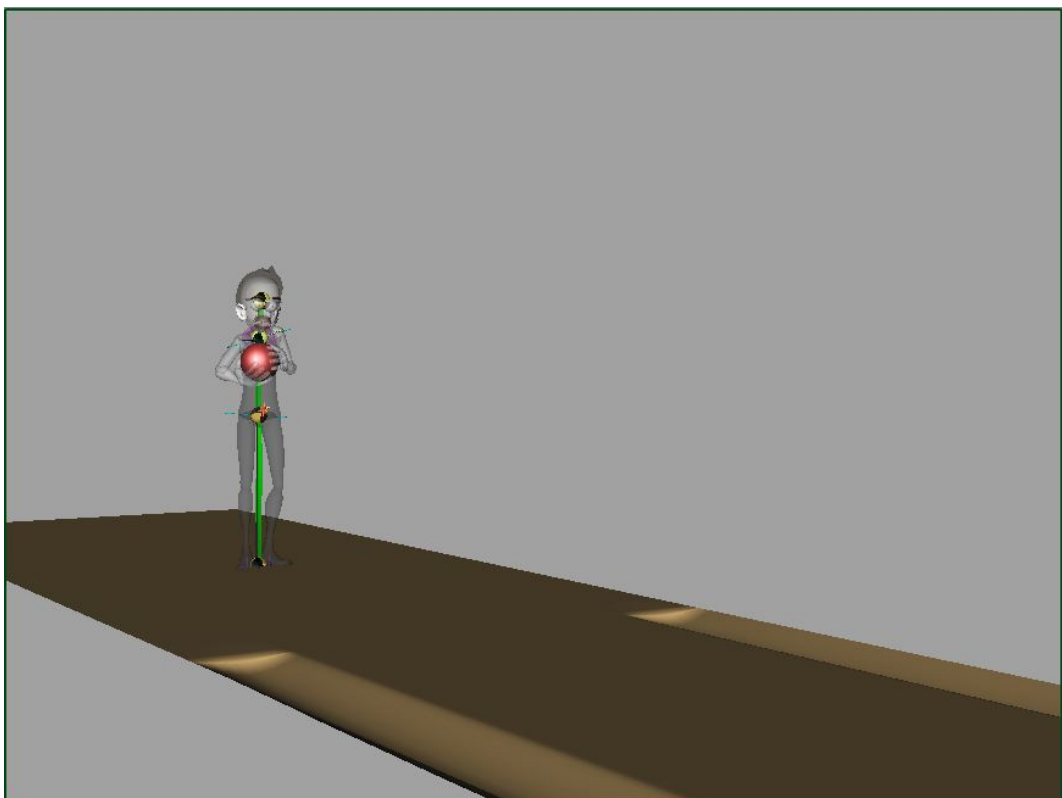
5.1, with 3D Pose Tool.
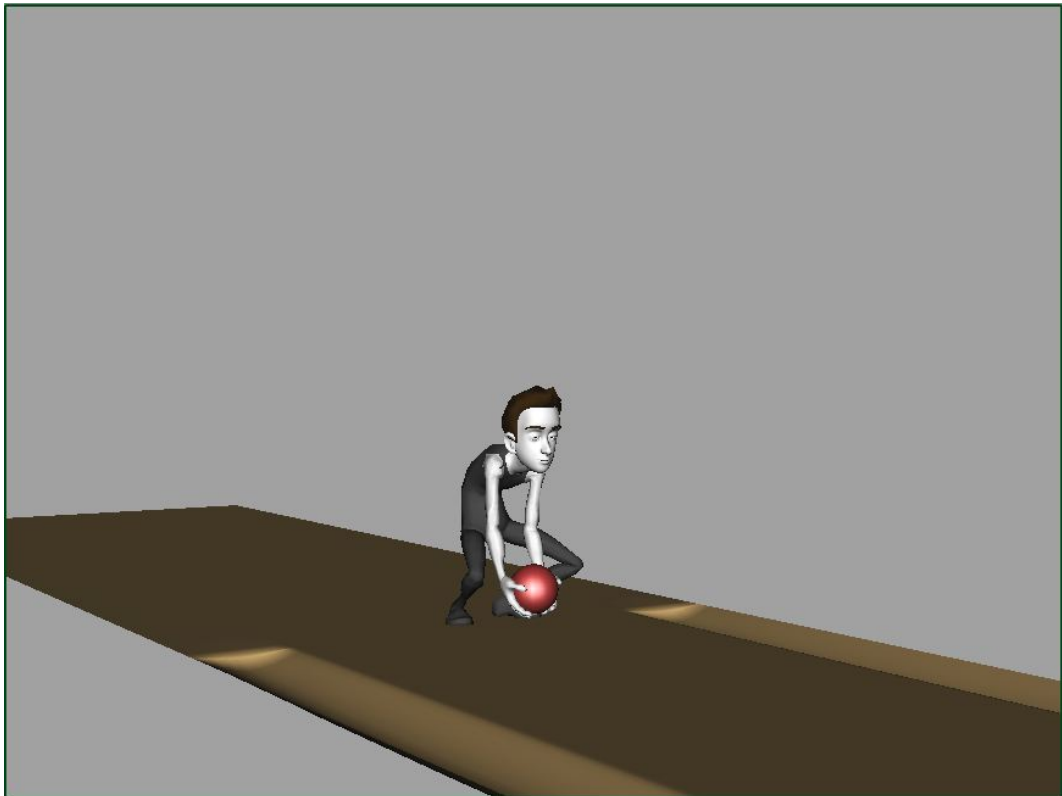
5.2
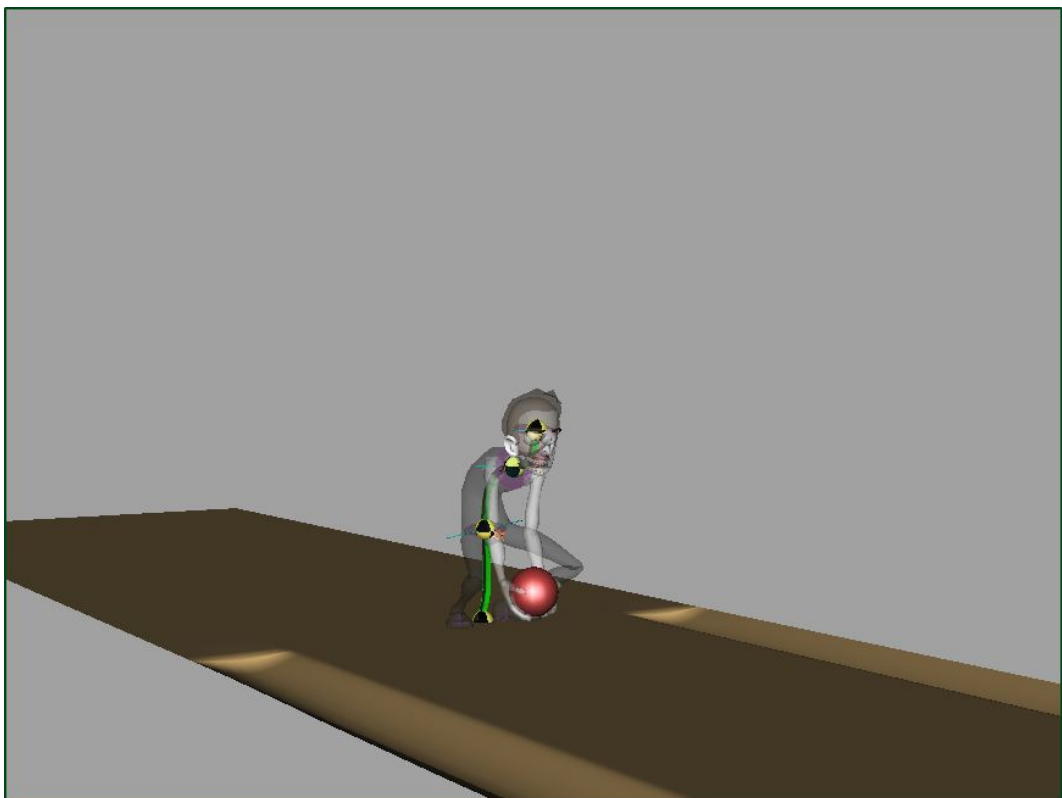
5.2, with 3D Pose Tool.
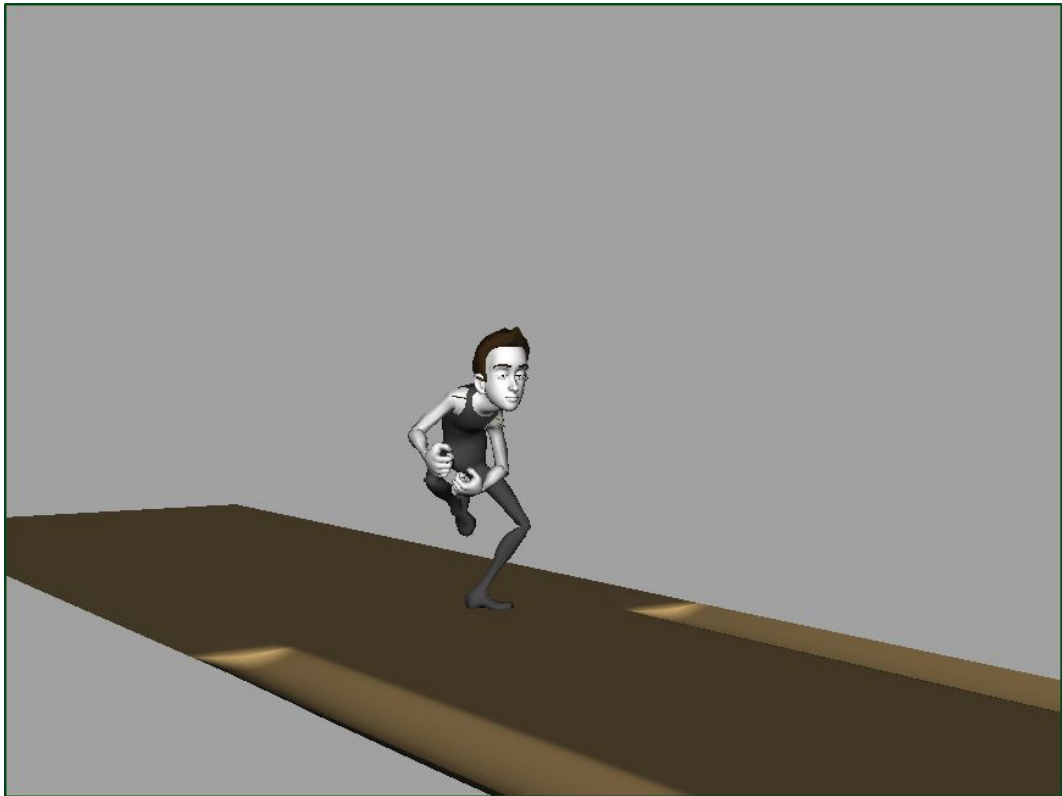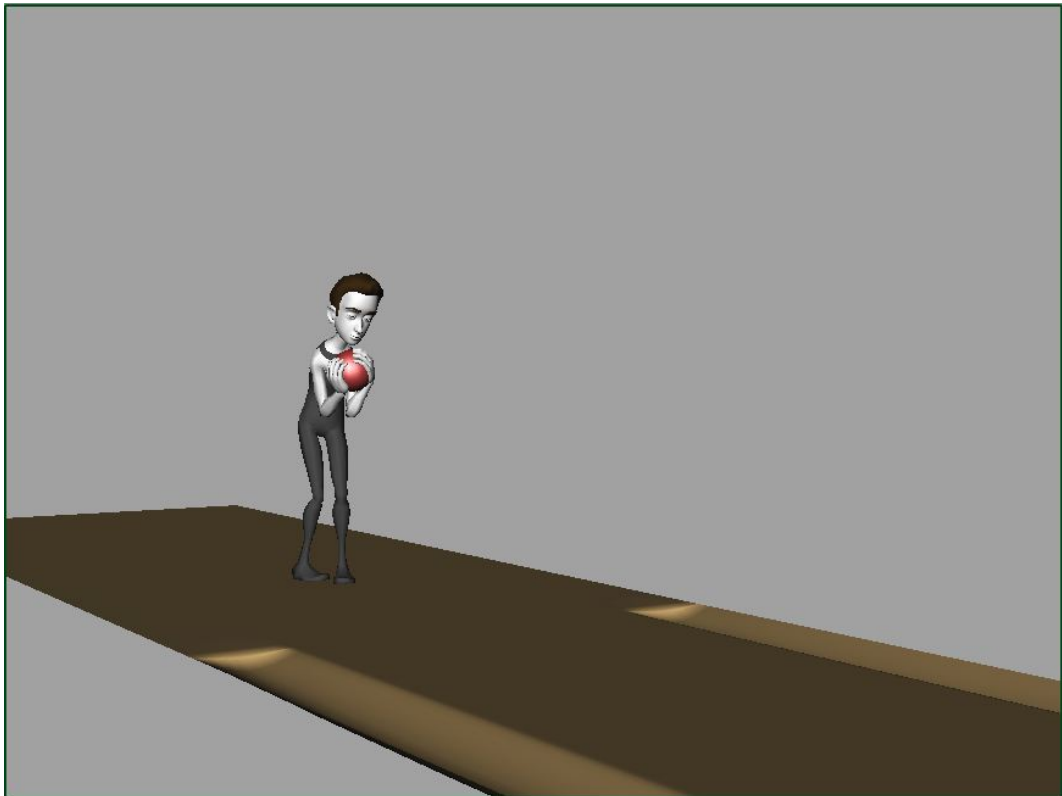
