

# Canon and Process in the 3D modelling of Human Anatomy

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## ABSTRACT

The authors argue that the concept of the anatomical canon is not just an arbitrary standard of anatomical beauty but an indispensable mnemonic tool for the artist. The authors further argue that the canon is most relevant when adapted to a specific artistic process and tools, and in particular must be updated to the requirements of the digital tools of 3D modeling. A proposal of such a canon is discussed, as well as the process of its synthesis from standard 3D primitives and its artistic applications.

## INTRODUCTION

How to draw the human figure? The trite answer, much in vogue in the hands-off school of drawing instructors, is “just draw what you see”. This is good enough advice for amateurs who may use art for purposes ranging from amusement to therapy, and there is nothing wrong with that. But even skin deep reflection will show that we have no clear concept of what we see, nor how to translate what is seen to what is drawn. All it takes is a peek at the optical illusions of anamorphosis (Araújo, 2020) to make sure of that. The fact is that there is no clear road from the object to the visual brain and certainly no straight road from eye to hand. There are several attempts in the literature at codifying what “drawing what we see” might mean. One who enjoys favor in art schools is the method of Nicolaides, who equates seeing with a sort of phantom touching, a sort of trick of proprioception. It is a method with great charm, but to call it “The” natural way to draw, as Nicolaides does in the title of his book (Nicolaides, 1990), is going too far. “Natural for what” is the question. The illustrator who must draw to tight requirements will not be using that method. Not touch, but geometry, subdivision, analysis, measurement, will be his tools. In short, there are many “natural” ways to draw, just as many as there are purposes for drawing. Some types of drawing require that you draw what you see (in some sense), some require that you draw *what you know*.

So today, as ever, the artist who must draw or sculpt *to spec* must *know*. And so it is in particular with drawing or sculpting the human figure. And in that field a great hurdle of learning is the understanding of the high volume of information on human anatomy (Eaton, 2006). The knowledge of the human body has been mostly acquired by anatomical exploration (Skrzat & Zdilla, 2019), and today this knowledge can be transmitted in more accessible ways than through direct human dissection (Chaker et al., 2021), the digested information embodied in virtual

models. Yet the wide and deep well of detailed, medical anatomical knowledge is hard enough to translate into the specific abstractions required by the artist, which are different than those of the medical doctor. Another “dissection” is required.

The 3D sculptor with his digital tools faces the same problem of the mind as the old masters with their chisels and scopes, because the problem is one of the intellect: the body is incomprehensible when seen as a whole. That is the purpose of the *anatomical canon*.

The canon is today in disfavor in many artistic circles due to its association with the notion of a measurable standard of beauty, and both *beauty* and, dare one say, *standards*, are out of favor. But even without questioning the trend itself, it can be said that dropping the canon over that objection would be throwing the baby out with the bathwater. The canon is not just a standard of anatomical beauty – it is also an anatomical mnemonic (Azevedo & Araújo, 2020). It is a model of the body that above all must be simple enough to keep in the artist’s mind, as a standard against which a real body may be triangulated and measured: upon seeing or conceiving a specific body the artist can ask: are the legs longer, is the chest wider than that of the canon? For we see only by *comparison* to a reference. Without a reference, all is confusion. To complain that the canon does not have the shape or proportions of “real bodies” (whatever that means) is as misguided as to complain that a one meter ruler should not be used for measuring because not all measurable things are one meter long. That’s not how you measure things.

So the canon — and in particular the digital canon — serves both as starting point, and as continuous support and guide during the process of sculpting; it is a compass and a map.

We are not claiming that there is *one* correct canon! The canon is not unique. Every artist could have his own personal canon. But a good, ready-made canon is a useful tool that the artist — sculptor or painter — profits from acquiring at the start of his creative life. The canon carries the experience of more senior artists. Slowly, as time progresses and experience grows, the artist is almost sure to tweak the canon to his own preference, to make in fact his own canon, slowly evolving for the rest of his life. But a start is required. What we propose here is one such canon (or at least a first iteration of one) that is especially fitted to the needs of the digital sculptor.

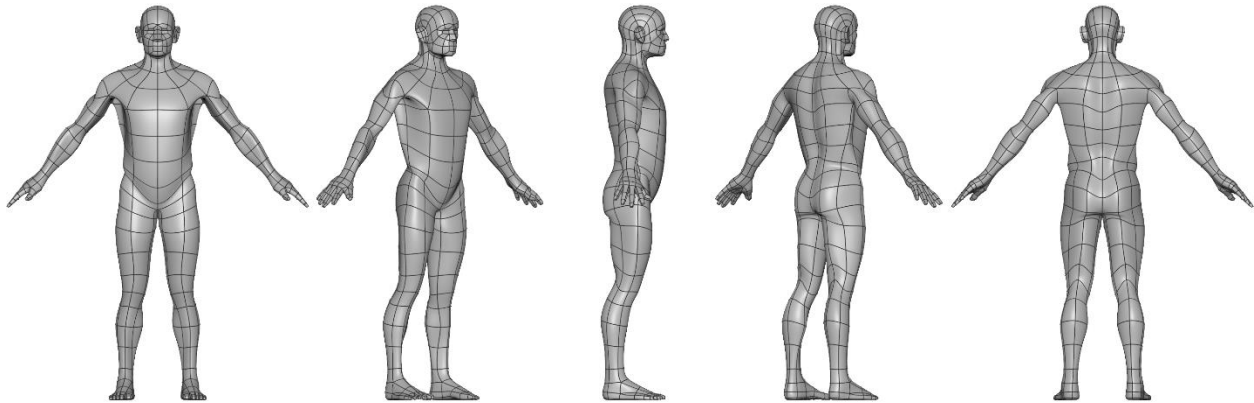
But why can’t the digital sculptor just take one of the canons of the past and be done with it? The canon must adapt to the tools, and digital sculptors face a new problem with their tools: they must specify geometry but also a topology: the geometric surface requires proportions both accurate and simple, so as to be easy to grasp in the mind; the topology — that is, the connectivity of the vertices and edges of the mesh that subdivides the figure — must be both simple and adapted to deforming correctly during the animation process (Lee et al., 2009)(Seo & Magnenat-Thalmann, 2003), that is, a digital canon is necessarily a *dynamical* one.

