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The role of secondary emotions in action selection and its effects on the believability of a character

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Abstract:

This thesis investigates the role of secondary emotions in action selection, and how this affects the believability of a character.

A mod for a First Person Shooter (FPS) game "2 minutes of Mayhem" was developed in Virtools game engine. The modification involved adding an affective component into the game. This component created secondary (complex) emotions by combining two primary emotions using fuzzy logic.

An action selection mechanism was created using Finite State Machine and Nash Equilibrium. This mechanism relied on the secondary emotions as its main input. It coupled the secondary emotions together with the agent's goals and came up with the relevant action that an NPC (Non Playing Character) should take.

In order to evaluate the role of secondary emotions in action selection and its effects on believability, six tests were developed. These tests were based on sub-dividing the problem formulated into six hypotheses. A total of 60 subjects were involved in the final exploratory study.

The results of the study show that secondary emotions play a crucial role in action selection, and as a result they enhance the believability of a character.

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PREFACE

This thesis is written as a documentation for the project ”The role of Secondary Emotions in Action Selection and Believability, “ as part of the work on the 10th semester study in Medialogy at Aalborg University, Copenhagen.

The purpose of this thesis is to pursue an initial research by investigating the role of secondary emotions in enhancing believability.

It is expected that the reader has knowledge of the common terms connected to emotions, computer games and Artificial Intelligence.

The thesis consists of three parts and several appendices. The first part provides an introduction to believability, and research on the field of emotion and artificial intelligence.

The second part describes how a prototype (a game modification) was designed and implemented, so as to be able to serve as the basis for evaluating the problem formulation.

The final part describes the different hypotheses created, and the tests developed under each. The test results are presented together with a detailed discussion of the results.

The appendices contain test questionnaires and their results, C++ files, Virtools scripts and other materials that may be relevant for a thorough understanding of the thesis.

One cd is attached together with this thesis. It contains the mod developed and instructions on how to run it.

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Table of Contents

PART 1

1. Introduction

The entertainment and computing industries are striving hard to achieve some kind of realism in their work. This realism has been termed as believability. Believability places a number of demands on an interactive character. These include goals, emotions, reactivity and social competence. Jones (1989), an animator at Warner described believability as the belief in the life of characters. Within the entertainment world, one of the most successful implementation of believability is evident in the animation industry.

Leading companies like Disney and Pixar have released animated features that have become so impressive that they not only appeal to the younger population but the older generation as well. This is evident in widely successful animated features like Shrek, Ratatouille and The Incredibles. One could argue that this is due to good writing, but the key to good animation lies in making the character's behavior seem real

Realism here does not refer to the animations acting intelligently, but instead being believable (Thomas and Johnston, 1981)[1]. Disney and his animators have clearly expressed believability in terms of emotions. To them, emotions are the major factor to enhancing believability. To quote Thomas and Johnston, "*it's the portrayal of emotions that has given Disney characters the illusion of life*."

Bates (1994) states that believability of an actor is made possible by the emergence of emotions clearly expressed at the right moment. Emotions are what make an actor or a Non Playing Character (NPC from now on) in a game not to act like a robot. They make actors/agents placed in the same context to react differently to the same stimuli. An emotionless character is lifeless, and thus not believable.

In computing, work has been done in creating robotic agents that are based on emotional control (e.g. Michaud & Audet 2001, Breazel 2002). There has also been research and development of tutoring agents that use emotional reasoning. These include the work of Hudlicka & Billingsley (1999) and Takeuchi, Katagiri and Takahashi (2001) where the tutoring agents can recognize the emotions of the users, and thus adapt their teaching to the user's level. Researchers like Elliot (1992) and Gratch & Marsella (2001a), have also developed computational models of human emotions which have been studied in simulations in artificial environments. A lot more work in this field has been done by the MIT affective sciences department. These will be reviewed in section 6.2.

[1] Two of Disney's original animators

The video game industry, just like its computing counterpart is striving to enhance believability as well. However, most of its work has been focused on agent's goals and reactivity. This has led to games with better search engines, and also the game agents moving with more realism and accuracy. Good examples can be seen in the success of games like "Unreal Tournament" and "Star Trek: Elite Force". Despite this fact, numerous gamers still complain that most of the characters in current games are lifeless. Their behavior is robotic. It is quite normal to see some of the characters in games being totally oblivious to the violence around them. Most of the fighting characters usually show almost no reaction to the tremendous violence that engulfs them.

It is also common in some games to see a group of NPCs reacting in the same way when subjected to the same stimuli. This shows scripted behavior, which is quite different from how humans behave. Human reasoning is affected by a lot of factors, and one of those could be deemed to be emotions. The process behind human reasoning is a controversial issue. Traditional cognitive theories are of the opinion that reasoning is more or less like problem solving in formal logic. When faced with a problem, humans list all the different options available, coupled with their possible outcomes, and then they use logic in its best sense to perform a cost/benefit analysis which provides the best possible choice (Velesquez, 1998)

Modern cognitive theories on the other hand are of the opinion that reasoning and decision making processes are associative. This means that when we are faced by a problem, we also take into account how we reacted in the past to such a situation. Damasio(1994) did an experiment on patients who had frontal-lobe disorders, affecting a key part of the cortex that communicates with the limbic system. The patients were inexpressive of emotions and seem unusually rational. These patients made disastrous investment decisions and they never learnt from their mistakes. The final results of the experiment showed that lack of emotions impaired reasoning.

If we decide to work with traditional approach to cognition, then the scripted behavior of NPCs can be justifiable, but if we take the more recent approaches then factors like emotions, intuition and memory would have to play a big part in NPCs reasoning and decision-making process.

One may argue that gamers are just laymen who know nothing about the best behavior for NPCs. However, their point of view has also been considered by Peter Molyneux, a well known game designer and programmer who has noted that despite the major improvements in game AI, more focus needs to be put into believability instead of intelligence. Believability here refers to characters behaving in a way that make them seem alive, and as a result the audience ends up having emotions for or about them (Reilly, 1996). Freeman (2003), did a research on why most TV fans are not gamers. Some of Freeman's test subjects informed him that the computer world seems shallow and lacks the kind of emotional depth offered by television. Thus, Freeman argues for emotioneering[2] in games.

The Disney company and other animators have left audiences identifying with a talking mouse that has ambition to be the best chef in Paris, an Ogre that falls in love and a robot that goes all the way to become a star. These are unrealistic scenarios, yet the characters strike a chord with the audience. On the other hand, current games based on real life scenarios, with human looking characters, good scripts and exceptional graphics, still leave the audience feeling nothing. Could animators and other artists be having a magic touch that the AI (or gaming industry), need to borrow? Could this trick be the role emotions in enhancing believability?

From the above discussion one can hypothesize that the key to believability actually lies in emotions. We can theorize that emotions can be used in the gaming industry to create characters which seem more alive.

1.1. Preliminary Problem area

As a conclusion to the prior discussion, this project will focus on how emotion simulation can be used to enhance the believability of characters in computer games.

1.2. Reading guide

This chapter will contain the reading guide for the whole report

Chapter 1 of the report is the introduction which wraps up by identifying a general area that the project will focus on.

Chapters 2 – 4 give an outline of the initial research area which leads to an initial problem formulation.

Chapters 5 & 6 present a more narrowed down research area arising from the initial problem formulation.

Chapter 7 gives an overview of the state of art, with a conclusion that leads to the final problem formulation.

Chapter 8 defines the design of the system that will be developed so as to be able to test the problem formulation.

[2] The term emotioneering refers to adding emotions into games

Chapter 9 describes how the system is implemented so as to provide the necessary functionality needed for testing purposes.

Chapter 10 outlines the hypotheses developed, plus the tests conducted to prove these. The results of the tests are provided with a general discussion leading to a conclusive end.

Chapter 11 gives the project conclusion together with any foreseeable future work.

2. Believable Characters

In computer games, the term believability has become synonymous with believable agents. However, in animation, "Believability" is a term mostly used by character artists to describe compelling characters that engage in internally consistent, lifelike and readable behavior in such a manner as to support the audience in suspending disbelief and entering the internal world of the character. This is not the same as realism (Mateas, 2002).

Bates(1994) has described a believable agent as one that "*provides the illusion thus permitting the audience's suspension of disbelief*". According to him, one of the main prerequisites of believability is the use of appropriately timed and clearly expressed emotions. This fact has been supported by most of Disney's artists as pointed out in the introduction chapter. This is supported by Meyer(2004) who views behavior in terms of the evolution of the mental states of the agent over time. Thus believable behavior entails expressing the right emotional state at the right time. This is also supported by Loyall (1997) where he states that some of the requirements for achieving the illusion of life include personality, emotion, self motivation, growth of character and social relationships. In his thesis, Mateas (2002) describes believable agents as being the union of AI-based autonomous agents and the personality-rich, emotive characters that appear in drama.

Mateas (1997) supports this description by outlining some of the believability requirements stated by the Oz group[3] as follows:

1. Self-motivation –This is a characteristic of autonomous agents who have their own internal drives and desires, which they pursue whether or not other characters are interacting with them.
2. Illusion of life – This is the act of believing in the life of the character. To be able to achieve this, a character must meet a collection of requirements which may include: pursuing multiple or simultaneous goals, reacting on time to stimuli in the environment and also having huge capabilities such as movement, perception and memory.

[3] This is a research group at CMU that has spent the last ten years studying believable agents and interactive drama

3. Emotion – characters should exhibit emotions and also respond to emotions of other characters in a way that is distinctive to their personality.
4. Personality – This is about the character being unique in the way they do things.
5. Change – Characters should grow and change in time, according to their personality
6. Social relationships – There should be some relationships formed as characters interact with each other.

It is interesting to note that the Oz group does not classify emotion to be one of the requirements for achieving the illusion of life as stated by Disney and other animators. To them, emotions and illusion of life are different requirements of believability, and they can co-exist without each other. But what does believability entail in terms of AI? Classic AI has been more involved with autonomous (goal oriented) agents. This approach is not good when dealing with believable agents as it does not take into account important characteristics of human sciences which include emotions, personality, and feelings ETC.