5.3
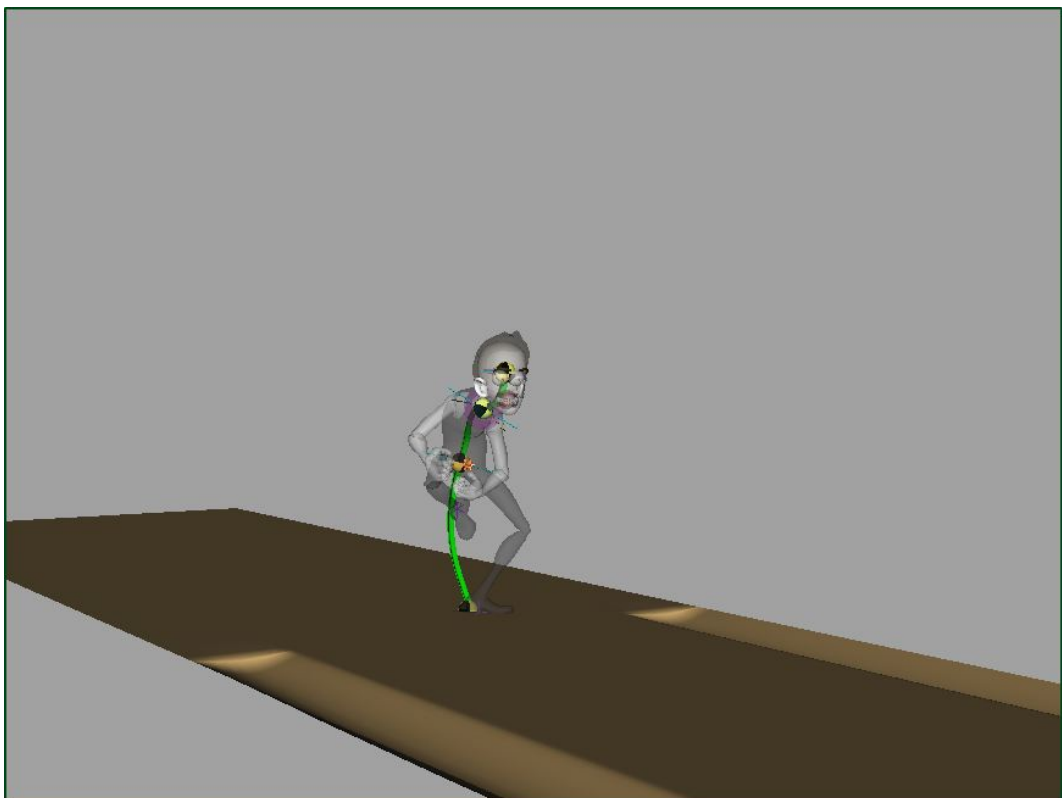
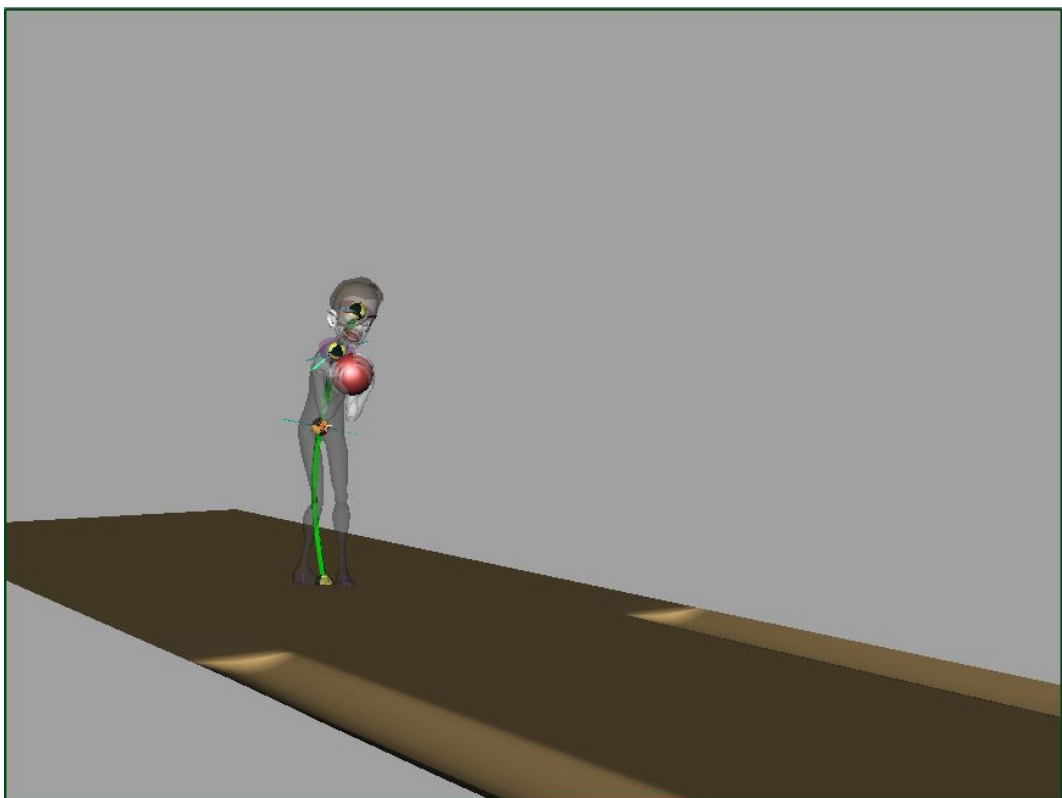5.3, with 3D Pose Tool.
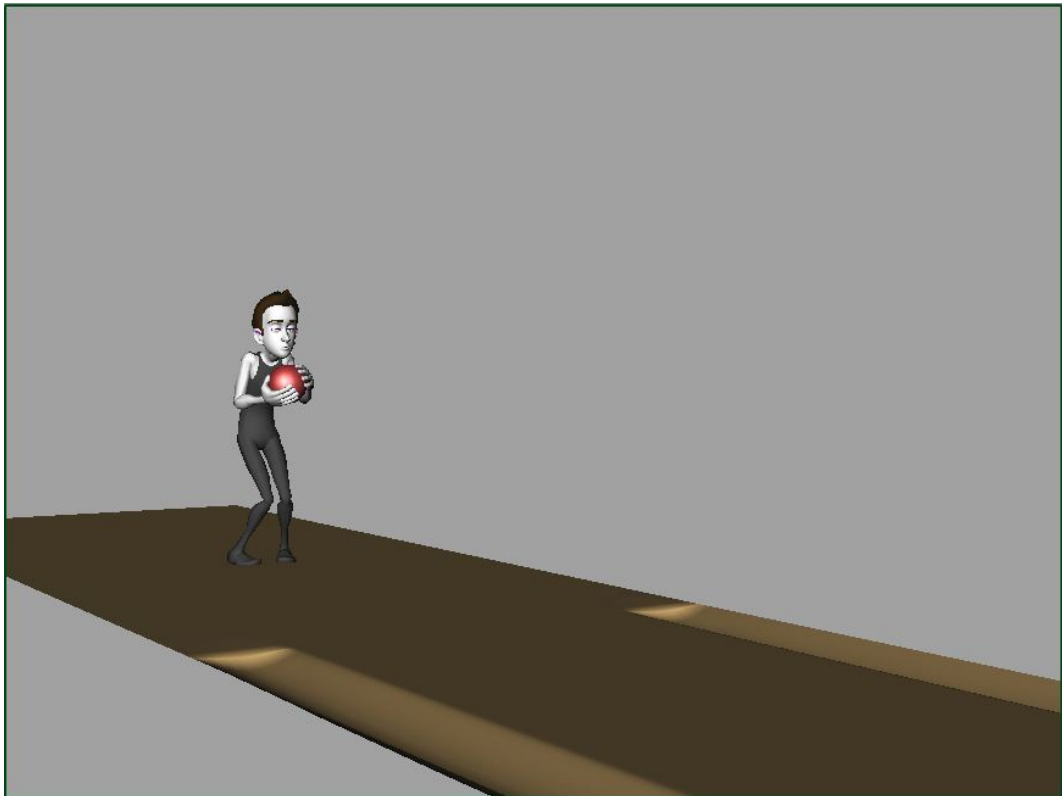
6.1
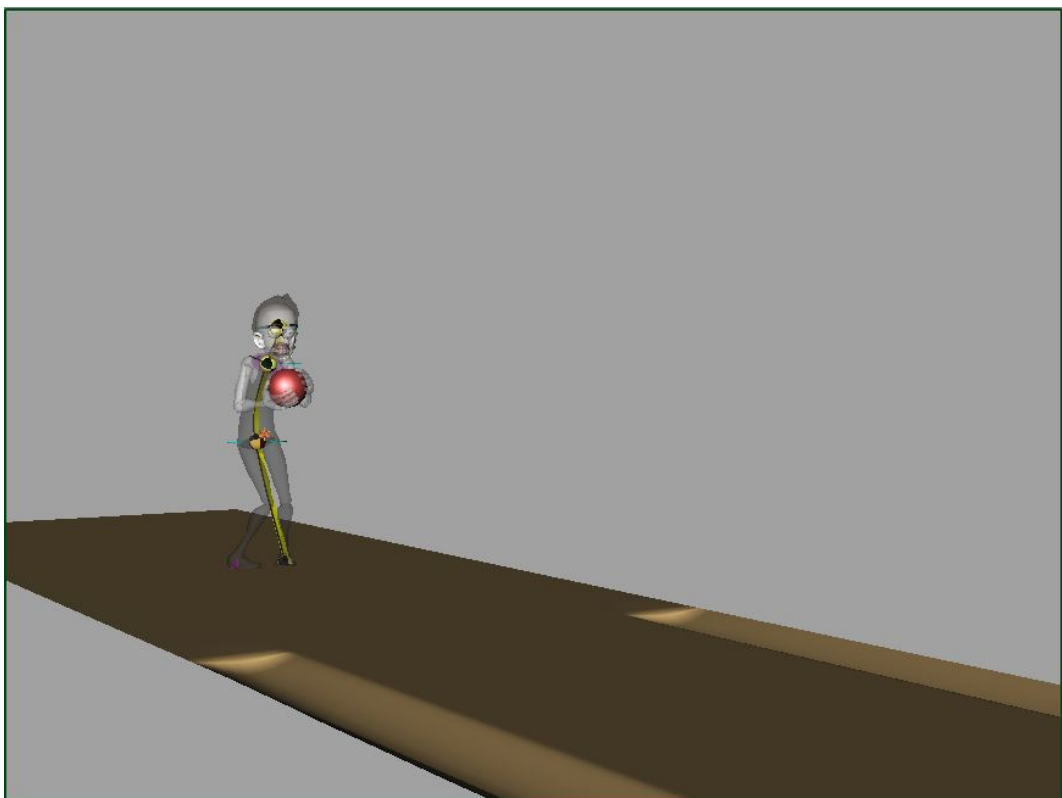