## **Modeling Approaches**

Simulating the behavior of the human body in an anatomically correct way is a problem of great complexity (Scheepers et al., 1997). In the past few decades, artistic practice has converged on several techniques to model the body in three dimensions. Each technique has its own peculiarities they mostly agree on two important key points: the need for good anatomical reference of the human body, and the use of a skeleton model as a basis for muscle modeling (Briggs, 2018). The 3D model of the human skeleton is currently used in physical simulations of the anatomical structures of animated characters. This approach enables the deformation of a character's body in an anatomically and physically realistic way (Jacobs et al., 2016). However, finding a suitable human skeleton model or modeling one with a correct anatomy and anthropometry is very laborious as even the slightest inaccuracy may render the final result inadequate for the purpose. Garvey (2002) used a method to model the human body that started by creating several circles, positioned and scaled according to the anatomical reference projected in front and side views. At the end, these circles are used to create the surface of the model using NURBS. This method does not present an anatomic topology and it is very difficult to implement on specific areas such as the head and the shoulders, or the hands and feet. With the polygon subdivision technique, Ratner (2003) creates the human model from a cube, by doing multiple geometry subdivisions and extrusions. This approach is complex because it requires numerous operations and uses several modeling tools. In addition, the topology has little anatomical precision, and the model is not suitable for digital sculpting because it does not avoid triangles and has a non-uniform mesh. The method is also complex to implement by the artist because there is no easy way to memorize its construction sequence. Spencer (2010) proposes a method to create a low poly base human model for digital sculpting. This method can be developed using 3D software, such as Maya, Blender, among others. It consists of blocking in the mesh by creating the basic forms and proportions of the human figure, however, the resulting geometry has no anatomical accuracy and the mesh's topology needs to be completely reconstructed within the digital sculpting process.

We propose a new canon that allows the construction of a low poly geometry human model. Our model's resolution increases in such areas where the human body's details are more relevant, (e. g., the face). The topology respects the main features of human anatomy and the traditional edge loops approach for animated geometry deformation (Figure 1).

*Figure 1: Anatomic low poly model.*



## **Premises**

Our proposal has three structural premises, considered fundamental for the artist who intends to model the human body using 3D software, with anatomical accuracy.

1 - Low definition: According to Eaton (2008) the basic geometry of a digital human model must be low definition while preserving the main features of human anatomy. A low poly base mesh allows you to change its shape by moving each single vertex at a time in a simple way. This provides an easy way to shape the critical landmarks and basic contours of the model's anatomy.

2 - Anatomic topology: Base model topology must respect the human anatomy, however, it must be appropriate for the mesh deformation in animation. The model must be made from quads with uniform distribution, in order to achieve correct subdivision in the sculpting process (Eaton, 2006). Polygon edges serve as boundaries to define the muscles of the model.

3 - Anatomic precision: The previous two premises must provide solid structure to achieve anatomic precision. However, the human body cannot be understood only by the observation of its surface. It is necessary to understand the interior and its structural elements recorded in the mind (Gage, 1980). The human anatomic study is an endless process necessary to achieve greater understanding about body mechanics and all its complexity.

## **3D Scanned Reference**

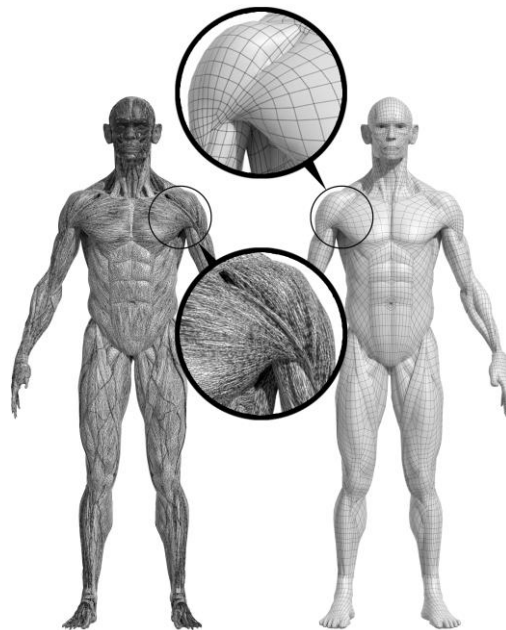
In order to avoid the sort of divergences that might arise from models built merely on aesthetical considerations, we decided from the start to use a detailed human body model as reference. Since our main goal is the adaptation of the anatomical canon to digital practice we decided to start from a safe point, by following historical practice, by adapting the most classic of canons: an adult male, with anthropometric proportions approximately equal to the eight head Greek canon, with an athletic body with relevant muscle mass and no significant body fat. Aside from an appropriate human model for the surface anatomy we also needed a proper skeleton model. 3D scanning would be the obvious way to capture these models. Since 3D scanning was a technical hurdle and not our proper objective, we decided it would be for the best not to waste our efforts on it and rather to use