When discussing believability, Livingstone (2006) states that believability in AI depends on the game being played and the type of AI. He gives an example of a combat game where believability may be judged by whether the computer player beat their human counterparts, or whether the computer players were behaving in a way similar to how human beings would in a combat situation. Livingstone's description here is a bit vague since different human soldiers would react differently in a combat situation. This behavior could be affected by a lot of factors that will be discussed later in this work.

It is therefore more appealing to rely on Laird and Luchi's (2000) more definitive explanation of the requirements for believable AI. They came up with the following requirements when judging the Soar Quakebot[4] on Quake II[5]. They state that the AI designer should:

• Give the AI some human-like reaction and decision time (one twentieth to one tenth of a second).

• Implement some strategic reasoning so that the AI is not a purely reactive agent.

• Try to avoid giving the AI superhuman abilities such as over precise aiming or x-ray vision.

Kline & Blumberg (1999) describe the main factors behind believability in an agent as being perception, motivational drives, emotions and action selection.

- Perception ensures that agents can sense their environment, and evaluate the happenings in it.

[4] This is a general cognitive architecture for developing systems that exhibit intelligent behavior.

[5] Quake II is a first person shooter computer game developed by Id software

- A properly motivated character works towards meeting its desires while effectively handling any unexpected situations.
- Emotions tend to bias a character's action selection as well as motion. For example, an angry creature is more prone to violence, and its way of moving (walking) should portray anger.
- The kind of action that an agent selects should be based on evaluating its current situation in relation to its goal.

From all the above descriptions on what constitutes believability, this work will focus on it as being the union between autonomous and emotive characters. Autonomous means that they are independent with their own goals (or motivations) and also capable of perceiving their world. These should have an influence on their action selection. Emotive means that they are capable of feeling and expressing emotions, and also maybe using these emotions as a basis for their actions. This fact will be a major discussion of this thesis

3. Emotions

Emotions have been an interesting topic for artists and AI programmers. As mentioned in the introduction, artists (in this case, animators) have used emotions as a way of creating the illusion of life.

Thomas and Johnston describe 3 factors that are essential for an animator to successfully implement emotions in a character (Bates, 1994). These are:

- The emotional state of the character must be clearly defined. This implies that the audience must be able to point out definite emotional states of the character.
- The thought process reveals the feeling. The audience should be able to see emotions in how the character acts as its thinking and therefore its behavior is influenced by its current emotional state. Later on we will describe other factors that influence thinking.
- Accentuate the emotion. The animator needs to establish the emotion, to convey it to viewers, and let them enjoy the moment.

They further go on to state that the audience never grasps the emotional state immediately, and thus, its appropriate to use mechanisms that will convey the emotion. The mechanisms include foreshadowing the emotion, exaggerating it, and toning down other actions that are occurring concurrently.

Within the computing industry, some of the most influential work has been done by MIT's affective computing department. Some of their projects include:

1. AffQuake which is a system that attempts to incorporate signals that relate to a player's emotions into Quake II in a way that alters game play, and to some extent even cause the player's avatar within the game to alter its behavior to reflect the player's emotional state.
2. An affective learning companion which is a tool used for understanding how machines can work with humans in a better way so as to meet their needs.
3. Affective mirror, which is an automated system that intelligently responds to a person's affective state in real time.
4. A posture recognition chair, which recognizes posture patterns and their associated emotional states in real time [6].The work in this field is quite vast and these examples are just a fractional part.

When building such applications that rely on emotions, a major concern would be on how to firstly, synthesize the emotion and later, make the audience be able to recognize the synthesized emotion.

To model an emotion, one has to think about how an emotion occurs. It is not enough to say that "Peter was sad 10 minutes ago and now he is happy." We need to find out how these emotions occur and what causes them to change. To be able to do this some computer specialists, e.g. Picard (1997) and Bates (2004) have done a lot of research on emotions. Picard argues that one of the factors hindering emotional synthesis within the computing industry is the lack of a proper definition of what constitutes an emotion, plus how it occurs.

Therefore, in this chapter of this report, a lot of focus will be put on trying to define emotions and how they occur. Different theories of emotions will be discussed in detail with the hope of identifying some major features on which the work of this report will be based upon.

3.1. Definition of emotions

[6] The source for this information is MIT's affective computing department.

The definition of emotions could well be classified as one of the most controversial topics in research. This is due to the fact that there is no fixed definition for it. The literature on emotions is vast and there are a lot of variations involving both the definition and causes of emotions. Some major theories will be discussed in detail in this chapter.

Darwin (1872) suggested that emotions are evolved behaviors that exist in parallel across species. The language of emotion is common among humans and other species and it's identifiable by specific signs, facial and postural expressions. According to his definition, an animal's expression of emotion should be recognizable by humans and other animals. The opposite should hold as well. To some extent this theory has been justified by works of Eckman (1975) whose research supported the universality of emotions in humans. This research however only holds for the most basic emotions since emotions such as jealousy, contempt and guilt cannot be recognized by means of expressive behavior alone (Fridja 1953, 1969).

There are two main theories when defining emotions, the traditional versus contemporary theories, which are separated by whether or not the cognitive processes are involved in the emotion definition. This distinction arises from the early days of Aristotle where the body and mind were taken as two isolated and irreconcilable entities. Aristotle's definition of emotion is as follows:

"Emotions are the things on account of which the ones altered differ with respect to their judgments, and are accompanied by pleasure and pain: such are anger, pity, fear, and all similar emotions and their contraries." (Leighton, 1982)

This definition is unquestionably contemporary (or cognitive) as it emphasizes the role of thought on emotion. The main focus of Aristotle's analysis is thought and feeling takes a secondary position. Traditional theorist such as Lange (1884) defines emotions as being the resulting outcome from the perception and interpretation of bodily changes. This means that human's bodies react to certain stimuli. This reaction results in bodily responses and we experience emotions. One of the greatest critics of this definition is Cannon (1915). He argues that some emotions have identical or similar arousal mechanisms. And also, that people or animals with spinal cord or nerve injuries cannot sense what is happening in their body but they still experience emotions. Thus Cannon's definition of emotion is that it's a product of an arousal of the thalamus[7]. He assumes that body changes and emotional experiences are independent.

Authors like Bradley & Lang(2000) tend to agree with traditional theorists as they define emotions in terms of response systems in the verbal, behavioral and physiological domain. This is supported by studies of Bauer(1984), Tranel & Damasio (1985) and Bauer& Verfaellie (1988) where patients

[7] The part of the brain that relays sensory impulses

with prosopagnosia manifest skin conductance responses to familiar people whom they do not consciously recognize, and vice versa for unfamiliar people. This definition of emotion is however delicate since a physiological measure such as a heart rate or sweat though shows the presence of an emotion, it does not determine the exact emotion at hand. Some theorists such as Wenger (1950) and Schachter (1962) describe emotion as being a result of occurrence of physiological arousal. In their theory no arousal results in no emotion. Cannon as described earlier supports this definition. This is disputed by Fridja (1986) who views arousal as being part of the emotional process, but not the focal part of it.

Recent theorists like Ortony et al (1988) have described emotion as the outcome of an evaluation of the extent to which ones goals are being met while interacting with the environment. This evaluation means that cognitive processes must occur in order for an emotion to arise. The extent to which the cognitive processes are involved has been a great debate amongst cognitive theorists like Lazarus (1984) and Zanjonc (1980).

Lazarus is of the opinion that cognition must occur before the subjective feeling. He views emotions as being a process that works through a set of interdependent systems including processes for cognitive appraisal, physical interaction between an individual and the environment, coping and the emotional response itself (Juma, Sahaf & Ravn, 2007). Zanjonc on the other hand argues that feeling is shared and cognition is independent and not necessary for an emotional experience to occur.

Fridja (1986) agrees with Lazarus as he defines emotion as an action readiness change elicited by certain external events and thoughts. Shachter and Singer (1962) are also pro cognition. They define emotion as consisting of two components: physiological arousal and cognition. The cognitive component is used to interpret the meaning of physiological reactions to external events.

Authors like Averill (1980) have described emotion as having a transitory social role (a socially constituted syndrome) that includes an individual’s appraisal of the situation that is interpreted as a passion rather than an action. He comes up with this definition by following the classical method of definition by genus and difference where he indicates the generic class of phenomena to which emotions belong, then indicating how these emotions can be differentiated from other members of that class. The generic class of phenomena that he classifies emotions under include classifying emotions as syndromes, and also as transitory social roles. This classification is quite confusing, as even Averill notes that most people relate syndromes to diseases.

He argues that his definition is not exhaustive as it does not cover all that is labeled “emotional” in ordinary language, but it covers most recognized human emotions.One noticeable drawback of this definition is the labeling of emotion as passion. This means that humans cannot control their emotions. . This would infer that emotion is an unconscious effort, a fact which will be discussed in the next chapter.

Izard(1977) defines the occurrence of emotions as involving processes such as perception, neural transmission, hypothalamus, brain stem reticular system, facial postural patterns, feedback, subjective experience and emotion-cognition-motor interaction (Strongman, 1978). Simply put, emotion is the outcome of changes in the nervous system caused by both internal and external events.

Goldie (2002) defines emotion as being a complex state which includes various past episodes of emotional experience, as well as disposition to think, and act, all of which can interweave and interact.

This definition seems to suppose that emotions only occur due to cognitive process without any physiological arousal, or perception being involved. This may be true when thinking of a past event that caused a certain emotion at that past time, and making the emotion to repeat again in the present. This is a recognised way of eliciting emotions. However not all emotions occur in this way, some are caused by the current perception of a situation and the evaluation of it.

Candland (1977) retraces the change in the definition of emotions from the early 17th century until the 21st century as follows. In the 17th and 18th century, the English language remained faithful to the Latin derivation of emotion, namely, *emovere* (to move away from). Thus through 16th-18th century the term emotion was associated with definitions such as a moving out, a migration, causing movement, physical agitation etc.