6.1, with 3D Pose Tool.
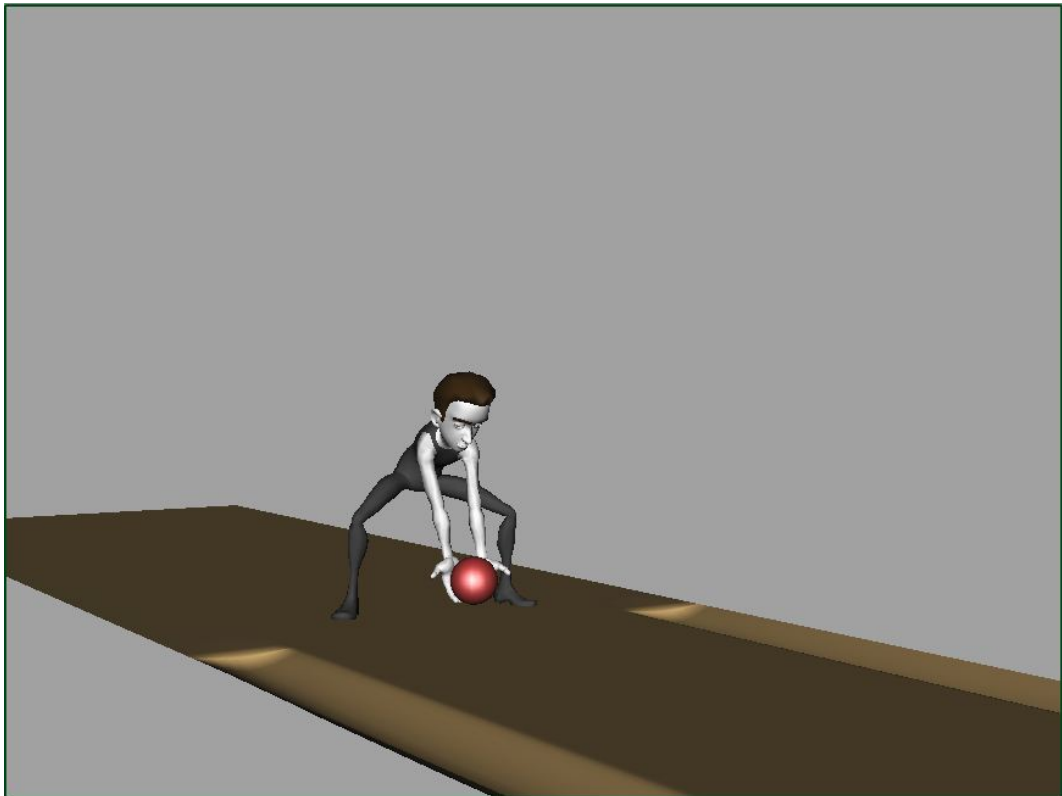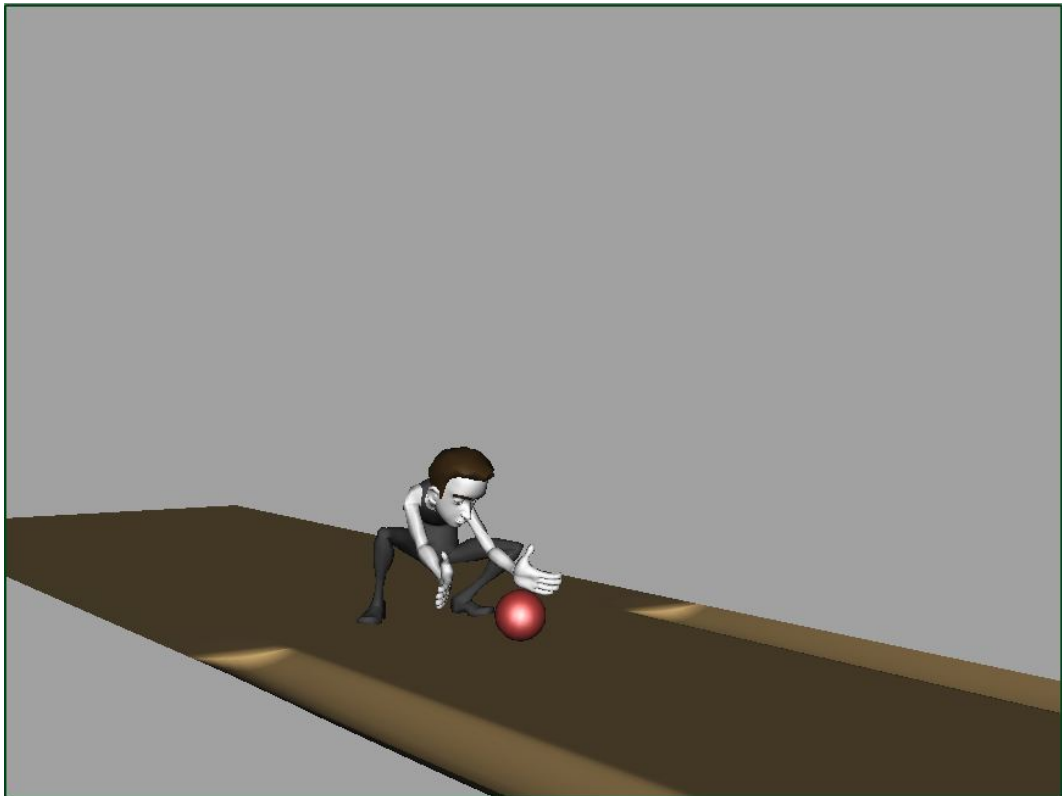
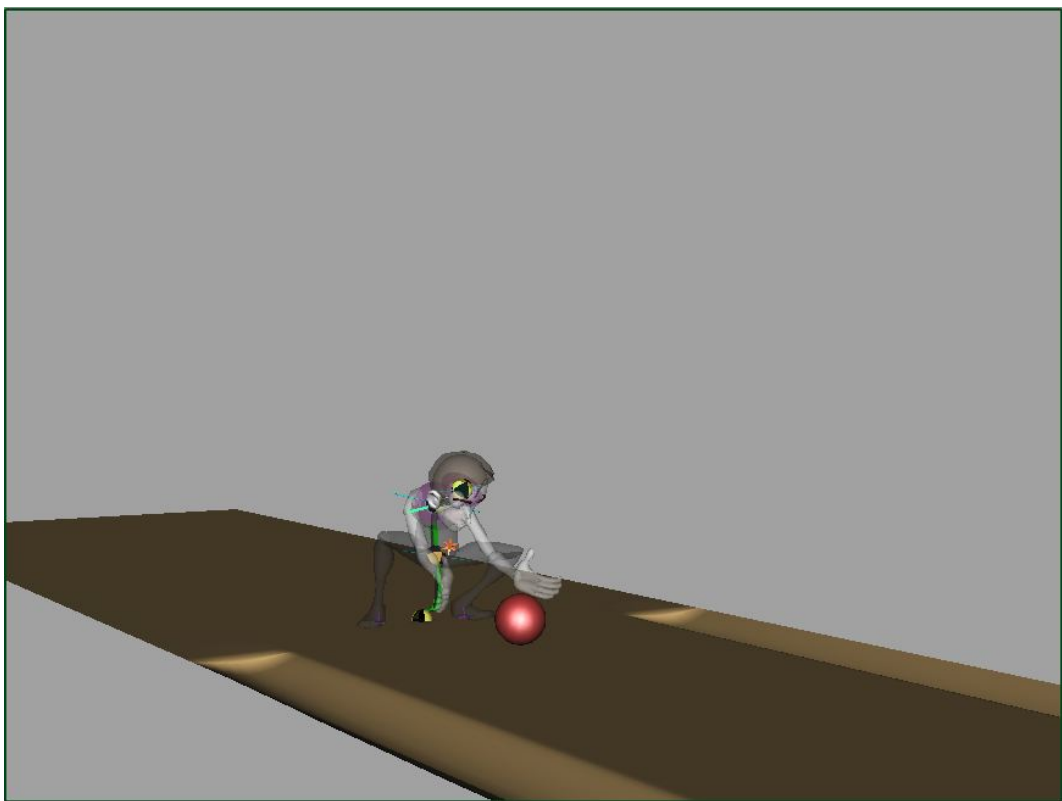6.2
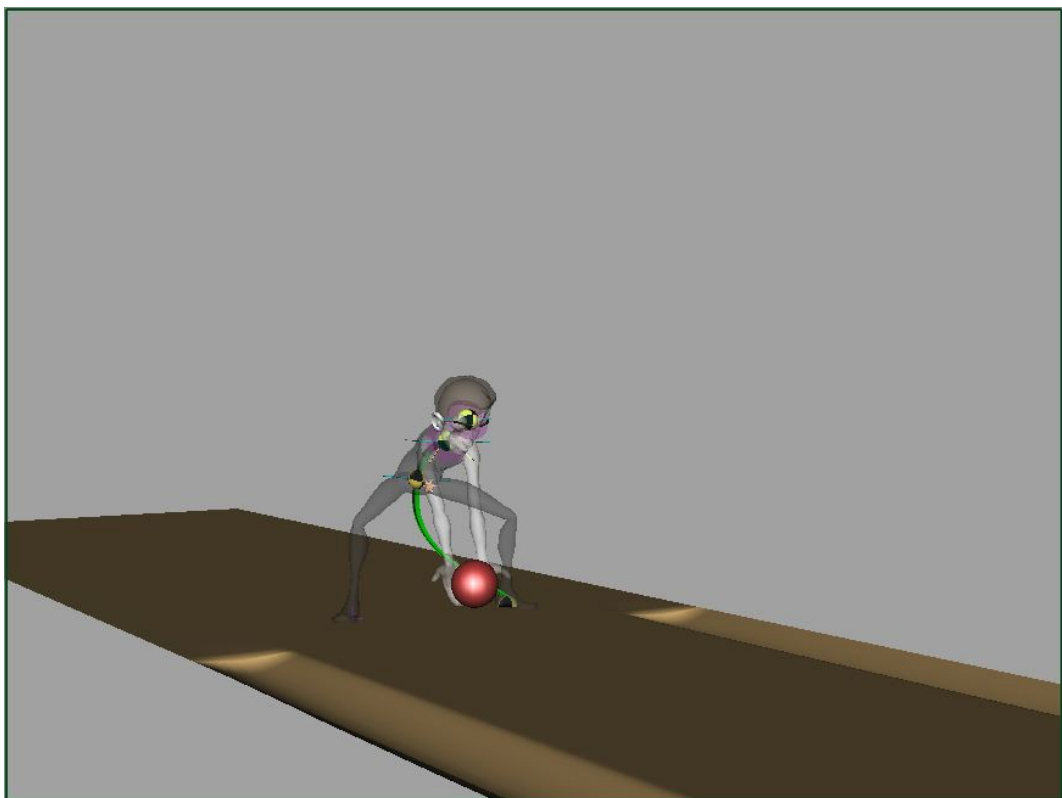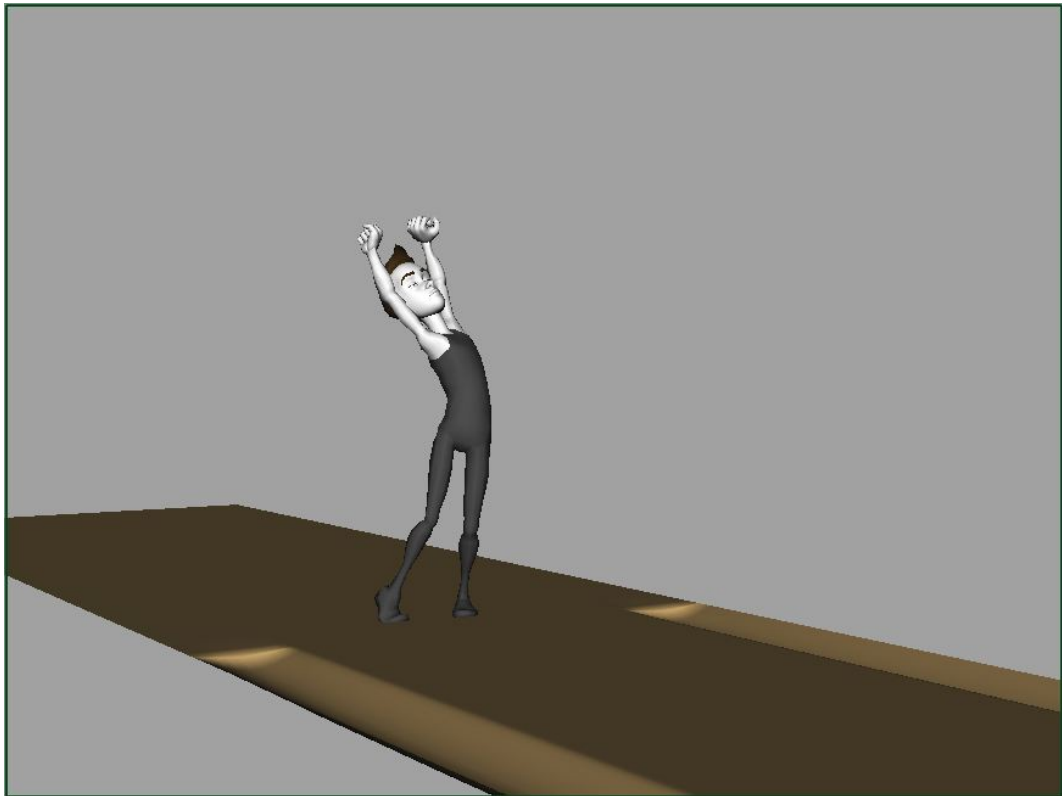