a ready-made one. We chose one of the TEN24 (*Ten24 – 3D Scanning*, n.d.) scanned models. This model has high poly definition and it is part of a model pack with additional écorché and skeleton models fitted to the human scanned model.

### **Optimized Model**

Using the high-resolution écorché model as reference, a new optimized 3D model was built with a correct topology suitable for human anatomy (Figure 2). This optimization was accompanied by a rigorous analysis of anatomical illustrations (Bourguery & Jacob, 2015)(Schider, 2013). With the conclusion of the optimized model, we have created the digital skeleton using the TEN24 skeleton model as a reference for the joints position. This digital skeleton was made using the standard hierarchy adopted in the film and game industry for the characters creation.

*Figure 2: Original TEN24 écorché model (left) and optimized model (right).*



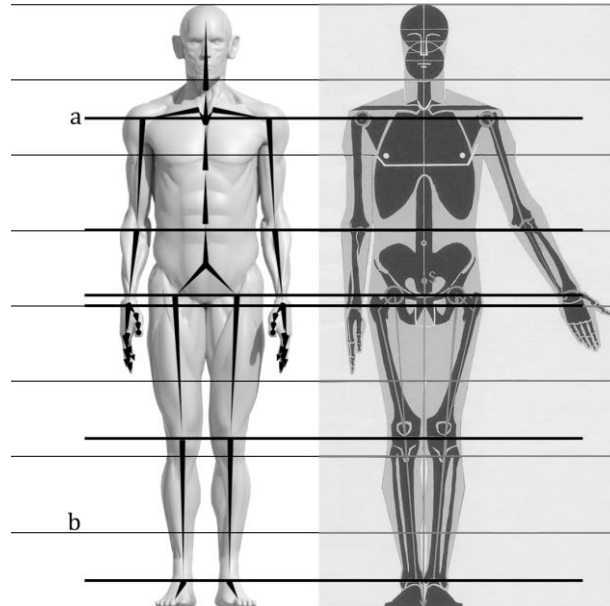
### **Anthropometric Correction**

After the digital skeleton creation along with the skinning process, we were able to move and rotate bones for the purpose of adapting our model to the chosen reference. As already mentioned, we used the eight head Greek canon for an adult individual. This canon was considered by Andrew Loomis (2011) and Gottfried Bammes (2017) as the one that presents the ideal human figure. More importantly, it is also the most used canon among artists. We performed the rigorous anthropometric correction of the optimized model using the measurements made by Bammes (Figure 3, «a»).

The joints were perfectly aligned with the references (anterior and lateral views), as well as the distance between the shoulder and hip joints, in relation to the Bammes model, maintaining the exact eight heads height (Figure 3, «b»). After this process, it was necessary to fix the mesh

topology to avoid incorrect deformations caused by the bone displacement of the digital skeleton. The correction was performed using the scanned human model as reference.

*Figure 3: Optimized model with skeleton (left) aligned with reference from Bammes (right).*

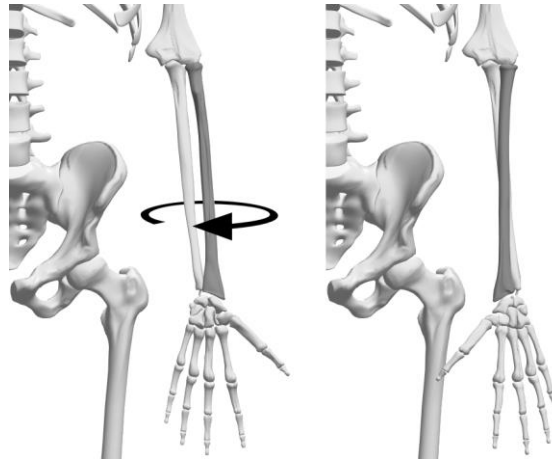


### **Adopted Pose**

Film and game industry usually adopt the «T» pose in character creation. In this pose, the arms are placed horizontally, which facilitates character modeling, skeleton creation and weights painting in the skinning process. The anatomical study tradition has a preference for the well-known «anatomical pose», chosen for the human osteological study, because the Radius and Ulna bones are parallel to each other and do not cross, thus facilitating the study of the anatomy of the forearm bones.

We considered inappropriate to use the «T» pose in our proposal because the Trapezius and Deltoid muscles are contracted. In addition, it seems more natural to portray the human figure with the arms close to the torso than with open arms — which is not the most common pose in our everyday life. The traditional «anatomical pose» was not used because, when the anterior hand face is oriented forward, the Radius bone is near to its maximum rotation, according to the KineMan (Barber, n.d.) skeleton (Figure 4 - Left).