The application of the word emotion to the mental state developed simultaneously and with time the following definitions begun to occur:

"1660: a vehement or excited mental state"

"1735: Tending or able to excite emotion"

"1808: A mental feeling of affection"

"1847: connected with feelings or passion"

By the 19th century emotion came to be regarded as being distinct from cognition and will. This is evident in the above mentioned traditional theories. This distinction is still regarded true by some, who regard emotion as a separate irrational faculty that should be guarded from interfering with cognitive processes.

Our everyday language may offer support to the contemporary theorists as it conveys the assumption that emotion is a unique feature of the mind and thus interferes with cognitive processes. The definition of emotions that this report will be based on will be given at the end of section 3.3.5. Conclusion, after discussing the different theories of emotions.

3.1.1. Difference between emotions, feelings and mood

The two terms “emotion and feeling” are commonly used interchangeably, though that should not be the case. The difference between them mainly lies in their duration, arousal and orientation. Just like any other subject under the emotions field, this distinction has been subjected to many variations.

Damasio (2000a) defines emotions as being outwardly and public while feelings are inwardly directed and private. Thus feeling can be seen as the mental reaction of emotion, while emotions are responses whose perception are called feeling (Damasio, 2000b).Feelings are deemed private because no outsider can observe them, while emotions are partially or clearly observable to outsiders. Damasio is of the opinion that feelings may occur without consciousness. This is the type of feeling that some animals have, though it’s uncertain whether or not animals are conscious of their feelings.

In day to day life, emotion is regularly used to refer to observable behavior. It is possible to hear a friend tell another "you look sad", or "why are you happy?” Such statements arise from having observed that emotion from the other person be it by facial expression, voice or body posture. On the other hand, whenever we are unsure of our loved ones mental state, we tend to ask "how are you feeling?" or "are you feeling any better?” Then it is up to the other person to communicate what they are feeling to us. They could say "I am feeling low, or am much better than yesterday".

Thus, we can refer to feeling as being an inferred state that is private to an individual. Candland (1997:pg 4), goes to give a different distinction where he refers to emotions as being intense and short lived while feelings are weak and permanent. This distinction is supported by Parkinson (1995), who defines emotions as being a temporary shift from a relatively stable baseline (mood).

Davidson (2002) seems to agree with this distinction. He terms emotion as being a relatively short event of coordinated brain, autonomic and behavioral changes that result in a response to an internal or external event, while feelings are the subjective representation of these emotions.

He defines mood as a spread affective state that is often of lower intensity (when compared to emotion) but lasts for a longer duration. Mood can occur when emotions became constant over a long period of time.

Conclusion

From the above, we can conclude that the definition of emotion seem to be dependent on the theory of emotion. There are several theories, which will be described shortly. A clear definition of emotions is a prerequisite for simulating emotions in an avatar. We cannot simulate something that is vaguely defined. The constituents of an emotion have to be clearly defined. For the purpose of this report the constituents will be stimuli (which are perceived by the agent), arousal (that is caused by the perception of the related stimuli) and cognitive processes (which will include reasoning and memory). As for the differentiation of feelings, mood and emotion, the main concern will be the later two, and how these will relate to the behavior of the character. Moods will act as an influence on the current emotional state.

3.2. How are emotions generated?

To simulate or "synthesize" emotions in artificial agents, it is necessary to have a good approximation of how these occur in the human brain. Thus this section will focus on how emotions relate to brain activity.

The most important structures involved in the production of emotions include the amygdala, hippocampus, thalamus, hypothalamus and prefrontal area. Together they are known as the limbic system. This definition results from the early labeling of the "papez circuit"[8] coupled together with the orbitofrontal cortex and basal ganglia as the limbic system or emotional brain by MacLean (1949, 1952). Later, Damasio (1994) and Ledoux (1996) added the amygdala into this system.

Its function includes evaluating information from a wide range of input systems, so as to provide emotional coding that is based on this evaluation. It also triggers an initial response, as well as monitoring the stream of emotional stimuli and responses (Smith, 1999). The structures within the limbic system must interact for this functionality to work,

Perhaps the most important of them is the amygdala. It is known to be involved in not only emotion generation but learning and memory.

Secondary to it are the hypothalamus and prefrontal area. It is important to point out that the structures that make up the limbic system, and the brain as a whole, are much interconnected thus

[8] This refers to a network of the brain that includes the hypothalamus, anterior thalamus, cingulated gyrus and hippocampus proposed by James Papez (1937)

none of them can work without the other. Smith, states that none of the subsystems has been shown to be sufficient enough to cause emotion without help from each other.

For an emotion to occur, the stimulus that acts as a signal must be strong enough i.e. above a certain threshold. The signal can arise from a subset of systems which play a part in the general process of producing emotion. These systems include sensory stimulation, conscious cognition, physiological changes such as facial nerves and body posture, autonomic nervous system (e.g. respiration and digestion), and non conscious processing by the central nervous system.

Emotion processing begins with perception of stimuli which may cause sensory stimulation. This provides the information to be processed. Some neurons carry this stimulation to the limbic system and cerebral cortex. In the limbic system, the thalamus passes nerve impulses to the frontal lobes of the cerebral cortex. Here, the frontal lobes play an active role in the experience and expression of emotion. Though the physiological changes associated with emotions are activated by the brain, they are carried out by the endocrine and autonomic nervous system.

For example when responding to anger or fear, the brain usually signals the pituitary gland to release a hormone. This hormone causes the adrenal glands to secrete the hormone cortisol which triggers what is known as the fight or flight response. This response is a combination of physical changes that prepare the body for action in dangerous situations (Gale, 2001).

3.3. Different Theories of Emotions

The ontogenesis of emotions is a controversial subject, with different theories, which seem to branch from either cognitive or physical theories of emotions. These theories will be discussed briefly in the following section, with an intent of coming up with the most suitable theory that would be the base of modeling emotions in this project.

3.3.1. Cognitive vs. Physical (biological) approach

This seem to be the most common classification of the theories of emotions, and the rest of the theories, one way or the other, seem to fall under this categorization. The cognitive aspect of emotions emphasizes the mental component while the physical part emphasizes the physiological component.

In the physical approach, emotions are taken as an experience of bodily changes, for example, sweating of the palms or increase of the heart rate. This approach was supported by William

James (1884). It can be argued that this physical approach to emotions is the same as sensation. Whereby, in daily language sensation refers to "an *indefinite generalized body feeling*" or "*a perception associated with stimulation of a sense organ or with a specific body condition*"[9].

This distinction is given by Champandard (2003) where emotions are described as taking cognition into account while sensation is the change in body/physical aspects. Picard (1997) relates the physical theory of emotions to sentic modulation i.e. "the influence of emotion on bodily expression." Sentic modulation includes facial expression, gesture, posture and voice inflection. According to Charles Darwin, these are the primary means of communicating human emotion.

3.3.2. Exponents of physical approaches

Some of the most prominent supporters of the physical approach include Walter James (1884), Walter Cannon (1915), and most recently Bindra (1969).

3.3.2.1. James (1884)

This is one of the most famous emotion theories, and it emphasizes on the physical components of emotions. It states that feeling the bodily changes that occur during human's perception is actually what constitutes an emotion (James 1890, p 449). This implies that emotion is provoked by the activity of the cerebral cortex[10] as a response to a change of the body organs and muscles. Cannon (1915) disagrees with this theory stating instead that emotion arises when the thalamus is aroused by an element of the environment but he still believed in the physical basis of emotion.

This theory is in agreement with thinkers like Darwin who have listed the correlation between emotional states and changes in the body. Darwin's list of fear symptoms include: widely opened eyes and mouth, raised eyebrows, stiff posture, a racing heart, cold perspiration, trembling etc.

This theory can also find support in Eckman's work (1975) which will discussed in section 3.4.1. Discrete (basic) emotions where he defines basic emotions based on an extensive cross cultural research on bodily expression of emotions. The research results were that each emotion can be associated to a unique body pattern, and this pattern is identifiable cross culturally. Some common critiques of this kind of theories are Prinz (2003) and Harre (1986) who have argued that not every emotion can be aligned to a bodily change. Examples are guilt and loneliness.

[9] This are definitions from the freedictionary.com. An online dictionary

[10] The part of the brain that deals with functionality like voluntary muscle movement and sensation.

3.3.2.2. Bindra (1969)

This approach is also known as the central motive state (CMS), and it suggests the integration of emotional and motivational feelings. Usually, emotion is thought of as behavior elicited by external stimuli whereas motivation comes from within. Bindra's model unifies the two under CMS. Thus CMS can be defined as the outcome of a change in the neural state of an organism. This change requires both environmental stimulation and physiological arousal.

The CMS affects responses in two ways. Environmental stimulation may lead to selective attention and differences in threshold for responding due to the fact that it may inhibit the perception of other stimuli. The physiological level of responding may influence whether a discharge occurs or not. This model has an advantage of highlighting the active aspect of the central nervous system in learning, appraising, experiencing, judging and evaluating (Candland, 1977). Thus under this approach the CMS can be classically conditioned, i.e. an organism can be trained to react in a certain manner when subjected to the same stimuli.

3.3.3. Exponents of cognitive approaches

The most famous proponents of the cognitive approach include Schachter, Arnold and Lazarus who will be discussed briefly.

3.3.1.3. Schachter and Singer (1962)

This theory is also known as the two-factor theory of emotion. It states that emotions constitute the interplay between physiological arousal and cognitions that cause that arousal. It argues that when people become aroused they look for cues as to why they feel that way (an explanation). If the explanation is non emotive, then the individual will not experience an emotion, but if it is, then they experience the emotion. In such a case, the degree of arousal determines the intensity of the emotion.

To support this theory Schachter and Singer carried out experiments with 4 groups of people.[11]

- adrenalin ignorant(participants were given adrenalin injection and not told of its effects)
- adrenalin informed(participants were given adrenalin and warned of its real side effects)
- adrenalin misinformed(participants were given adrenalin and informed of its fake side effects)

[11] A complete description of this experiment is attached in the appendix.