6.2, with 3D Pose Tool.
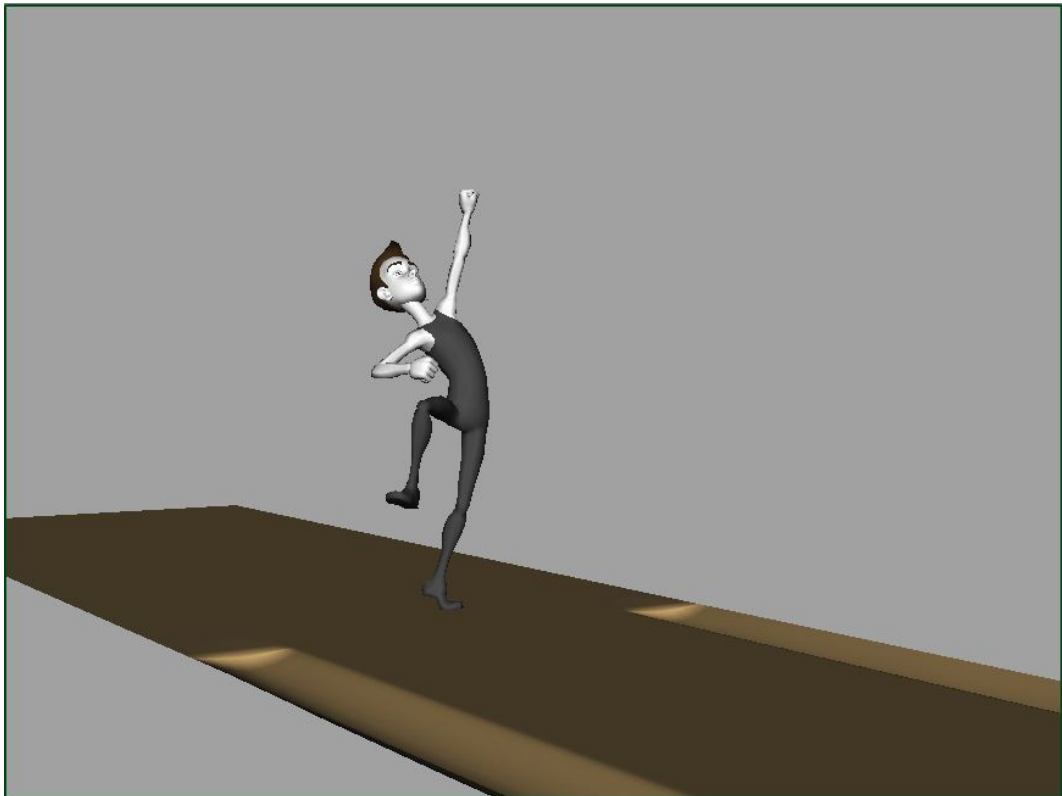
6.3
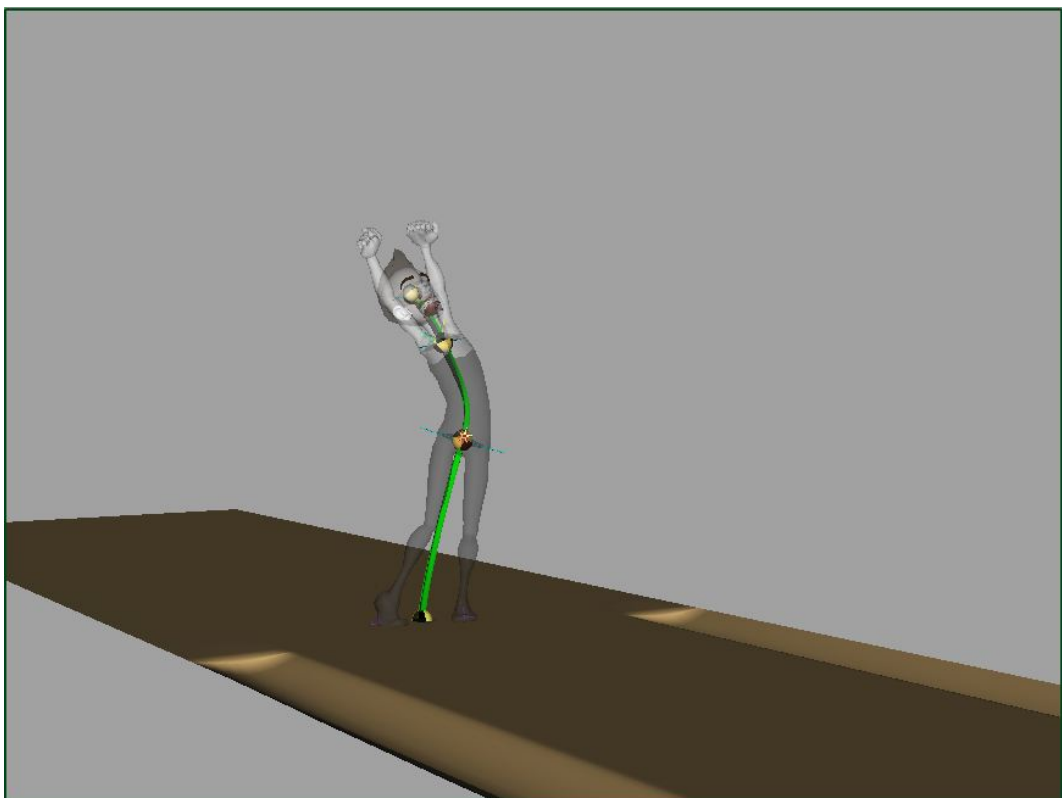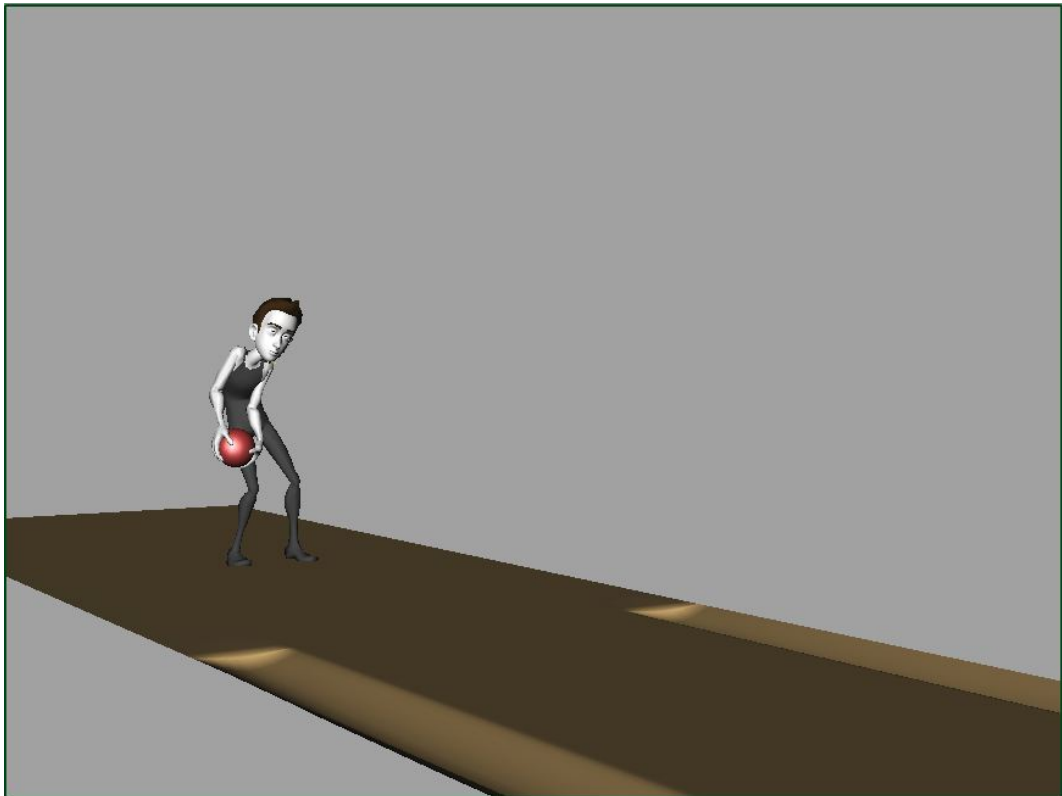