*Figure 4: KineMan's rotation range of the Radius bone. Left: Maximum rotation (5 degrees) «Anatomical Pose» Right: Minimum rotation (-155 degrees)*



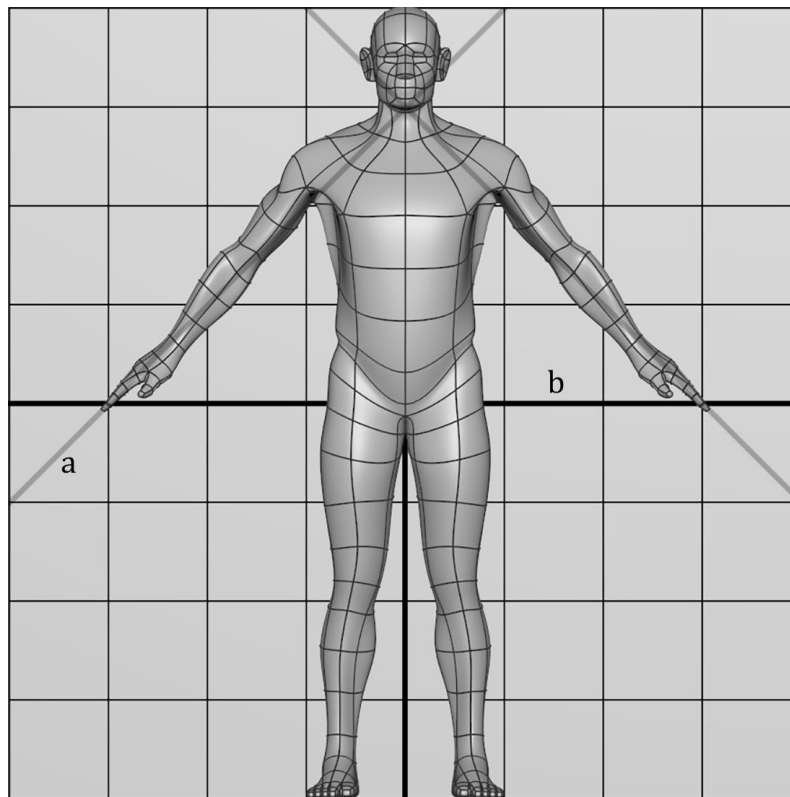
Hence, we adopted a new pose with approximately 45 degrees arm rotation from the torso, and anterior hand face towards torso, similar to the scanned model. In this pose, the forearm is at approximately half the amplitude of its rotation, and the 3D geometry of the forearm does not twist 160 degrees in just one direction, but 80 degrees for each direction. With this pose, the problematic deformation of the 3D model's forearm geometry is avoided, preventing anatomical inaccuracies. The only minor issue with this pose is related with diagonal arms position, which may be less convenient for the modeling process and skeleton creation, however, as mentioned above, this pose is near to human conventional posture and makes it easier to approach the anatomy of the forearm, arm and shoulder.

## **Canon**

We present a three-dimensional low poly model constructed without detriment to the main anatomical features of the human body. The modeling process was developed with the smooth subdivision algorithm, the same technique used by Vaughan (2019). This algorithm is inherent to the main 3D software used in industry, such as: Maya, 3ds Max, Blender, among others. The model was built upon the new optimized écorché model and can be constructed with simple low poly 3D primitives, however, some changes were implemented in order to make it easier to portray the human figure in three dimensions, and prevent geometry issues (as stated above), but also, to create a good mnemonic for the artist. With the adopted arm rotation, they can be aligned with a 45 degree diagonal between the chin and the finger tips (Figure 5, «a»). This canon creates an easy mnemonic in which the model has eight heads height, six heads width, the trunk has approximately two heads width and the fingers are located with four heads height — half height of canon (Figure 5, «b»). It was decided not to bring the legs closer together, in order to make it easier to paint weights in the skinning process, and also, not to spread them further apart, to prevent changing the models height, hence, breaking the eight head base canon rule.

The upper and lower limbs have six faces for each ring. The symmetrical shape of the hexagon allows the intentional edge placement in the middle of the anterior and posterior leg face, intending to create a continuity line for the global model topology. The torso was made with ten polygons for each ring to connect with the upper and lower limbs and preserve the main anatomical features. All fingers have four polygons for each ring to ensure a correct connection with the hand and foot geometry. To respect the neck's anatomy, we decided to create its geometry with fourteen polygon rings. This will also provide a good connection with the head, shoulders and torso geometry. The head was made with more polygons, aiming to provide more detail and create the edge rings around ears, eyes and mouth. The final low poly model has 764 faces without smooth subdivision. With one level of smooth subdivision, the model presents 3020 faces. Our low poly model approach seems close to the minimum appropriate to achieve the main anatomical features in the digital human model. It is necessary to use smooth subdivision, yet, our main challenge was to develop a simple way to model the human body with the right proportions and anatomy. Our canon can also be adopted to create the human digital model using NURBS.