- control group (given a placebo injection that had no effect, and they were not informed on what to expect)

Participants were then subjected to either euphoria condition (where a stooge in a room would try to amuse them) or an anger condition (where the stooge tried to annoy them). The results of the experiments showed that the informed group were the least happy and least angry because they understood why they felt the way they did, and thus they were not susceptible to the stooge as the other groups were.

The theory disagrees with both Cannon (1915) and Lang (1887). Scholars like Reisenzein (1983) argue that this is the most influential cognitive approach to emotions, and it has also been influential in areas of research other than emotions. These include Eating and Obesity (Rodin, 1981, Schachter, 1971), drugs (Nesbitt, 1974, Pliner and Cappell, 1974) and psychopathy (Schachter and Latane, 1964). The biggest critiques of this theory include Maslach (1979), Leventhal(1980) and Marshall & Zimbardo (1979).

Marshall and Zimbardo (1979) did replication experiments on Schatchter and Singer's theory. They found no effect from arousal and cognition manipulations. Maslach on the other hand found that subjects were less likely to imitate the stooge and more likely to apply negative emotional labels to their arousal regardless of the social situation that they were placed in.

3.3.3.2. Lazarus (1991)

This theory builds on Schachter and Singer's. It states that an emotion evoking stimulus triggers a cognitive appraisal (either consciously or unconsciously), and based on the result of this appraisal, an emotion or physiological arousal follow. This infers that a thought must occur before any emotion or physiological arousal.

A good demonstration to show how this theory works is:

A woman is in a gas station. Two young men with hooded sweatshirts almost covering their faces completely, enter the station with their hands in their pocket. The woman may think that they are there to rob the place. She may begin to tremble, have faster heart rates, deeper breathing and at the same time experience fear. This may result in her walking out of the shop quickly.This theory emphasizes highly on the cognitive aspect.

It is worthwhile to note that there are other cognitive theorists like Arnold (1970) who added the element of using past memories to evaluate current situations. This interaction between the current situation and evaluative memories results in imagination activity in the individual (Strongman 1978)

There is also a distinction on the occurrence of emotion based on behavioral and grand approaches. These are not as popular as the physical/cognitive theories.

3.3.4. Grand theory approaches contains

Plutchik models his view of emotions from three aspects, the biological, evolutionary and cognitive processes (Plutchik 1977). He identifies eight basic emotions and their combinations as discussed in section 3.4.4. Secondary/Complex emotions Izard's model on the other hand is taken to be the most comprehensive of the 1970s. It describes nine unique emotions (based on facial and physical activities) which produce the human motivational system. Izard (1977) identifies emotion as being activated by interaction between an individual and the environment, and also by intra individual processes. These include three types of perception and intra individual processes like obtaining memory, imagination, proprioception of motor activity and spontaneous activity of the neuromuscular systems.

Behavioral theories assume that emotion is subject to the nature of a reinforcing stimuli and classical conditioning. Theories that fall under this include Watson (1929) and Millenson (1967). These theories bring in something new that both physical and cognitive theorists seem to have neglected, and that is the power of learning on emotion elicitation which is the main fact behind reinforcing stimuli and classical conditioning. These will be discussed in detail in section 6.3.2

3.3.5. Conclusion

Having discussed what emotions are, and the different theories as to how they arise, we will now give our definition of emotions that this report will be based on. An emotion is either a physiological or cognitive process that arises from an arousal of the senses caused by the relevant stimuli. It involves processes for cognitive appraisal, interactions between an individual and the environment and physiological responses. The stimuli can be physical or purely cognitive e.g. memory.

This description of emotions is based on combining both the traditional and cognitive approach. The choice for doing this will become evident when the difference between primary and secondary emotions is discussed in the next chapter.

3.4. Types of Emotions

Having tried to explain what an emotion is, what constitutes it and how it occurs; the next section will focus on differentiating emotions with the intent of identifying the emotions that will be the focus of this work.

There have been several categorizations of emotions depending on whether they are basic, dimensional, primary or secondary. Let us take a look at these categories.

3.4.1. Discrete (basic) emotions

These are emotions that are claimed to have existed historically and evolved with time. They are assumed to be universal and thus found in most cultures. It is difficult to classify this type of emotions. Several theorists have come up with different categorization of basic emotions. One of the early emotions theorists, Tomkins(1962) stated that the basic types of emotions were fear, anger, anguish, joy, disgust, shame, interest and surprise.

Turner (2000), describes eight basic emotions defined by Plutchik (1980) when he developed a model called an emotional wheel. These emotions are Fear, Surprise, Joy, Anger, Acceptance, Expectancy, Disgust and Sorrow. They can be mixed to form a primary, secondary and tertiary level of emotions. In the late 80's Ortony, Clore and Collins collected a list of the common emotions, and the most prominent four were anger, fear, sadness, joy, surprise and disgust, followed by surprise (Picard, 1997: 168). Their classification is supported by (Eckman 1992, 1992a) who has linked the six basic emotions to those which have distinctive universal facial expressions associated with them.

Johnson-Laird and Oatley (1987) distinguished the basic emotions by analyzing words for emotion. They analyzed 590 English terms describing emotions, and concluded that the words could be based on five basic emotions which are fear, anger, happiness, sadness and disgust.

The main disadvantages of this classification is that though they are deemed to be universal, in some languages, there is no existence of terms for primary emotions. This was shown in studies by Wierzbicka (1992) who claimed that basic emotions are cultural objects of the English language. She exemplified this by stating that the Ilongot language of Philippines and the Ifaluk language of Micronesia do not contain a word for anger. She suggest for using words like "good" or "bad" instead, since these are more universally recognized (Herbon et al, 2005). The only problem with this is that "good" or "bad" are huge categories and thus different discrete emotions can be labeled under these. Thus it's not easy to define an isolated emotional state using such terminology

3.4.2. Dimensional emotions

Authors such as Lang (1995) and Schlosberg (1954), disregarded the basic emotions, and instead worked with a continuous dimension of emotions. This calls for various mapping between continuous dimensions of emotions and the basic emotion categories. The basis of this distinction arouse from the findings of Russell(1980), who conducted self report studies and discovered a specific pattern in the way emotions were spread. This pattern formed a two dimensional space. This configuration is known as the Circumplex of Affect since the pattern is circular as shown in figure 1.

The two common dimensions are arousal and valence.

Arousal represents the degree of intensity of the emotional response while valence represents the positive or negative dimension of the feeling.

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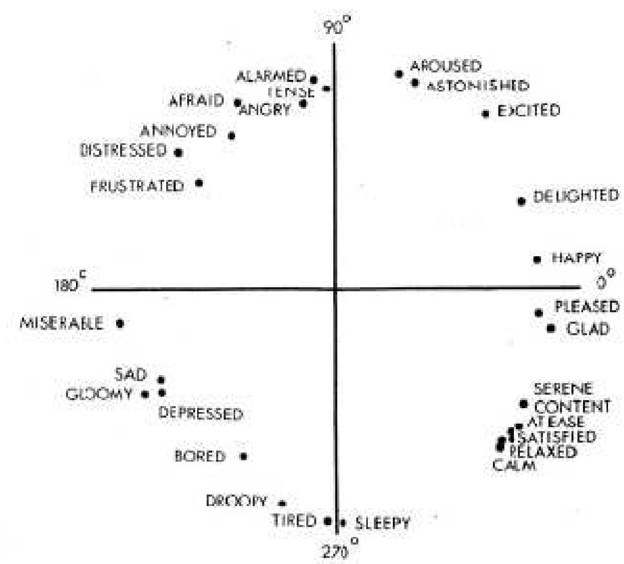


Fig 1: Russel's model of Circumplex of Affect showing how some basic emotions can be plotted in the Valence-Arousal space.

The advantage of using this method of classifying emotions is that the related emotions are in a way grouped together and there is a smooth transition from one emotion to the next. Numerous researchers e.g Lang, have worked with this method instead of with discrete (basic) emotions.

Lang (1984) argues that self reports across subjects are more reliable with respect to dimensions than with respect to discrete categories.

Picard (1997) argues that a lack of definition of emotion, coupled with lack of agreement on whether to classify emotions discretely(as basic emotions) or using the continuous space are obstacles to the goals of synthesizing and recognizing emotions using computers.

From the above review, we can conclude that at least four emotions appear to be common in all the classifications. These are fear, happiness, sadness and disgust. This is supported by Turner (2000), where most researchers agree that these are the prominent emotions.

3.4.3. Primary Emotions

These may be regarded as being the same as basic emotions. This is due to the fact that when stating the emotions that fall under the two categories i.e. basic and primary, then there seems to be a consensus. Some of the emotions include fear, happiness, sadness and disgust just to name a few. There are several theories on what constitutes basic emotions.

There are theorists like Damasio (1994) who believe that basic emotions are innate and thus these theorists label these types of emotions to be primitive. This is due to the fact that they arise automatically in the low-level limbic circuit. They can be thought of as being a “reflex” mechanism that is inborn. The term reflex is used since they occur unconsciously. These emotions are evolutionarily crafted in the limbic system and thus they occur in both humans and animals. They also involve physiological reaction and can be detected by sensors or viewing posture and facial expressions.

Paul Ekman (Eckman and Friesen, 1969) characterized the basic emotions by studying the universality of facial expressions. He discovered that despite racial, cultural and geographical differences, facial expressions that convey emotions are the same all over the world.

From the above study, Eckman classified basic emotions as being anger, fear, disgust, happiness, sadness and surprise. Plutchik (1980) describes eight basic emotions which arise as follows:

- Aggression is emotion connected with the exclusion of an obstacle, matched by rage
- Incorporation is reception of the exterior stimuli
- Protection is emotion whose aim is to avoid danger, matched by fear
- Orientation is reaction to an unknown stimulus, something like surprise

- Deprivation is emotion connected to the loss of an object or some psychological field similar to sadness
- Research is emotion connected to the examination of the environment, like curiosity
- Reproduction − emotion which appears during extension of species, like joy
- Rejection is emotion which appears when something harmful enters the body, matched by disgust

This classification is confusing because some of the words that he uses to label emotion such as research and reproduction are not universally used. These could instead be viewed as being the consequences of the emotion. For example, curiosity (an emotional state) would make an individual research or joy would cause humans to reproduce an event.