6.3, with 3D Pose Tool.
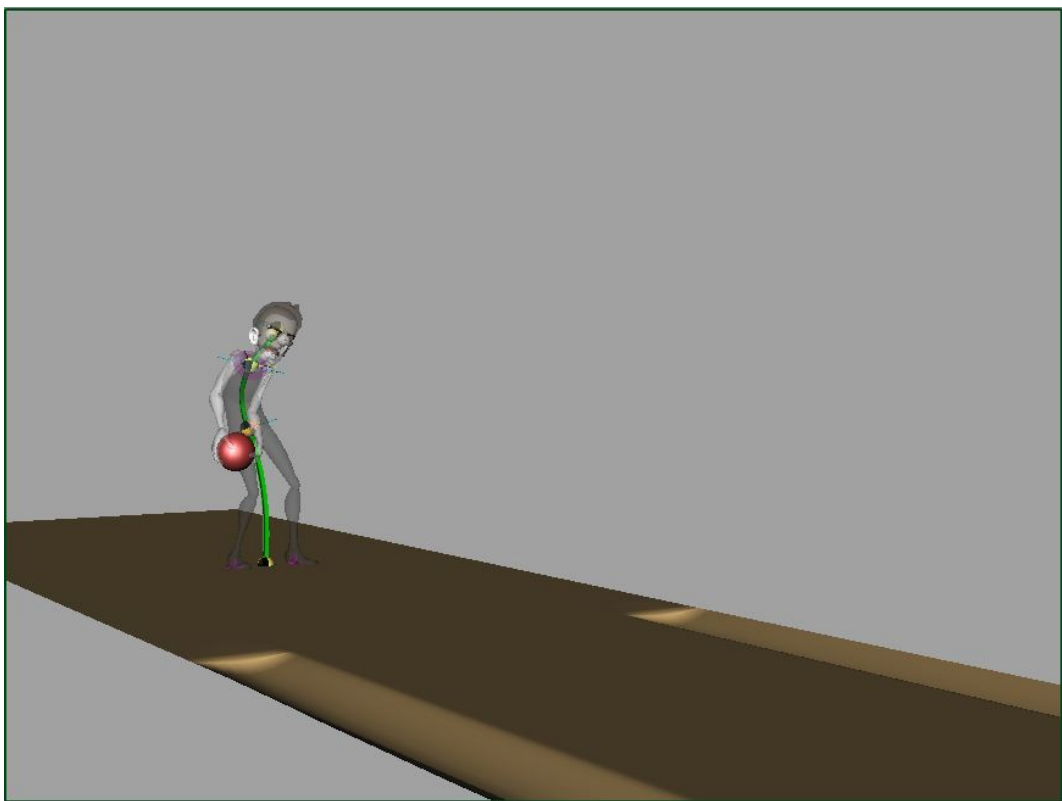
7.1

7.1, with 3D Pose Tool.
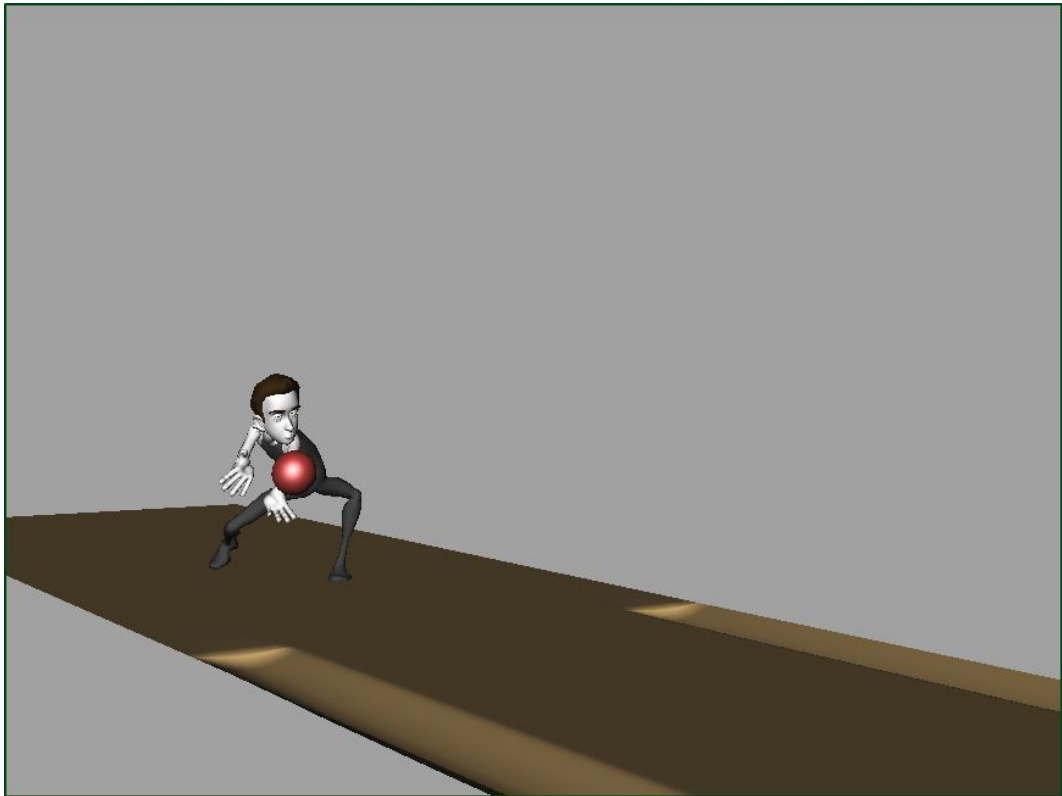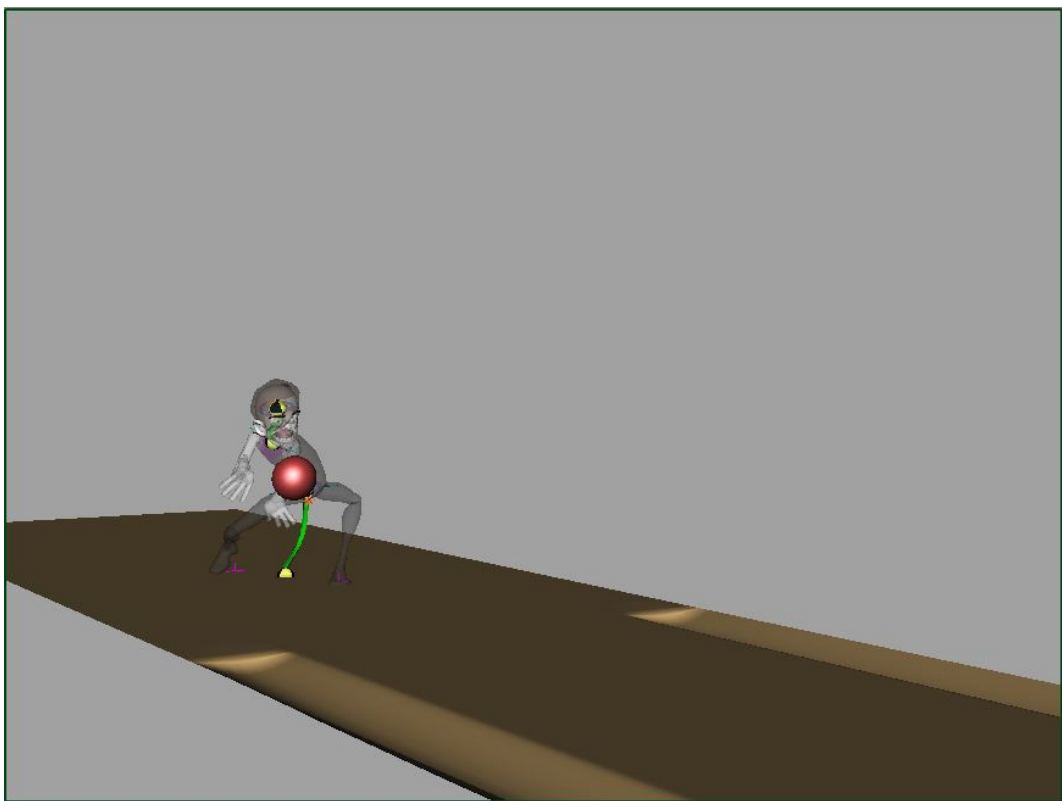
7.2