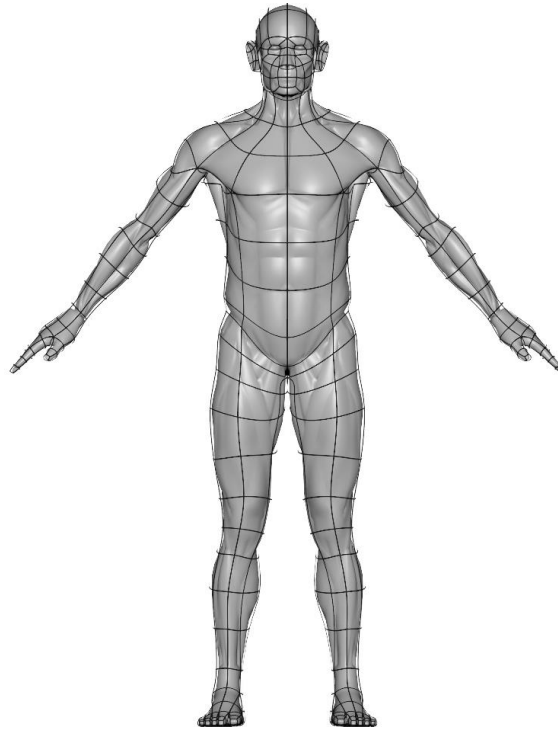
*Figure 5: Anatomic low poly model (anterior view).*



We present the description of the model in the anterior, lateral and posterior views. The edge location is quite deliberate, in order to ensure the preservation of the main anatomical features of the human body in such a low poly digital model.



*Figure 6: Anatomic low poly model overlay on reference anatomy model (anterior view).*



#### **Anterior View:**

**Head:** the edge loops define the contours of the eyes, mouth, nose and ears, respecting facial muscle anatomy and providing an appropriate topology for the geometry deformation in animation.

**Neck:** the edges highlight the form of the Sternocleidomastoid and Trapezius muscles.

**Back:** only the Latissimus Dorsi muscle shape is visible.

**Abdomen:** it is noticeable the contour of the «V» shape with special emphasis on the External Oblique and Latissimus Dorsi muscles, marking the exact location of the umbilicus.

**Shoulder:** special attention is paid to the contours of Deltoid and Pectoralis Major muscles.

**Arm:** edges were placed over the Brachialis muscle, located between the Biceps Braquii and Triceps Brachii muscles. Another edge is located between the Biceps Braquii long and short head muscle.

**Forearm:** edges show the limit between the Brachioradialis and Flexor Carpi Radialis muscles.

**Hand:** edge loops were placed precisely over the finger joints and wrist.

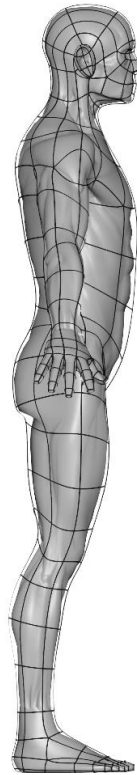
**Pelvis:** the edges highlight the Gluteus Medius muscle, and the Crest of the Ilium.

**Thigh:** the concavity where the Great Trochanter is located; also, in the anterior face of the thigh, the edges cross the middle of the Rectus Femoris muscle, separating Vastus Lateralis and Vastus Medialis muscles, crossing the Patellar ligament.

**Leg:** the edges highlight the left head of Gastrocnemius muscle boundaries and the anterior crest of the Tibia bone.

**Foot:** the edges highlight the Medial and Lateral Malleolus, the toes and ankle joints.

*Figure 7: Anatomic low poly model overlay on reference anatomy model (lateral view).*



### **Lateral View:**

**Head:** edge loops define the contours of the ear and eyes.

**Neck:** the edges draw the shape of Sternocleidomastoid and Trapezius muscles.

**Back:** only part of the Latissimus Dorsi muscle shape is visible.

**Abdomen:** the separation between the External Oblique and the Rectus Abdominis muscles is noticeable.

**Shoulder:** the edges draw the shape of the Deltoid muscle.

**Arm:** edges are located over the Brachialis muscle.

**Forearm:** an edge line provides the Brachioradialis muscle volume.

**Hand:** the edge loops are placed over the finger and wrist joints.

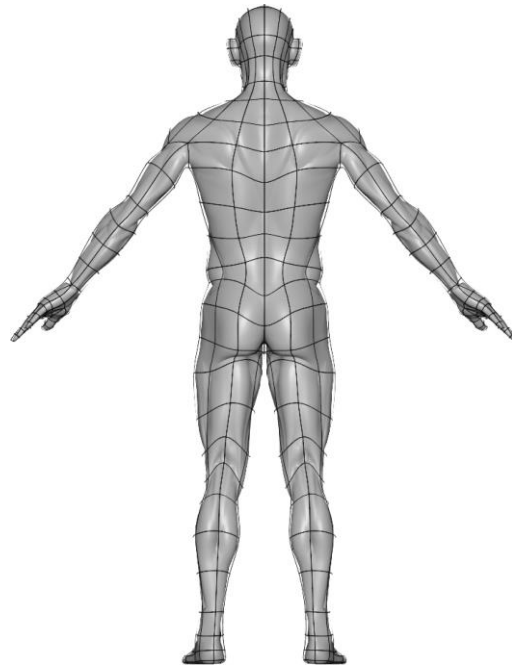
**Pelvis:** an edge loop defines the contour of the Crest of the Ilium.