Reich, one of Freud's most brilliant students, who had his books burnt by court order in 1956 came up with an interesting way of differentiating primary from secondary emotions.
He viewed primary emotions as originating deep within the organism. This can be equated to Damasio's view of these emotions as being inborn. He saw these emotions as being a necessity to human's health and sanity. This is equivalent to Plutchik's novelty of seeing basic emotions as being necessary for survival.

To paraphrase Reich (1949):
Primary emotions of life have a rational functionality. Pleasure has the function of discharging surplus energy. Rage has the function of eliminating life threatening situations, sadness expresses the loss of loved ones while longing expresses the desire for contact. This was his defence to the once common notion that emotions spring from drives and are therefore irrational.

3.4.4. Secondary/Complex emotions

These have been referred to by several different names including complex, blended, combined and a higher level of emotions. We will refer to them as secondary, as this makes the distinction easier from primary emotions.

In an experiment named "Lost Luggage", Scherer & Ceschi (2000) and colleagues were able to show that some events may give rise to several simultaneous emotions. This was observed when passengers at an airport were informed that their luggage was lost and thus asked to verbalize their emotional state. Some of the subjects indicated feeling different emotions at the same time. This is secondary emotions.

Damasio (1994) distinguishes primary from secondary emotions by identifying whether they are generated via cognitive processes or not. His idea is that there are certain features of stimuli to which we react emotionally first. These secondarily, activate a matching set of feelings and cognitive state. Thus primary emotions are triggered by external or internal stimulation of various sense organs, and secondary emotions as those which are triggered by purely cognitive events.

Secondary emotions arise later during an individual's development when systematic connections are identified between primary emotions and categories of objects and situations (Picard, 1995). Due to the involvement of cognitive processes, secondary emotions are taken to be more sophisticated. Thus they are likely to involve high level cortical processing that involves both prefrontal and sematosensory cortices in addition to limbic structures. They also require conscious awareness in order to occur.

Supporters of inborn primary emotions such as Izard(1977) and Plutchik (1980) argue that secondary emotions arise from combining primary emotions. However, Plutchik does not use the term “secondary” but “dyad” instead. Dyad refers to a combination of any of the primary emotions. This dyad can be primary (often felt), secondary (sometimes felt) or tertiary (seldom felt). He came up with this distinction by conducting a test where he asked the individuals to state which types of primary emotions form a complex emotion and also stating a complex emotion and asking what its constituents are. This kind of test will be used later in this project to test if people are aware of the existence of secondary emotions.

Social constructivists on the other hand, term secondary emotions as social constructs built on a set of elementary emotions (Taylor & Fragopanagos, 2005). This is evident in Kemper (1987) who argues that there are four physiologically grounded primary emotions: fear, anger, depression and satisfaction. These are universal and ontogenetically early to emerge.

Secondary emotions such as guilt, shame, gratitude, love and pride are acquired through socializing agents who define and label such emotions while the individual is experiencing the autonomic reactions of one of the primaries. Hence the authors argue that guilt is a socialized response to arousal of the physiological conditions of fear while pride is a socialized response to the physiological conditions of satisfaction.

Reich (1949), once again, had his own unique explanation as to why secondary emotions occur. He argued that they occur when primary emotions were blocked. This can be deemed to be true since a primary emotion and its associated secondary emotion cannot occur at the same time. For example, one cannot be alarmed and surprised at the same time.

He also regarded secondary emotions as being complex, frustrating, tending towards self absorption and addiction. It is disputable that this fact does not apply to all secondary emotions. Love and jealousy may fall in the above categorization of being complex, frustrating, self absorbing and addictive, but the same does not hold for other emotions like alarm, remorse, disappointment or submission.

Psychoanalysts Oatley & Jenkins (1996) have an opinion on secondary emotions which is almost close to Reich. They call them defences. This is due to the fact that they emerge to cover certain primary emotions which are unacceptable or not known. For example men who have been never to be afraid, tend to hide their fear with anger. In this case anger is the secondary emotion.

According to studies by Martin et al (2006), secondary emotions occur in different ways. These include superimposition of emotions, masking of emotions, and suppression of one of the emotions or the overacting of one emotion. Masked emotions occur when one of the emotions has a higher intensity and thus it is used to control the outward physical expression. The same applies on the suppression or overacting of one of the emotions.

Superimposed emotions are modelled after the theory of superimposed waves. The two emotions are mixed together to form a new type of emotion. This is the kind of emotion that Plutchik (1980) was referring to.

There are 3 types of secondary emotions:

- Purely central secondary emotions. These involve redirection of ongoing cognitive processes (such as reasoning, planning, reminiscing) but without producing any new detectable external behavior. In other words, these are emotions that produce some internal changes in cognitive processes but which cannot be noticeable as a behavioral change by an external observer.

- Partly peripheral secondary emotions. These occur when global signals change both the central and externally detectable states of the body (this is referred to as sentic modulation by Picard).

- Purely peripheral secondary emotions. These produce only peripheral changes without any modification on the internal deliberative processes. This classification is partially supported by Sloman(1999,2003).

Secondary emotions are hard to visualize, and so far, they have been expressed in terms of blending facial expression of the discrete emotions that constitute the blended emotion by using fuzzy logic. Or, showing one emotion on the upper face, and the other on the lower face.

3.4.5. Conclusion

Secondary emotions are not as widely researched as primary emotions. The basis of this could be due the innate nature of the latter coupled with the fact that they are not deemed a necessity for human survival. Nevertheless, the research above indicates that basic emotions are more like "reflexes" since they do not require social consciousness whereas secondary emotions require cognition in order to occur. That would give the notion that modeling primary emotions would not be a daunting task for designers/programmers. However, for modeling of secondary emotions, since cognition has to come into play, there may be a requirement to add some artificial intelligence into the game. Some of the AI algorithms that may be used will be discussed in the next chapter.

4 Artificial Intelligence

4.1. Introduction

This chapter examines the different AI algorithms that could be used to model emotions. Their pros and cons will be examined in view of coming up with an appropriate model for creating artificial emotions.

4.2. Neural Networks

This is a computational model inspired by how the brain processes information, and thus it's based on the biological neural network.

It is composed of a large number of neurons (highly interconnected processing elements) that work in unison to solve specific problems.

Neural nets work with two sets of data from the real world. These are all the inputs to the system, and the proper outputs related to the input values. The first data set is used to train the neural network so that it can produce the correct output for each input values. The second data set (also known as the validation set) is then used after the neural net has been trained to make sure that correct output has been produced in relation to the input data (Siler, Buckley, 2004).

The simplest form of neural network is known as a perceptron. Perceptrons consist of a layer of weights mapping a set of inputs onto a single output. The mapping of input to output is achieved with a set of linear weights connecting the function inputs directly to the output as shown in fig.2 below:

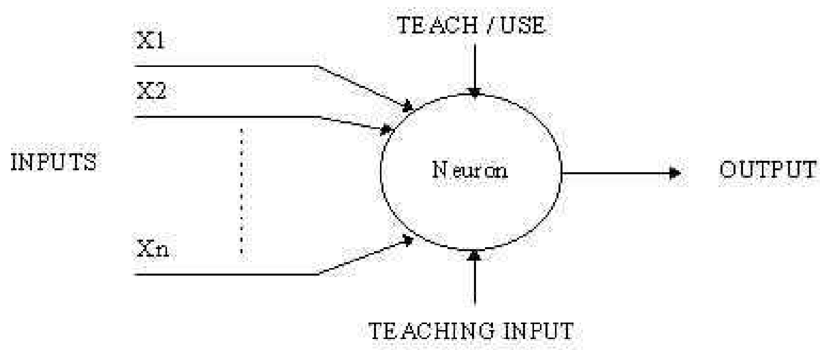


Fig 2: A simple neuron

To come up with the output y, the input pattern ->x, is filtered through the network in two stages. First computing the next sum, and then applying the activation function.

The net sum is simply the addition of all inputs multiplied by their weights. This process is also known as a combination function (Stergiou and Siganos, 2004).The second process is achieved by passing the output y, through an activation function. This function outputs a result based on the sign of the net sum. If the net sum is positive, the output is set to 1, and if the output is negative, the output is set to a negative value (Champandard, 2003).

The algorithm is shown below in pseudo code:

```
net_sum=0

for all i

   net_sum += input[i] * weight[i]

end for

output = activation(net_sum)
```

Though there are many advantages of using neural networks, the main one is that it does not require the thinking patterns of an expert to be explicitly specified. This fact acts as a major plus when comparing it to expert systems like fuzzy logic.

Other advantages for using neural nets arise from the fact that they are good for deriving meaning from complicated or imprecise data. This implies that they may be a good tool for extracting patterns, determining suitability of a behavior and also in detecting trends that are too complex for human or ordinary computers to detect. Neural nets also have the capability of adaptive learning. This is achieved by learning how to do tasks based on the training data. To date, the key disadvantage of neural nets is the substantial training set that it requires.

Judging by its pros and cons, neural nets can be best used in situations where there is substantial training set data, and there is no knowledge/interest in the relation between input and output data. Neural nets have been used as a tool for modeling both the physiological and psychological properties of the brain region due to their representation of the biological neural network.

This is evident in works involving studying facial expression for emotion recognition (Pagget and Cottrell, 1997), the interaction of emotion and attention (Taylor, Fragopanagos 2005), studying a multi modular global brain (Taylor, 2005), emotion estimation using physiological measures (Yoo et al, 2005), modeling the relationship between emotion and memory (Tanaka et al, 2000) and also in studying the symptoms of autism (You et al, 2007). These are just a few examples as the work in this area is quite vast.

4.3. Finite State Machine

A finite state machine (FSM) is a model behavior for a system composed of a finite number of states and transitions, coupled with actions between those states. It consists of four main elements:

- Inputs which are either internally or externally generated.
- States which define behavior and can produce actions.
- State transitions which are simply movements from one state to another
- Rules or conditions which must be met to allow a state transition.