7.2, with 3D Pose Tool.
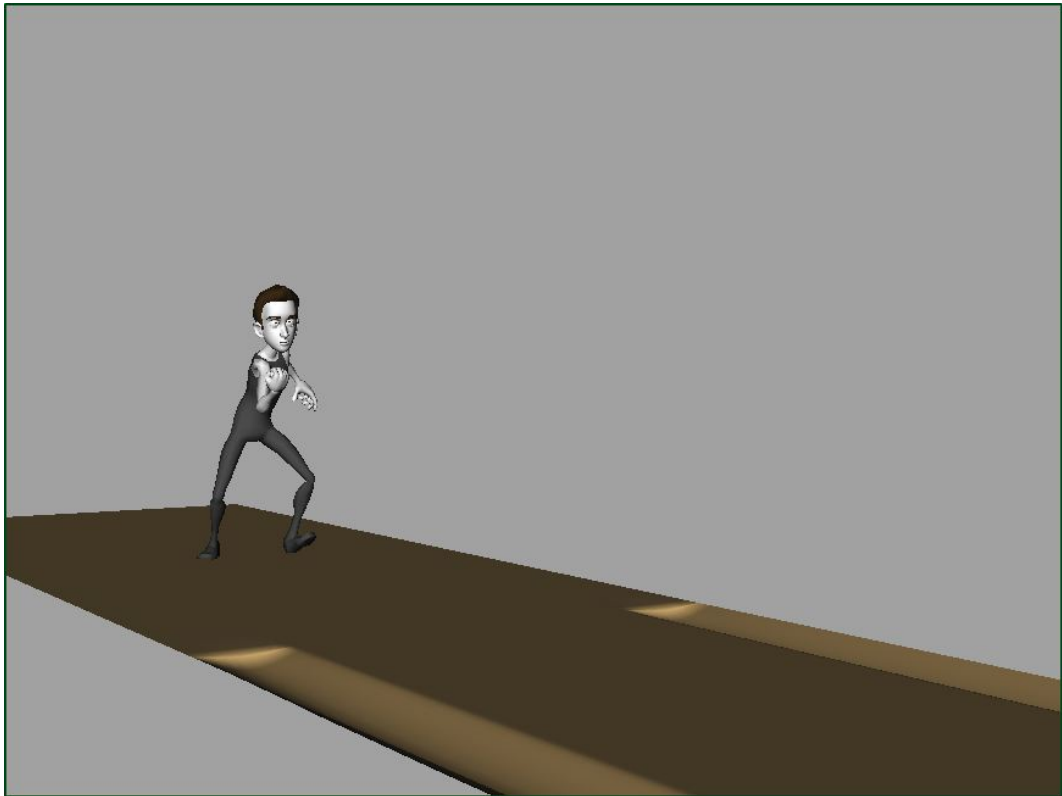
7.3

7.3, with 3D Pose Tool.
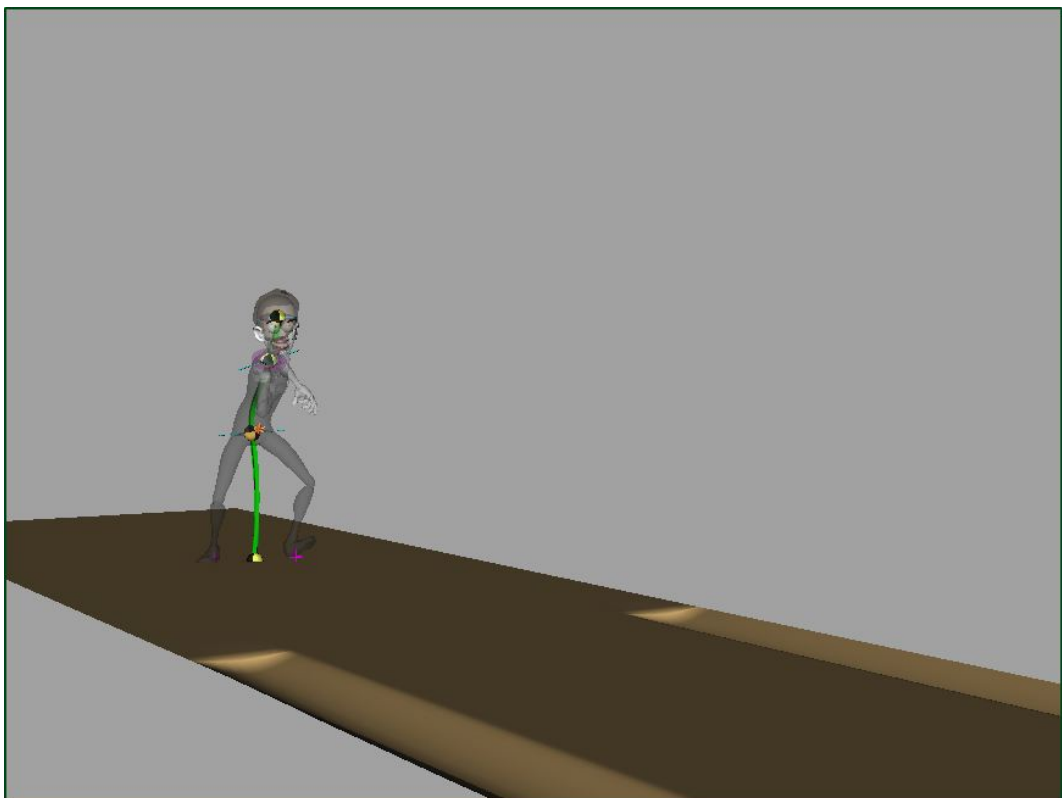
8.1

8.1, with 3D Pose Tool.

8.2

8.2, with 3D Pose Tool.

8.3

8.3, with Pose Tool.

G3 - Answers to the questionnaire

Section 1 (About the participants' approach to posing)

Questions	Answers			
	Participant A	**Participant B**	**Participant C**	**Participant D**
1.1 - What are your main concerns in the process of creating a pose, and how important do you think it is to achieve a good pose?	Poses which have decent silhouettes and a relatively strong basis and relevance to reality can add an immediate professionalism and intrigue to an animated sequence.	I think it's highly essential to my animation to create good poses so, I approach it meticulously. I convey weight, balance, line of action and silhouette – my concern is that all of these are readable.	It is vital to create the key poses. Making sure the silhouette is readable from the desired angle.	Mesh deformation in terms of natural looking expression. Does the pose look like a human could do it? Does it express the emotion I want?
1.2 - Are there any specific concepts that you follow when creating a pose?	Usually I approach this by trial and error, and eventually I find a right direction.	All my poses need to be readable and expressive, and also dynamic. They should capture the emotion of the scene.	I try and follow the principles of animation; silhouettes, arcs. I try and capture the characters personality/mood while posing.	Not really, no.
1.3 - What is the workflow of your approach, while posing?	I try basing my pose on real life reference materials. And then teak it and exaggerate it so it departs from reality more – while keeping the substance – until an interesting pose is created.	I look at reference and act out the action and pay attention to what my body is doing in different angles. I draw thumbnails to get right silhouette and line of action.	I start with the hips, then torso and legs then arms, hands, feet and head (can vary depending on the pose).	Stand in position and look at how my body is working that pose.
1.4 - Which part of the body do you manipulate first, secondly, etc.?	I tend to manipulate the torso and arms, because I think they are the most expressive, and then the legs.	I start with the centre of gravity and the spine, which is ESSENTIAL for good posing! The head/eyes secondly, then I look at the legs for weight and arcs then the arms.	Hips, torso, head, feet, arms, hands.	Feet -> hips -> claws/shoulders/ -> arms -> hands -> neck -> head -> TWEAKS (everything).
2. Would you say that your approach is unique or is it similar to the one your colleagues and friends use?	My approach is not unique, in fact I don't think it is as professional or academic.	I draw a lot more meticulously than my colleagues –> a lot of animations are really reference-based stuff, I don't like this. I draw all my poses and try to really push the emotion.	Pretty similar.	Fairly standard?
3. Do you use that approach because you consider it is the one which allows you to get better results or/and because it is the only one you know?	It is definitely a way which works for me provided that I am not an animation specialist. I suppose there are other better ways.	Because it gets the best results. Dynamic, expressive posing for me is so much better than straight-ahead animation. You need to understand the character.	Only one I know. It can give good results but I tend to re-tweak poses which slows me down.	I can animate quickly this way.

Section 2 (Opinion about the new approach to posing)

Questions	Answers			
	Participant A	**Participant B**	**Participant C**	**Participant D**
1. What do you think of the proposed new posing approach? Do you find it useful?	I think it helps with the initial blocking a lot. Being able to see the line of action is great.	I find the new posing approach very useful. It's very helpful visual feedback and it got me thinking specifically about how the shoulders and hips are working.	It was a very useful reminder of the principals of animation.	I find it very helpful. It is a good learning tool and a decent reminder of the basic principles.
2. Does it help you to get more expressive poses?	Yes, it allows me to ensure the body sits in a dynamic position.	I feel that it was a lot easier to quickly get more expressive poses using the tool.	It helped remember to exaggerate the poses. I found that it changed how I initially wanted the pose, there has to be a balance between the two.	It didn't particularly make the poses more expressive, but it helped to correct certain curvatures of the shape of the characters in some camera angles.
3. Does it make it easier/faster for you to create the poses?	Easier but no faster. Maybe faster actually... It makes it easier to know when I've got a good line.	I created the poses in the second exercise about twice as fast as in the first exercise. It was a very useful and improved method of thinking.	Yes, it gives a better visual reference.	It took longer because the tool shows me what I have not done correctly which means I spend more time amending them.
4. What are the virtues of the visual tool/3D Pose Tool?	Seeing the line of action react to the posing of a character.	It helped me to immediately develop strong line of action and sensible balance in my poses.	It is a very good visual reference.	Simple and straight forward visualization, especially coloured visualization.
5. What are the flaws of the visual tool/3D Pose Tool?	?	It would be easier with the final version where the control manipulates the rig, but as visual feedback the tool works fantastically.	Hard to see through the control...	Slightly decrease in performance, also needs "Xray" visualization.
6. Are there any features that you think would be useful to have?	Additional lines for arm movement.	I'd like to be able to switch between active/inactive so the tool drives the rig, and can be switched just to a visual tool as well.	Adapt it so that the line has controls which influence the rig.	Not off the top of my head. It's a helpful tool, at the very least for beginners, amateurs.