**Thigh:** an edge line is located between the Vastus Lateralis muscle and Biceps Femoris long head muscle, and the base line of the Gluteus Maximus muscle.

**Leg:** the limit between the Tibialis Anterior and Extensor Digitorum Communis muscles is highlighted.

**Foot:** the horizontal line defines the position of the Lateral Malleolus.

*Figure 8: Anatomic low poly model overlay on reference anatomy model (posterior view).*



### **Posterior View:**

**Head:** the edges emphasize the shape of the Occipital bone and ears contours.

**Neck:** the line defines the Trapezius muscle volume.

**Back:** the Trapezius, Latissimus Dorsi, Infraspinatus and Teres Major muscles volume are highlighted. We did not outline the muscle shape, in an effort to maintain the model without triangles. However, some vertices are located with precision over the triangular shape of the Latissimus Dorsi and Trapezius muscles. To define the shape of these muscles it is only necessary to connect the vertices with diagonal edges.

**Abdomen:** only the External Oblique muscle and its edge border with the Latissimus Dorsi muscle is relevant.

**Shoulder:** the edges outline the shape of the Deltoid muscle.

**Arm:** is it possible to observe the line over the Long Head of the Triceps muscle.

**Forearm:** there is a precise line over the Olecranon and a line that divides the posterior face, from elbow to the hand.

**Hand:** edge loops are placed over the fingers and wrist joints. In the anterior surface of the hand, it is possible to observe the boundaries of the Flexor Pollicis and Abductor Pollicis muscles.

**Pelvis:** the shape of the Crest of the Ilium stands out. The edges also form the «V» shape between the two Gluteus Maximus muscles, formed by the Sacrum bone.

**Thigh:** and edge line defines the limit between the Vastus Lateralis and Biceps Femoris muscles.

**Leg:** the main highlight goes to the edge border between the Gastrocnemius left and right head muscle.

**Foot:** a horizontal line defines the location of the Lateral and Medial Malleolus and the ankle joint. A vertical line defines the Achilles tendon.

## Procedural Canon

One of our purposes was to treat not only the final model as a canon of proportions, but to achieve a canonical generating process for the model – that is, a set of steps that adapted well to the digital tools and were easy to remember. This canonical construction process will be described in detail in a future work, but at present it became evident to us that this modeling process had its own artistic interest, as an object of art – in digital media art installation that could be displayed to an audience.

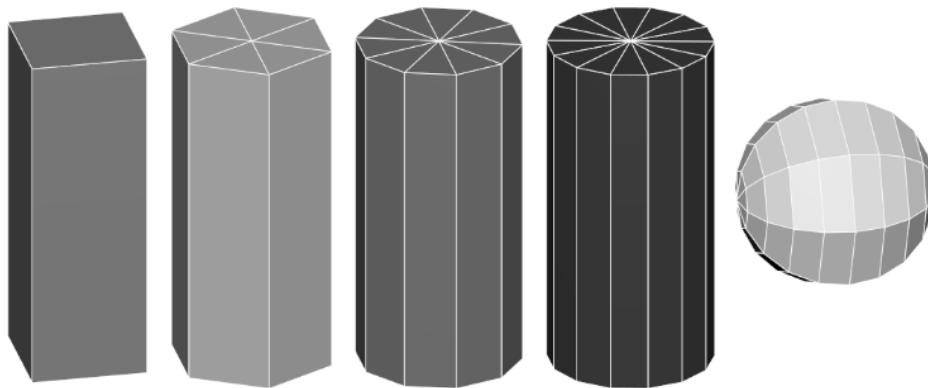
Hence we proposed an installation that explores the construction of the canon using only two 3D standard primitives: the cylinder and the sphere.

The reason for using only 3D primitives is two-fold: first, they are platform-agnostic, since these primitives are available in any 3D modeling software; second, they follow drawing tradition, as there is a classical approach of constructive anatomy drawing that always starts by simplifying anatomical regions into simple shapes such as boxes and ellipsoids, or cylinders and spheres, and then refining by subdivision and smoothing (Bridgman, 1973). One of the advantages is that these simple primitives allow the artist to predict very easily the overall lighting of the figure (Hale, Robert, 1964).