A finite state should have a starting point which is known as the initial state, and a current state which remembers the product of the last state transition. Inputs act as triggers, and they cause an evaluation of the rules governing transitions. There are two types of finite state machines, deterministic and non- deterministic. For deterministic, as the name implies, given an input and the current state, the transition state can be predicted. For non deterministic, the state transition cannot be predicted. Finite State Machines have mostly been used in the game industry to model character's behavior. The character can be assigned states, events and action performed.

FSMs are simple to use. This characteristic makes them quick to design, implement and execute. This makes it easy for non programmers to implement them. It allows for easy testing since given the input, the state transition can be predicted. It is easily adaptable to incorporating other techniques.

One of FSM's biggest disadvantages is its predictable nature which makes it undesirable for computer games. This problem however can be solved by combining it with fuzzy logic, thus giving rise to fuzzy state machines (FuSM) which are non deterministic. Implementing an FusM is quite flexible. It may be implemented by applying fuzzy values to inputs (fuzzifying) or adding the fuzzy values to state transitions.

FSMs have been used in web applications as they provide an easy way of dealing with unexpected events or user behaviour, since they create deterministic responses. They have mostly been used in adventure games where the adventure is modeled as an FSM. This is visible in games like JADVENTURE[12] to determine the actions of the character

Despite the above facts, FSMs are declining within game genres due to other factors which include:

- They are difficult to reuse across multiple games or in different parts of the engine. This results in most games instead using scripting languages as these can be reused.
- They also do not adapt well to concurrency. If several finite machines are run in parallel, the result is usually a deadlock which is a nightmare for any programmers.
- They are low level (i.e. they do not support Meta programming), and thus the developer may end up rebuilding the same behavior over and over again.

For these, amongst other reasons, the industry is moving towards other alternatives like behavior trees[13] (Champandard, 2007).

4.4. Fuzzy Logic

Fuzzy logic is a multi-valued logic that unlike Boolean logic, allows for intermediate values to be defined between conventional evaluations. It was developed by Lofti Zadeh in 1965, and works with degrees of truth (varying between 0 and 1) assigned to variables. Thus it allows for definitions

[12] a graphical massive multiplayer online adventure(MMORPG) written in java

[13] These focus on increasing the modularity of the states by encapsulating logic transparently. This can be done by using nested states. Transitions are moved to external states so states become self contained

like "pretty cold", "quite warm" instead of viewing variables as being either true or false. Thus, it can be termed as reasoning that is approximative.

The fig.3 below shows a drawing of a fuzzy controller that will be discussed briefly.

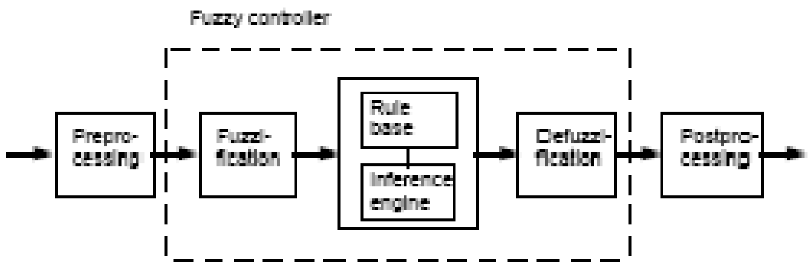


Fig 3: from Matlab fuzzy logic toolbox, showing the fuzzy controller

Some of the main concepts in fuzzy logic include:

- Fuzzy sets

A set is any collection of objects that can be treated as a whole. Members of a set characterize it completely. Sets can be defined explicitly for example, the list of members A ={0,3,4,7}, or implicitly with a predicate, for example x>10. The only difference with fuzzy sets is that they have more than an “either or” criterion for membership. Membership depends on a grade/truth value that ranges fro 0 to 1. This grade of membership was proposed by Zadeh(1965), as a means of ensuring that transition from membership to non membership is gradual.

- Fuzzy universe and variables

The universe or universe of discourse is simply the input space. It contains all the elements (variables) of the fuzzy set.

- Fuzzification

This is the process of converting each piece of input data to degrees of membership by a lookup of one or several membership functions.

- Membership functions

Every element in the universe of discourse is member of the fuzzy set to some degree. Membership function is a curve that defines how each point in the input space is mapped to a degree of membership that ranges between 0 and 1. There are different membership functions ranging from triangular, trapezoidal, Gaussian to singleton. It is advisable to start with triangular membership function as it is the easiest to implement.

- Rules

Rules are normally in the if-then format, but they can also be represented in other formats like relational, graphical or tabular linguistic. If-then formats, though not so compact, are easily understandable, and simple to change into programming code. If more than one rule exists for a particular input, then they are combined using logical operators (Siler, Buckley, 2004). Relational representations are more compact and thus better suited for experienced users who need a quick overview of the rule base. It is also good for storage in a relational database. Tabular linguistic formats are even more compact. If the number of inputs is greater than 2, then the table grows to an n-dimensional array and this can be user unfriendly. Graphical format represents fuzzy membership's curves. It is more user- friendly as it displays the inference system better, when compared to the other formats, but it also takes more space on a monitor.

- Defuzzification

This is the conversion of the output fuzzy set into a crisp output signal[14]. This is practical in situations like decision making where you need to take an action

- Fuzzy inference systems

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. It involves all the prior mentioned parts of the system such as membership functions, rules and logical operators. This mapping provides a basis for decision making as well (Jantzen, 1998).There are three popular types of fuzzy inference systems (FIS). These are Mamdani, Sugeno and Koskos.

A Mamdani fuzzy inference system (FIS) has fuzzy inputs and a fuzzy output (Mamdani & Asiljan, 1975). In this system, crisp input is first transformed using a fuzzifier into a set of linguistic variables. The fuzzy inference engine uses the input variables and rules (in the fuzzy rule base) to derive a set of conclusions. From this set of conclusions, a defuzzifier is used to convert the output set into a crisp number (Jassbi et al, 2007). This is as shown in fig.4 below.

[14] This is supported by Matlab fuzzylogic toolbox

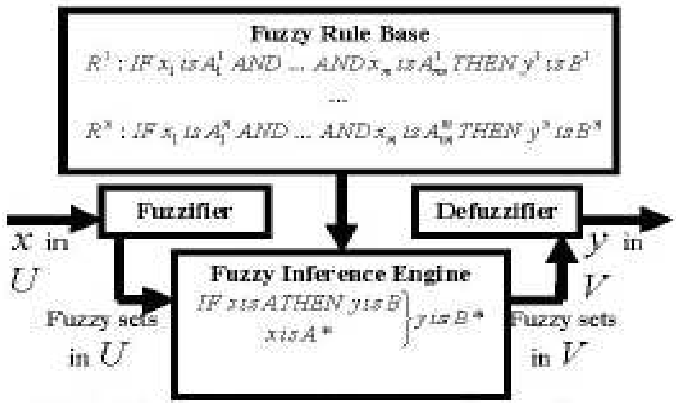


Fig 4: A scheme showing Madmani fuzzy inference system (adapted from Wang, 1994)

Tagani fuzzy inference system (Takagi and Sugeno, 1985) has fuzzy inputs and a crisp output. The system works likes Madmani's FIS with the only difference being that it does not require defuzzification to come up with a crisp output. The result is instead obtained as a weighted average of the rules logic together with an assigned weight. This is as shown in fig.5 below.

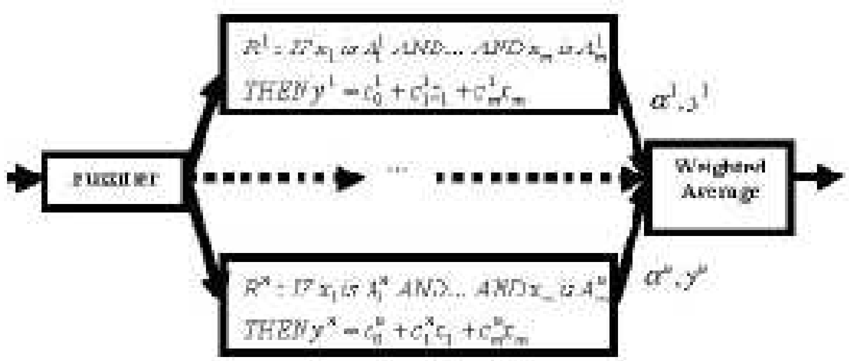


Fig 5: A scheme showing Sugeno fuzzy inference system.

Madmani FIS are more widely used for decision support applications due to the fact that they are more intuitive in nature of the rule base (as they are linguistic terms). The same cannot be said of Sugeno FIS as it does not have a direct semantic meaning. Sugeno's FIS is more flexible. It translates into more degrees of freedom. In terms of computation, a Sugeno FIS is more efficient than Mamdani because it does not involve the computational expensive defuzzification process.

Fuzzy logic has several advantages including the fact that it is easy to understand, and quite intuitive because it is based on linguistic terms. It is tolerant to imprecise data and also acts as a good tool for expressing expert and common sense knowledge. Fuzzy logic has been used as a tool for modeling emotions in various applications because it mimics human logic. It does not work like traditional logic where something is either true or false (a crisp value) and no in between. Emotional states have no boundaries, and thus it is not suitable to represent them using Boolean values. It is also possible to experience two or more emotions at the same time. An individual can be a bit sad, and very annoyed at the same time, or a bit scared and in an anticipation mood at the same time. This kind of state cannot be represented using the ordinary Boolean logic.

Fuzzy logic has been used to model emotional intelligence in a pet (El Nasr, Loerger and Yen, 1998), for detecting severity of traumatic brain injuries (Guler, Tunca and Gulbandilar, 2008), for perception and expression of emotion in interactive robots (Mobahi and Ansari, 2003) and also for personalized facial recognition where it was combined with neural networks (Kim, Bien, and Park 2003). This list is by no means exhaustive.

4.5. Reinforced Learning (RL)

Reinforced learning dates back to the early days of cybernetics and work in statistics. It is a trial an error mode of working that is achieved through interacting with an environment. In such a case, an agent learns from the consequences of its actions and it selects its actions on basis of past experiences (exploitation) and also by new choices (exploration).