H - Permission for using Morpheus character

Jose Fonseca

From:	Josh Burton <jjburton@gmail.com>
Sent:	26 February 2013 18:44
To:	Jose Fonseca
Cc:	Jian Jun Zhang; Ari Sarafopoulos
Subject:	Re: Morpheus

Yup. :)

Here's a link to permission:
http://keyframeco-
op.com/CGM/Question/View/70/Can+I+use+Morpheus+1.0+for+commercial+work+or+other+things

Best,
-j

-Josh Burton
www.cgmonks.com

On Tue, Feb 26, 2013 at 12:29 PM, Jose Fonseca <jfonseca@bournemouth.ac.uk> wrote:

Hi, Josh.

I am a PhD student at NCCA (National Centre for Computer Animation) – Bournemouth University, UK, and my research is focused on a new posing approach to 3D character animation. I need to conduct some tests of my hypothesis with two groups of students of the animation course at this university and they seem to be very familiar with your rig. Thus, I would like to have your permission to use your Morpheus Rig v1.0 in those sessions and also to use some pictures of the resulting character poses in my written thesis.

In case you need to confirm this, my first supervisor is Prof. Jian Zhang (e-mail: jzhang@bournemouth.ac.uk) and my second supervisor is Anargyros Sarafopoulos (e-mail: asarafop@bournemouth.ac.uk).

I would appreciate your reply.

Best regards,

Jose Fonseca

Phone: 01202 62247

Tolpuddle Annexe 2 - Room TA120
NCCA - Bournemouth University
Talbot Campus, Fern Barrow
Poole, Dorset
BH12 5BB, UK

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I - 3D Character – Nguy

This 3D character was created with a stylized and minimalist human body form and a face without eyes and mouth (see Figure 110), as if he was wearing a mask. The idea is that the impossibility of facial expression emphasizes the need for the animator to consider the whole body when creating the poses, following the rationale pointed out by Lecoq (2009, p. 54) who stated that wearing a mask delegates to the body the job of expressing essential attitudes. For the same reason, the fingers (except the thumb) are fused to each other, to avoid the temptation to animate them individually.

a   b
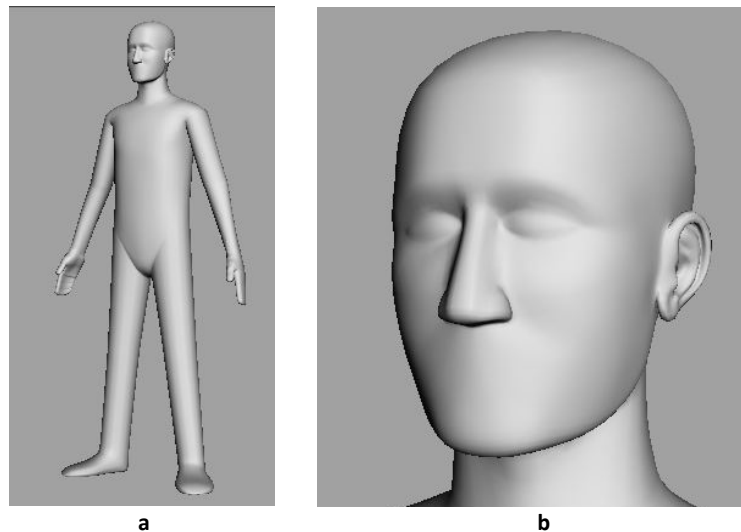
Figure 110 – 3D Character (a) and head detail (b).

The character setup (also known as character rigging) was created using the Autodesk HumanIK rig solution included in Maya, as described in section 4.5.

The purpose of creating this 3D character – NGuy – was to be used to illustrate the examples of poses discussed in this thesis and in the Posing Experiment, as well. However, since the participants in the experiment (animation students) were familiar with another rig – Morpheus Rig – which includes its own character, and had been used by them in their animation classes, it was later decided to use the same, in order not to introduce another conditioning variable to the experiment.

J - Body planes

Anatomy planes, with NGuy.
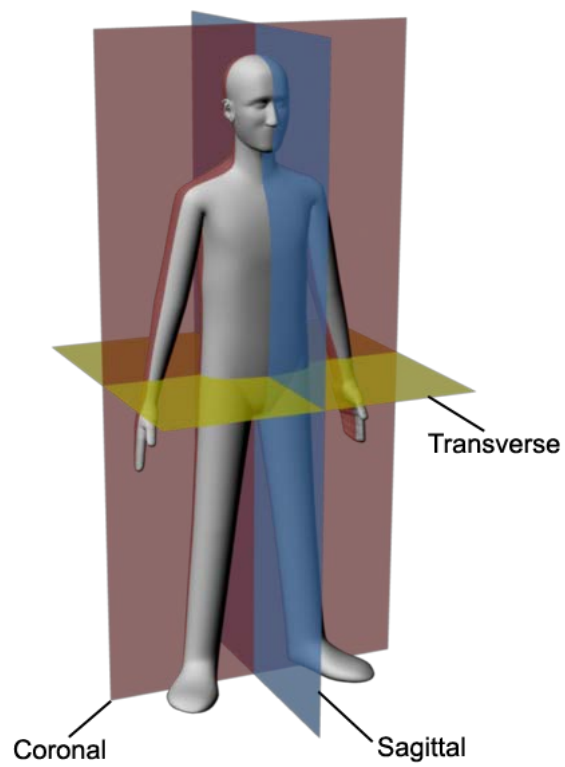
Annexes

Developed MEL scripts for Autodesk Maya, by D. Kravtsov (personal communications)

To activate the NGuy character's *X-ray* display

```
string $_shapesPose[]={"NGuy_Body_smoothShape"};
for ($shp in $_shapesPose)
{
  displaySurface -xRay 1 $shp;
}
```

To deactivate the NGuy character's *X-ray* display

```
string $_shapesPose[]={"NGuy_Body_smoothShape"};
for ($shp in $_shapesPose)
{
  displaySurface -xRay 0 $shp;
}
```

To activate the Morpheus character's *X-ray* display

```
string
$_shapesPose[]={"hand_right_geoShape","hand_left_geoShape","Head_geoShape","hair_bigShape
","eye_left_geoShape","eye_right_geoShape","tongue_geoShape","lwrSepTeeth_geoShape","uprS
epTeeth_geoShape","body_geoShape"};
for ($shp in $_shapesPose)
{
  displaySurface -xRay 1 $shp;
}
```

To deactivate the Morpheus character's *X-ray* display

```
string
$_shapesPose[]={"hand_right_geoShape","hand_left_geoShape","Head_geoShape","hair_bigShape
","eye_left_geoShape","eye_right_geoShape","tongue_geoShape","lwrSepTeeth_geoShape","uprS
epTeeth_geoShape","body_geoShape"};
for ($shp in $_shapesPose)
{
    displaySurface -xRay 0 $shp;
}
```

To change the colour of the segments of the tube (*expression cord*).

For segment 1:

```
$x_b = PT_ball_Bottom.translateX;
$x_p = PT_ball_Pelvis.translateX;

$z_b = PT_ball_Bottom.translateZ;
$z_p = PT_ball_Pelvis.translateZ;

$rx_b = PT_ball_Bottom.rotateX;
$rx_p = PT_ball_Pelvis.rotateX;

$rz_b = PT_ball_Bottom.rotateZ;
$rz_p = PT_ball_Pelvis.rotateZ;

$ry_b = PT_ball_Bottom.rotateY;
$ry_p = PT_ball_Pelvis.rotateY;

$dx = abs($x_b-$x_p);
$dz = abs($z_b-$z_p);

$drx = abs($rx_b-$rx_p);
$drz = abs($rz_b-$rz_p);

$dry = abs($ry_b-$ry_p);

$epsilon = 0.001;

$bdx = $dx > $epsilon;
$bdz = $dz > $epsilon;

$bdrx = $drx > $epsilon;
$bdrz = $drz > $epsilon;
$bdry = $dry > $epsilon;
```

```
$bdt = min($bdx+$bdz, 1);
$bdr = min($bdrx+$bdrz, 1);

$dif_num = $bdt + $bdr + $bdry;

if ($dif_num >= 3) {
        PT_TubeColour_section1.colorR = 0;
        PT_TubeColour_section1.colorG = 1;
        PT_TubeColour_section1.colorB = 0;
} else if ($dif_num == 2) {
        PT_TubeColour_section1.colorR = 1;
        PT_TubeColour_section1.colorG = 1;
        PT_TubeColour_section1.colorB = 0;
} else if ($dif_num == 1) {
        PT_TubeColour_section1.colorR = 1;
        PT_TubeColour_section1.colorG = 0.5;
        PT_TubeColour_section1.colorB = 0;
}  else if ($dif_num == 0) {
        PT_TubeColour_section1.colorR = 1;
        PT_TubeColour_section1.colorG = 0;
        PT_TubeColour_section1.colorB = 0;
}
```

For segment 2:

```
$x_b = PT_ball_TorsoTop.translateX;
$x_p = PT_ball_Pelvis.translateX;

$z_b = PT_ball_TorsoTop.translateZ;
$z_p = PT_ball_Pelvis.translateZ;

$rx_b = PT_ball_TorsoTop.rotateX;
$rx_p = PT_ball_Pelvis.rotateX;

$rz_b = PT_ball_TorsoTop.rotateZ;
$rz_p = PT_ball_Pelvis.rotateZ;

$ry_b = PT_ball_TorsoTop.rotateY;
$ry_p = PT_ball_Pelvis.rotateY;

$dx = abs($x_b-$x_p);
$dz = abs($z_b-$z_p);

$drx = abs($rx_b-$rx_p);
$drz = abs($rz_b-$rz_p);
$dry = abs($ry_b-$ry_p);

$epsilon = 0.001;

$bdx = $dx > $epsilon;
```

```
$bdz = $dz > $epsilon;

$bdrx = $drx > $epsilon;
$bdrz = $drz > $epsilon;
$bdry = $dry > $epsilon;

$bdt = min($bdx+$bdz, 1);
$bdr = min($bdrx+$bdrz, 1);

$dif_num = $bdt + $bdr + $bdry;

if ($dif_num >= 3) {
        PT_TubeColour_section2.colorR = 0;
        PT_TubeColour_section2.colorG = 1;
        PT_TubeColour_section2.colorB = 0;
} else if ($dif_num == 2) {
        PT_TubeColour_section2.colorR = 1;
        PT_TubeColour_section2.colorG = 1;
        PT_TubeColour_section2.colorB = 0;
} else if ($dif_num == 1) {
        PT_TubeColour_section2.colorR = 1;
        PT_TubeColour_section2.colorG = 0.5;
        PT_TubeColour_section2.colorB = 0;
} else if ($dif_num == 0) {
        PT_TubeColour_section2.colorR = 1;
        PT_TubeColour_section2.colorG = 0;
        PT_TubeColour_section2.colorB = 0;
}
```