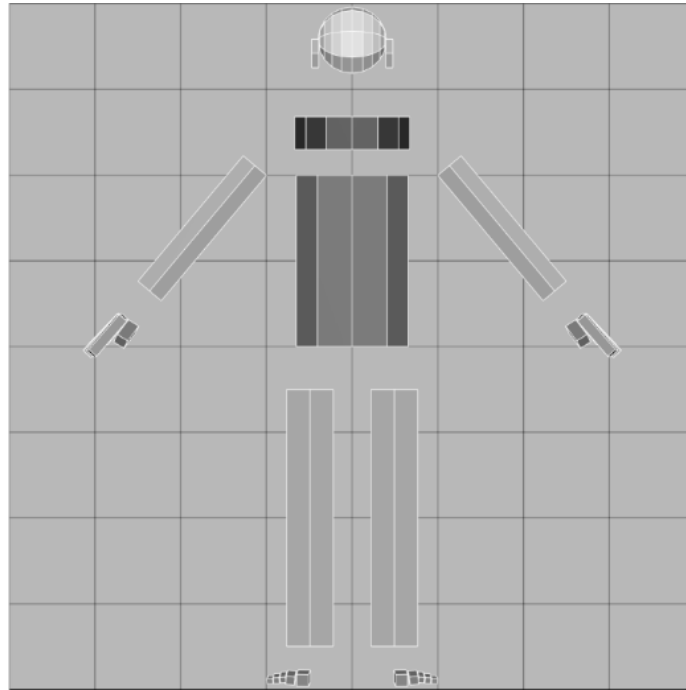
## Synthesis as Artefact

We propose and installation that explores the construction of the canon using only two 3D standard primitives: the cylinder, created in four different versions, with 4, 6, 10, and 14 subdivisions on the axis; the sphere, with 8 subdivisions along the axis and 10 in height (Figure 9). In the installation, each primitive presents a different color to help the visitor to identify it in the modeling process (e.g., the 6 subdivisions axis cylinder is used in the upper and lower limbs and ears).

*Figure 9: Primitives used to build the model.*



*Figure 10: Placing 3D primitives over the matrix.*



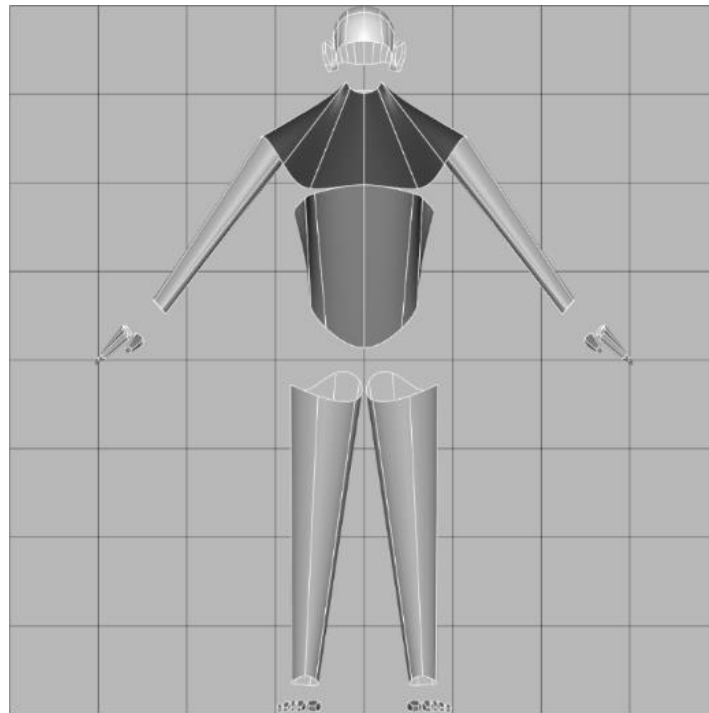
The cylinders are rotated so as to have an edge at the center, facing forward in the anterior view. All cylinders and spheres are scaled and placed over the reference eight head matrix proposed (Figure 5). Placing the primitives for the feet and hands is the most complex part of the process; it is necessary to use several views while the 4 subdivisions axis cylinder is duplicated, rotated and scaled according to each finger and toe.

Unnecessary cylinder faces are deleted to keep only the side geometry, allowing future geometry connections from the cylinder tops. Many faces from the sphere are also deleted; the face of the model will be created using more advanced 3D modeling techniques. All the vertices are repositioned over the matrix to reshape the primitives according to the reference canon anatomy (Figure 11).

The next step consists on creating additional geometry in each primitive (Figure 12). This extra geometry is created according to the reference canon and it will allow to increase the anatomic surface features presented in our canon proposal.

The installation presents the multiple steps carried to create the final geometry (Figure 13, black color). This final geometry is created using more advanced modeling techniques and tools. However, these techniques are developed in a simple way to facilitate visitor understanding.

*Figure 11: Reshaping primitive's geometry.*



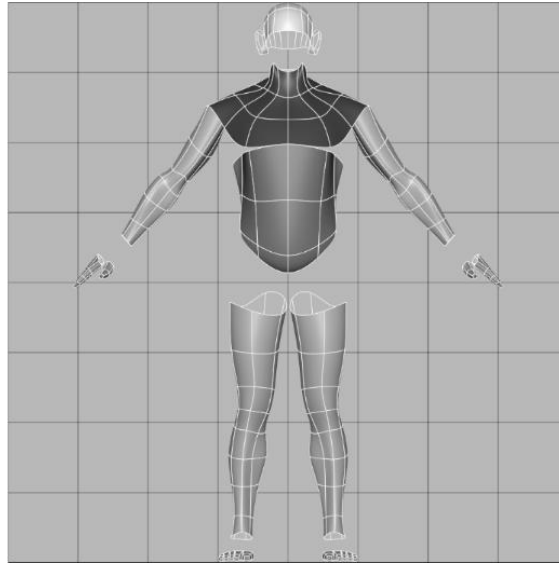
## **The Installation**

The installation invites the visitor to draw, and through the drawing process to explore human anatomy through the particular conceptual filter of the canon. Concurrently, the inexperienced visitor is invited to enter the language of 3D modeling process, by interpreting complex shapes through the filter of simple primitives. The artefact is a collaboration with the visitors, who are invited to pin their drawings in a board that will fill up with artwork as visitors arrive, creating an evolving art gallery. It is an interesting experiment to see how visitors will interpret the model, in tone or line, or what graphical languages they decide to use in order to abstract this object, itself an abstraction of anatomical reality.