A standard model of RL consists of input, the current state, environment, actions and output. The action is used to change the current state of the environment. The value of this transition is communicated to the agent through a scalar reinforcement signal. This signal can be either negative (punishment) or positive (reward) depending on the action taken. Thus agents try to choose actions that maximize values of the reinforced learning. (Kaelbling, Littman & Moore, 1996).The most important parts of RL are the environment, the reinforcement function and value function.

The environment should be at least partially observable to the agent. The reinforcement functions maps actions to rewards (reinforcement) in form of scalar values. An RL system designer must define a function that properly defines the goals of the RL agent. Finally, a value function maps states to state values using any type of function approximator like multi layered peceptron, lookup table etc.

Here state values (of any state) denote the sum of all reinforcements received when starting in that state and following some fixed policy (a mapping from states to actions) to a terminal state. (Harmon & Harmon, 1996). Some of the common RL algorithms include Q-learning (Watkins, 1989) and SARSA (State Action Reward State Action)

In games, RL is mostly used to control an agent by trying out different actions and using rewards (the obtained feedback) to strengthen (reinforce) its behavior. RLs have also been used to navigate robots with rewards being given if a position is reached, and punishment subjected if the robot makes a collision. This kind of reward system determines the robot's most desired behavior.

In addition they have been utilized in elevator control, traffic control, network routing, playing games like chess etc. It has also been used for action selection in robotic control (Ayesh, 2004), to investigate the impact of believability on learning (El Nasr et al, 2000), to test the usefulness of emotions in artificial creatures (Gadhano & Hallam, 2001) and also in investigating the importance of historical information on action selection (Wang & Laird, 2007)

The main advantages of RL lie on its simplicity i.e. reward/punishment system. It is also a good way of implementing how memory works in that the current decision will be based on rewards or punishments that an individual got in the past. Thus of course, the individual will opt for an action(s) that led to the most reward.

4.6. Conclusion

From the above, it is visible that all of the above algorithms can be used one way or the other to implement the synthesis of emotions. It would seem like the easiest to implement would be a FSM, followed by RL, Fuzzy and finally neural nets[15]. The difficulty of neural nets is being assumed due to their need for training data which may not be available. If dealing with only primary (discrete) emotions, which were earlier defined, as being almost reflex like then a FSM would be sufficient. Otherwise, if the aim is to synthesize secondary emotions then fuzzy logic would seem like a more logical option. This is due to the fact that they provide for the integration of different circumstances, and this is the basis of secondary emotions (i.e. they are the integration of primary emotions).

Finally, if the work is based also on simulating how memory plays a role on the current emotion, then the logical choice would be RLs. This is because they can allow for the influence of current state by past events.

[15] This is purely a subjective opinion based on the discussed facts.

5. Pre-Analysis Conclusion

The last few chapters have given an outline from believability to emotions and AI algorithms.

The author of the report stated how emotions are a prerequisite to believability. To have believability in games we need emotions amongst other things. These emotions have to be generated somehow and placed within the game environment. To be able to do this, AI comes into play. Different AI algorithms were discussed with a conclusion on which was best for modeling emotions under different circumstances. A casual relationship has developed here. Believability needs emotions, emotions need AI, and AI needs believability to seem "real".

How can this relationship be implemented and maintained?

5.1. Initial Problem formulation

From the above pre-analysis, it is clear that that the three main topics believability, emotions and AI are interrelated neither can function properly without the other. Thus the initial problem will be as stated below:

How can we incorporate emotions into games using AI so as to enhance the believability of NPCs behavior?

6. Artificial Emotions

6.1. Introduction

This chapter will begin with investigating the role of emotions in AI and in games. After wards, a brief overview will be given on how to activate emotions both within a laboratorial context and in a virtual environment. This will be followed by a discussion on how to model and represent emotions, coupled with the effect of the emotions on decision making. Finally, examples will be given of successful implementations of theoretical and computational emotional models.

6.2. Role of Emotions in AI and in games

This section will try to explain the role of emotions in games in general, followed afterwards by the role of emotions in AI.

Marvin Minsky, one of the pioneers of AI, has characterized this notion of separating the mind and the brain as being a disaster. This is a statement that would have not been valid before the big cognition revolution. This was the revolution of bringing feeling (emotions) into thinking. It is claimed to have been brought about by young MIT scholars around 50 years ago. Up till then, most scholars insisted on a clear distinction between thinking and feeling. These revolutionary scholars, including Noam Chomsky brought about the cognitive revolution, also termed as bringing cognition into psychology. Previously psychology had been based on behaviourism[16]. This revolution was built on the notion that it is possible to study the actual processes of thoughts with scientific precision.

A part of the success of this revolution is owed to the invention of the computer which became an intriguing metaphor for the human mind. The cognitive revolution has had bearings in many fields including marketing, design, computer games and many others. For example Norman (2004) introduces a framework of analyzing products in a holistic way to include their attractiveness, behavior, and the image they present to the user and owner. These aspects of a product are identified with different experience levels of processing by people: visceral, behavioral and reflective. Behavioral is about functionality, Visceral refers to the look and feel of the product, while reflection is about one thoughts afterwards, how the product makes the person feel.

In games the behavioral aspect can stem from being that a game "*is a learning tool for a systematic demonstration of a concept*" (Bura, 2008). In games, the behavioral and reflective aspects relate to how games have an emotional impact on their players. Following Norman, if we look at the visceral level, the question to ask would be "How does the game make the player feel?" and the reflective would be "How does it make the player feel afterwards i.e. after playing the game?" Feeling here is synonymous to the emotional state. Thus to be able to achieve these two types of processing in games, emotions have to be involved.

Bura (2008) has described a given game state using game-play variables to show the relevancy of emotions in games as shown in fig 6 below:

[16] Studying psychology in relation to behaviour

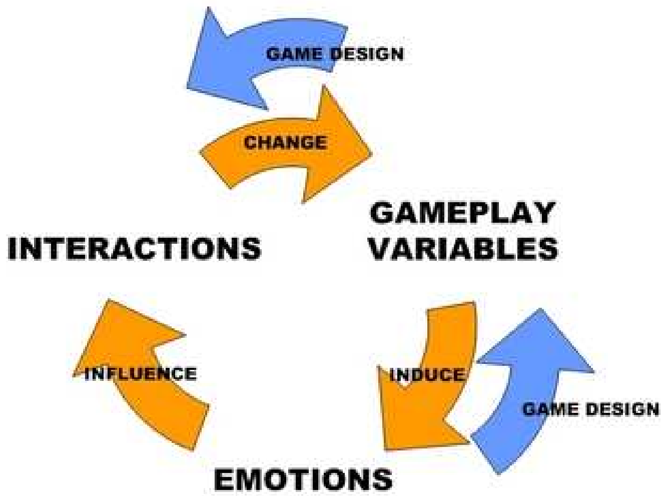


Fig 6: showing the role of emotions during a game state

From the above diagram, while playing, the player will interact with the game and produce changes in the game variables. This will induce emotions in the player. For example, an increase in the player's health bar would make him more confident, and vice versa for a decrease in his health bar.

On the other hand, the player's emotions influence how he interacts with the game. For example being less confident would make him take less risks, pride may keep him chasing a high score and boredom may result in halting play altogether. It is important to note that different players will react differently to a given situation at any point in time. Situation A may result in happiness in player 1, and frustration in player 2. The emergence of these two different emotions will affect the players' interaction with the game in different ways. Player 1, due to being happy may be more motivated to beat the "highscore"[17], while player 2 may decide to quit the game due to the frustration. The emotions may stem from the dynamic interaction with the game (as shown above), or from the result of carefully crafted sequence of events.

Bura notes that to incorporate emotions in games, most game designers are forced to work backward around the above shown cycle in fig. 6. That is, they try to predict the player emotions from changes in the interactive system. This is a challenging task because as noted earlier, players react differently to given situations. Thus this kind of design involves a lot of user tests.

Rebenstrunk (1988) describes the new catchphrase to be AE (Artificial Emotions) instead of AI. He attributes this to the failure of classical AI coupled with the fact that a lot of AI researchers have

[17] A term used in games to indicate the highest score achieved by the past players

come to accept the fact that emotions are imperative for the functioning of an "intelligent" computer. This idea is supported by Picard (1997) who is of the opinion that emotions are relevant for us to act like rational beings.

This is supported by (De Sousa, 1987) who has argued that emotions are integral to cognition. Damasio (1994) proved that a defect, caused by neurological damage, invariably leads to defective decision making, with people being unable to evaluate their options. It is interesting to see that both authors though working from different backgrounds, Sousa (in philosophy) and Damasio (nueropsychology) have come up with the same conclusion. Korb and Nicholson (2000) trace the initial marginalisation of emotion and cognition from Socrates to modern day Christianity as follows:

> *“Socrates praised the reective life of the mind and maligned the body and its emotions as interference. Christianity supported this separation leading to there being a distance between cognition (then known as the soul) and the degenerate emotion. It almost became a norm not to associate emotion to cognition and only think of them as being antagonistic towards each other.”*

They go a step further into criticizing authors such as Russel & Norvig (1995) who do not include emotions within their AI work. Russel & Norvig describe a rational agent as “one that does the right thing”. Since their work does not include emotion, one may be nudged into believing that their definition of “right” here refers to logical thinking without any emotions. If that was the case, then their definition would be indirectly implying that incorporating emotion into an agent may lead to it doing the wrong thing. This again, like most of the topics in emotions, is debatable. Picard (1997) and other authors previously mentioned contradict this, by stating that emotions are necessary for rational thinking in human beings.

Marsaella and Grath (2001a, 2001b), state that emotions play an important role in virtual training environments where intelligent agents interact with a human participant. In such an environment, emotions play the role of enhancing believability and realism, increasing the sense of attachment to the synthetic characters and adding suspense to the simulation.

6.3. Activation of Emotions

This chapter will describe how emotions are elicited in real life, and then try to explain how these can be related to virtual worlds.