For segment 3:

```
$x_b = PT_ball_Head.translateX;
$x_p = PT_ball_Pelvis.translateX;

$z_b = PT_ball_Head.translateZ;
$z_p = PT_ball_Pelvis.translateZ;

$rx_b = PT_ball_Head.rotateX;
$rx_p = PT_ball_Pelvis.rotateX;

$rz_b = PT_ball_Head.rotateZ;
$rz_p = PT_ball_Pelvis.rotateZ;

$ry_b = PT_ball_Head.rotateY;
$ry_p = PT_ball_Pelvis.rotateY;

$dx = abs($x_b-$x_p);
$dz = abs($z_b-$z_p);

$drx = abs($rx_b-$rx_p);
```

```
$drz = abs($rz_b-$rz_p);
$dry = abs($ry_b-$ry_p);

$epsilon = 0.001;

$bdx = $dx > $epsilon;
$bdz = $dz > $epsilon;

$bdrx = $drx > $epsilon;
$bdrz = $drz > $epsilon;
$bdry = $dry > $epsilon;

$bdt = min($bdx+$bdz, 1);
$bdr = min($bdrx+$bdrz, 1);

$dif_num = $bdt + $bdr + $bdry;

if ($dif_num >= 3) {
        PT_TubeColour_section3.colorR = 0;
        PT_TubeColour_section3.colorG = 1;
        PT_TubeColour_section3.colorB = 0;
} else if ($dif_num == 2) {
        PT_TubeColour_section3.colorR = 1;
        PT_TubeColour_section3.colorG = 1;
        PT_TubeColour_section3.colorB = 0;
} else if ($dif_num == 1) {
        PT_TubeColour_section3.colorR = 1;
        PT_TubeColour_section3.colorG = 0.5;
        PT_TubeColour_section3.colorB = 0;
}  else if ($dif_num == 0) {
        PT_TubeColour_section3.colorR = 1;
        PT_TubeColour_section3.colorG = 0;
        PT_TubeColour_section3.colorB = 0;
}
```

To show user interface/Plugin (still work in progress)

```
global string  $windowName;
global int     $newSceneJobId;

string $rigName;

string $rigCtrl;
string $headCtrl;
string $torsoCtrl;
string $pelvisCtrl;
string $footleftCtrl;
string $footrightCtrl;
string $rigName;
```

```
global proc int deleteWindow()
{
  global string  $windowName;
  global int     $newSceneJobId;

  int $res = `window -exists $windowName`;

  if ($res == true) {
    // we've already got the window, recreate it
    deleteUI $windowName;
  } else {

    // this script job recreates window (if it was opened) after new scene is loaded
    if ($newSceneJobId < 1) {
      $newSceneJobId = `scriptJob -e "NewSceneOpened" "resetWindow(false);"`;
      scriptJob -e "SceneOpened" "resetWindow(false);";
    }
  }

  return $res;
}

global proc resetWindow(int $forceCreate)
{
  if (deleteWindow() == true || $forceCreate == true) {
    // window existed, so recreate it
    createPoseUI();
    print("window recreated\n");
  } else {
    print("No window existed\n");
  }
}

global proc connectThruScale(string $parent ,string $sel)
{
  global string $rigName;

  $mulNode = `shadingNode -asUtility multiplyDivide`;
  setAttr ($mulNode+".operation") 2;

  $scaleAttr = ($rigName+".globalScale");

  connectAttr ($parent+".translate") ($mulNode+".input1");
  connectAttr $scaleAttr ($mulNode+".input2X");
  connectAttr $scaleAttr ($mulNode+".input2Y");
  connectAttr $scaleAttr ($mulNode+".input2Z");

  connectAttr ($mulNode + ".output") ($sel+".translate");
}


global proc selectPoseComponent(string $comp)
```

```
{
  $sels = `ls -selection`;

  global string $rigName;

  global string $windowName;
  global string $rigCtrl;
  global string $mainCtrl;
  global string $headCtrl;
  global string $torsoCtrl;
  global string $pelvisCtrl;
  global string $footleftCtrl;
  global string $footrightCtrl;

  if (size($sels) != 1) {
    error("Choose one object only! Currently " +size($sels)+" selected.");
    return;
  }

  $sel = $sels[0];
  eval("textFieldButtonGrp -edit -text \"" + $sel + "\" $" + tolower($comp)+"Ctrl");

  print("Sel: "+$sel+"\n");

  // TODO:
  /*
    driverGrp - "listAttr MRig_StudentV2:rig_spine_0_skin_Shoulders_anim" any attr after "driverGrp"
  */

  if ($comp == "Rig") {
    print "Rig selected";
    $rigName = $sel;

  } else if ($comp == "Main") {
    parent $sel "PoseTool_MainCtrl";
    print("Parenting "+$sel + " to PoseTool_MainCtrl" );

  } else if ($comp == "Head") {
    //parent
    print("Parenting "+$sel + " to PT_ball_Head" );

    $mulNode = `shadingNode -asUtility multiplyDivide`;
    setAttr ($mulNode+".operation") 2;

    $scaleAttr = ($rigName+".globalScale");

    connectAttr "PT_ball_Head.translate" ($mulNode+".input1");
    connectAttr $scaleAttr ($mulNode+".input2X");
    connectAttr $scaleAttr ($mulNode+".input2Y");
    connectAttr $scaleAttr ($mulNode+".input2Z");

    connectAttr ($mulNode + ".output") ($sel+".translate");
```

```
} else if ($comp == "Torso") {

  $infoNode = `createNode unknown`;
  addAttr -shortName gs -longName globalScale -defaultValue 0.01 $infoNode;

  $mulNode = `shadingNode -asUtility multiplyDivide`;
  setAttr ($mulNode+".operation") 2;

  $scaleAttr = ($rigName+".globalScale");

  connectAttr "PT_ball_TorsoTop.translate" ($mulNode+".input1");
  connectAttr $scaleAttr ($mulNode+".input2X");
  connectAttr $scaleAttr ($mulNode+".input2Y");
  connectAttr $scaleAttr ($mulNode+".input2Z");
  connectAttr ($mulNode + ".output") ($sel+".translate");

  print("Parenting "+$sel + " to PT_ball_TorsoTop" );


} else if ($comp == "Pelvis") {

  connectThruScale("PT_ball_Pelvis", $sel);
  print("Parenting "+$sel + " to PT_ball_Pelvis" );

} else if ($comp == "FootLeft") {

  connectThruScale("PT_FootLeft", $sel);
  print("Parenting "+$sel + " to PT_FootLeft" );

} else if ($comp == "FootRight") {
  connectThruScale("PT_FootRight", $sel);
  print("Parenting "+$sel + " to PT_FootRight" );

} else {
  print("Incorrect component '"+$comp+"' requested");
  return;
}

print("\n");

}

global proc performPoseSetup()
{
  print("Pose setup is being performed");

}

global proc createPoseUI()
{
  global string $windowName;
  global string $rigCtrl;
```

```
global string $mainCtrl;
global string $headCtrl;
global string $torsoCtrl;
global string $pelvisCtrl;
global string $footleftCtrl;
global string $footrightCtrl;

deleteWindow();

 $windowName = `window -title "3D Pose Tool" -rtf on`;

// Head, Top Torso/Chest, Pelvis, Right foot, Left Foot


string $columnLayout = `columnLayout -columnWidth 100  -p $windowName`;

  rowLayout -numberOfColumns 1 -columnWidth2 285 40;

    $rigCtrl = `textFieldButtonGrp -label "Rig" -text "" -columnWidth3 100 140 40 -editable false
          -buttonCommand "selectPoseComponent(\"Rig\");" -buttonLabel "Select"
          -annotation "Main character rig"`;

  setParent ..;

  rowLayout -numberOfColumns 1 -columnWidth2 285 40;

    $mainCtrl = `textFieldButtonGrp -label "Main" -text "" -columnWidth3 100 140 40 -editable false
          -buttonCommand "selectPoseComponent(\"Main\");" -buttonLabel "Select"
          -annotation "Help coming later"`;

  setParent ..;

  rowLayout -numberOfColumns 1 -columnWidth2 285 40;

    $headCtrl = `textFieldButtonGrp -label "Head" -text "" -columnWidth3 100 140 40 -editable false
          -buttonCommand "selectPoseComponent(\"Head\");" -buttonLabel "Select"
          -annotation "Help coming later"`;
  setParent ..;

  rowLayout -numberOfColumns 1 -columnWidth2 285 40;

    $torsoCtrl = `textFieldButtonGrp -label "Torso/Chest" -text "" -columnWidth3 100 140 40 -
editable false
          -buttonCommand "selectPoseComponent(\"Torso\");" -buttonLabel "Select"
          -annotation "Help coming later"`;
  setParent ..;

  rowLayout -numberOfColumns 1 -columnWidth2 285 40;

    $pelvisCtrl = `textFieldButtonGrp -label "Pelvis/Hips" -text "" -columnWidth3 100 140 40 -
editable false
```

```
            -buttonCommand "selectPoseComponent(\"Pelvis\");" -buttonLabel "Select"
            -annotation "Help coming later"`;
    setParent ..;

    rowLayout -numberOfColumns 1 -columnWidth2 285 40;

        $footleftCtrl = `textFieldButtonGrp -label "Left Foot" -text "" -columnWidth3 100 140 40 -editable
false
            -buttonCommand "selectPoseComponent(\"FootLeft\");" -buttonLabel "Select"
            -annotation "Help coming later"`;
    setParent ..;

    rowLayout -numberOfColumns 1 -columnWidth2 285 40;

        $footrightCtrl = `textFieldButtonGrp -label "Right Foot" -text "" -columnWidth3 100 140 40 -
editable false
            -buttonCommand "selectPoseComponent(\"FootRight\");" -buttonLabel "Select"
            -annotation "Help coming later"`;
    setParent ..;

    rowLayout -numberOfColumns 1 -columnWidth2 285 40;

        button   -label "Apply" -width 50 -command "performPoseSetup()"
            -ann "Help coming later";

    setParent ..;

  setParent ..;



  // parent child child parent

  showWindow $windowName;
}

//string $parentMode = "normal";
string $parentMode = "reverse";
string $connMode = "translate";

global proc parentIt(string $obj1, string $obj2)
{
  global string $parentMode;
  global string $connMode;
  global string $rigName;


  if ($parentMode == "reverse") {

    //connectAttr ($obj1+".translate") ($obj2+".translate");
    //parentConstraint -mo -weight 1;
    parentConstraint -mo -weight 1 $obj2 $obj1;
  } else {
```

```
    connectAttr ($obj2+".translate") ($obj1+".translate");
  }

}

global proc parentFeet(string $obj1, string $obj2)
{
  global string $parentMode;
  global string $connMode;
  global string $rigName;

  if ($parentMode == "reverse") {
    //connectAttr ($obj1+".translate") ($obj2+".translate");
    //parentConstraint -mo -weight 1;
    pointConstraint -offset 0 0 0 -skip y -skip z -weight 1 $obj2 $obj1;
    parentConstraint -mo -skipTranslate x -weight 1 $obj2 $obj1;
  } else {
    connectAttr ($obj2+".translate") ($obj1+".translate");
  }

}
```