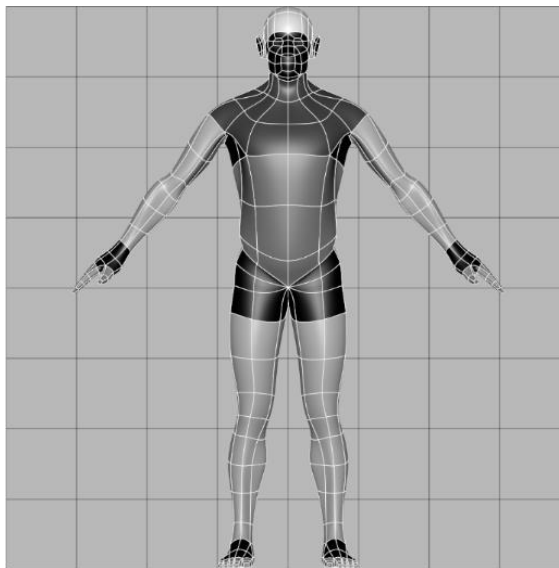
For the general public this installation may work like the preschool drawing experience, wherein young children may be invited to make constructions with simple polygons: a step-by-step guide of growing complexity avoids the fear of the empty page.

For the visitor artist, the experience may instead recall the sequences of quick poses in life drawing class, of 30 seconds or one minute, involving the quick interpretation of a form and pose, that should result in a drawing that – although quick – is always complete. In the same way, we intended each step in the construction of the final form to be itself a complete object, although a step in the direction of something else.

*Figure 12: Adding extra geometry.*



*Figure 13: Conclusion geometry built without primitives.*

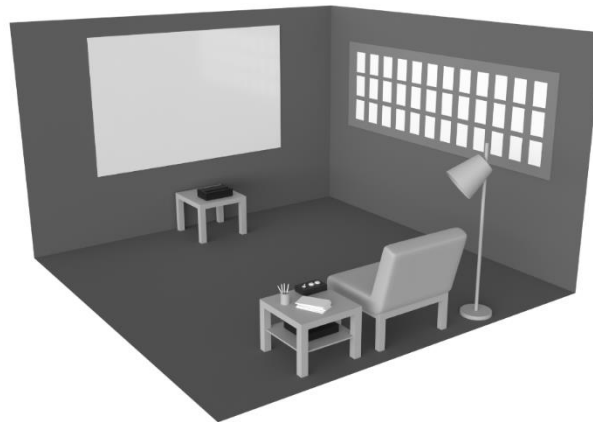


## **Technical Setup**

The installation room is 4m x 4m, or similar. The presentation is made on a large projection screen, with dimensions over 2m x 2m, placed on the wall. On the opposite wall, a comfortable low chair or lounge chair, and a small table with pencils and paper for drawing. There is a large board on the side wall, for pinning drawings. The installation control device is also over the table and a laptop on the table's shelf below, hidden and not accessible to the visitor. Another small table placed next to the projection screen is used to place the vertical projector.

The room environment should ideally be dark, to help the visitor observe the interactive model geometry, and, to keep an intimacy ambience during the drawing process. The only light source should be a floor lamp next to the chair, lighting the visitor's drawing.

*Figure 14: Installation preview.*



## **Interaction**

The visitor interacts with the installation using the controls placed over the table, next to the chair. Pencil and paper, for drawing, may be obtained from the table next to the controls.

The model is presented animated by a slow rotation around its vertical axis, allowing the observation of its geometry details in all angles. The controls allow the interaction with the model: one button moves the construction process forward; another button moves it backward; a third button enables or disables the model rotation allowing the observation of its geometry in different angles. The model construction process will always be accompanied by brief text explanations for each step.

## **Conclusions and Further Studies**

We have argued for both the relevance of the Canon and the need for its update to the digital modelling process, and have proposed one such possible update, both in its final form and in its construction process. By no means does this intend to be a final word, but a call for the attention of other artists to this problem. The construction of the Canon is not – as far as we at least can see – not a scientific problem with a single answer but mostly an artistic problem, with various answers that are informed, though not determined by the scientific requirements. There is a lack of academic literature in this regard, and we hope that our efforts will stimulate further works. As for the present authors, the present work is only the start of the development of our canon. The obvious next step is the modelling of a female canon (we followed the historic precedence by starting with the male canon) and maybe a canon for children; less obvious, and more interesting, is the fact that the alteration of the muscle form with motion could itself be made canonical, a process entirely new and specific to the digital tools of 3D modelling, which are inherently



dynamical. The question of course, is what should such a canon's dynamical measurements be based upon, and how to satisfy both anatomical plausibility and the requirements of aesthetics and mnemonics.

## ACKNOWLEDGMENTS

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