This seems to be one of the few areas in which emotion theorists agree. Though they have come up with different explanations of how emotions are activated, essentially they all merge into the following broad categories.

6.3.1. Mood induction

This means getting the subject into a particular emotional state by using different techniques. These may include using imagination, social interaction, verbal description of mood eliciting scenarios and facial expressions.

This is one of the most common means used in a laboratory. Subjects are normally presented with emotional evoking stimuli and asked to rate them on a scale that defines the intensity of the emotion. The stimuli used include slides/pictures of emotional scenes (GreenWald & Bradley, 1988), films (Gross & Levenson, 1995), words that represent emotional concepts, loud noise and mild electric shock. This has been used in studies by Kenealy (1988) where they tested the validation of "sad" and "happy" music on behavior and self reported mood, and Schneider et al (1994) where they study the possibility of using socially relevant emotional stimuli to obtain reliable mood changes in healthy subjects. The emotional stimuli consisted of happy and sad facial expressions.

One of the most commonly used methods is the use of Internal Affective Picture System (IAPS) developed by Peter Lang and his colleagues (1995). Research done during an earlier project on creating an immersive emotion-evoking environment (Juma, Sahaf & Ravn, 2007) showed that negative images or sounds[18] resulted in negative emotions such as fear and sadness, while positive images and sounds resulted in positive emotions.

In games, this can be done by subjecting the character to the emotion eliciting stimuli. This has been described extensively for basic emotions by authors such as Plutchik (2000) and Brazael (2000)

[18] These include images of death, helpless human or animals and sad children, and sounds of bomb explosions or alarms.

They describe the common stimuli for eliciting each type of emotions as follows:

Emotion	Trigger
Fear	Threatening stimulus
Sadness	Loss of desired stimuli
Anger	Obstacle or delay, difficulty in achieving goal
Surprise	Sudden unexpected stimulus
Disgust	Undesired stimulus
Interest	Appearance of new or salient stimulus
Joy	Success in achieving goal
Anticipation	Being in a new territory.

These findings have been supported by play testing consultant Lazzaro (2004), where she observed the emotions of test persons playing games through facial gestures, body language and verbal comments. The games used included Halo which stimulated fear and surprise and Odd World which stimulated disgust. Her research identifies other emotions such as wonder, and pride together with their triggering stimuli, but these will not be discussed in this report as they do not constitute universally recognized basic emotions.

6.3.2. Classical conditioning

This is the imparting of emotion elicitation power to an object or event by pairing it with stimuli that have biological significance such as pleasure or pain inducing stimuli.

The most common type of conditioning is fear conditioning. This has been used in experiments where non threatening conditioned stimuli are paired with unconditioned stimuli. For example light can be paired with mild shock and subjected to an animal. This is done until it gets to a point where the animal shows a fear response to both the mild shock and the light alone.The most famous example in this was an experiment conducted by Watson & Rayner(1920), where they paired loud noises with white rats, and as a result they made Albert(an infant) become scared of white rats and anything that resembled them.

This classic conditioning is similar to what some authors' (Keane & Eysenck, 2000) term a reward and punishment method mostly used for animals. In this approach when animals, for example, dogs do something good, then they are rewarded with treaties. Thus they start to associate treaties with good behavior. Food is normally used as stimulus when working with animals, and money is used when working with humans.

In games this is used by implementing reinforced learning as described in section 4.5. Reinforced Learning (RL) where the character is rewarded when they do something good. Such has been implemented in path finding, where agents are rewarded for finding the most optimal path to getting the enemy. The reward system ensures that whenever they are subjected to the same scenario, i.e. where they have to find the enemy, then they will use their memory and choose the option with the best reward value.

6.3.3. Using knowledge of context

Context here refers to the setting or specific circumstances in which an event (namely, an emotion) occurs. Findings in this area have been quiet controversial. Schachter and Singer's (1962) experiment described earlier in section 3.3.1.3. Schachter and Singer (1962) showed that knowledge of context influences the elicitation of emotions. In this case, the subjects who were aware of the context (the ones who had been informed about being injected with a drug and its possible side effects) were less susceptible to reacting to happy or sad cues.

Dror et al (2005), proved that providing background material(such as nature of crime) to people during a fingerprint matching exercise, altered the way in which the subjects processed the information, leading to different results as compared to when no context was provided.Earlier research done on this (Juma, Sahaf & Ravn 2007) did not come up with any conclusive results as to whether knowledge of context was instrumental in eliciting emotions. In games, this can be done as suggested by Freeman by use of pre and in game pre-rendered animations[19]. These would ensure that the player is aware of the background information about the game and the characters in it. However it cannot be used to simulating elicit emotions from characters unless this background information is hard coded in their knowledge base.

From the above we can conclude that the best methods to be used to simulate eliciting emotions from NPCs would be using emotion evoking stimuli as described by Plutchik and others, and also by using classical conditioning. The latter can be used to simulate the use of memory in affecting the current character's emotional state and actions taken.

[19] This will be discussed in detail in the next chapter

6.4. Emotioneering in games

This section will examine the elicitation of emotions in virtual environments.

Emotioneering seems to be a term that has become tantamount to David Freeman who has written about over 300 techniques on how to add emotions into games. Emotioneering refers to the adding of emotions into games. In the following section we will describe a few of the techniques that may be useful to this project.

- **NPC deepening technique**

These are techniques that give major NPCs emotional depth and complexity. This involves processes like making the character show emotional pain, have a hidden secret , inner wisdom and the ability to put up a false front i.e. mask their actual emotion with a fake one.

An interesting concept that is introduced here is the notion of using emotion to influence a character's actions and decisions within a game. These emotions coupled with the goals of the character should trigger the actions within the game.

- **NPC toward NPC chemistry technique**

This is a technique that using very little or no dialogue, makes it look like two npcs have "chemistry" i.e. they belong together as friends, comrades or lovers. To achieve this emotional entanglement, little dialogue can be used. This can be in the way in which the npc's refer to each other. Lovers and friends in most cases refer to each other fondly (Kane, 2003). Other ways to achieve the emotional involvement include making the characters think in the same way, or be able to read each other's thoughts.

- **Group interesting techniques**

These are techniques designed to get rid of boring groups of NPCs and turning them into fascinating and intriguing characters to the player. To do this, a designer ought to give groups interesting traits that set them apart from ordinary groups.

These traits may include their warlike nature, their belief of fighting to the end, dying for honor, or loyalty to their race etc. Giving traits to groups can also enable a designer to have distinguishable groups in a game (Freeman, 2003).

One of the criticisms towards freeman would be that he thinks of game environments as worlds which are as rich as the film world. His techniques are based on the assumption that the game designer has all the time and resources to create the emotions.

Some games, like adventure games or RPGs[20] may allow for this kind of indulging in emotions, but combat and First Person Shooter (FPS) games which are quiet fast paced may not allow for the inclusion of this. Imagine trying to add NPC toward NPC or toward player chemistry in a game like Mission Impossible III, a racing game or Tekken? This would involve adding an introduction story at the beginning of the game because once the game has started, it is so fast paced that there is no time for additional time consuming elements. It is worth noting that the examples given by freeman involve vast worlds where the player has all the time to walk within the environment, explore, examine and interact with each character keenly. This is not possible in fast paced games.

Other techniques that have been offered, which seem more plausible in a game world include:

- **Injecting game elements with emotion**

This involves finding a way(s) to add emotion to game elements. Game elements include things like competition and opposition which are common in many stories. These elements imply a story in progress (Freeman, 2003).

In addition to simple emotions, Freeman specifies that designers can also add complex emotions to game elements. If a scene is more emotionally complex, then it's more immersive. This complexity arises from the storylines converging in a scene. Few storylines imply simple emotions while more imply complex emotions. Complex emotions in a scene act as a way of heightening up a task that would seem simple.

It is interesting to note that though freeman describes complex emotions from another angle, his description is still similar to Plutchik's description given in section 3.4.4. Secondary/Complex emotionsThere, complex or secondary emotions were described as arising from the integration of two or more emotions. These emotions arise from evaluating situations which can be equated to storylines. Thus more situations result in more basic emotions, which interact to form complex emotions. In Freeman's terms, more storylines converge to form complex situations, hence a complex emotion. This is supported by Saari et al (2005).

[20] Role Playing Games

- **True to life techniques**

These are techniques that are supposed to make the game more immersive. In the old days it involved making the visuals and sound feel realistic. This has been achieved by means of impressive texturing and lighting, and also use of employing 3D sound within games. With this being achieved, focus has shifted to trying to add a sense of realism to the emotional actions and reactions of NPCs. This involves having the characters undergo appropriate emotional changes. This may include expressing the following:

- Fear before or during a frightening situation
- Sorrow for a wounded or killed comrade
- Happiness or relief after a difficult mission is accomplished
- Having a character feign (or cover their real emotion)
- Having the player learn that despite an NPCs cool demeanor, he is actually terrified deep down

The lack of implementing the above makes characters look cartoonish i.e. unrealistic.

- **The opening and pre-rendered cinematic**

The opening cinematic, placed before the game starts, presents a possibility of sucking a player into the game. This is due to the fact that it is open to all the advantages of film making such as creating suspense by using the plot, character or scene setting to hook the player within the first few minutes.

A pre-rendered cinematic is a short movie like sequence which is rendered in a self contained animated recording and stuck into the game. This differs from an in-game cinematic that is rendered real time by the game engine.

The cinematic can be used to add emotional involvement into the game by creating or expressing relationships between NPCs. It can also be used as a tool for explaining an NPC's mood. For example if NPC Jack always looks sad, a cinematic showing how he lost his loved one in a past war may explain his gloomy outlook.

The most probable techniques to be used in this project are true to life techniques since they directly show the relationship between a stimulus evoking emotion and the emotion/action resulting from the player. Also NPC deepening techniques as they work with the concept of using emotion to influence the character's actions and decisions. This is not to say that the rest of the techniques are irrelevant. They could be of use as well, but they will not be used in the scope of this project.

6.5. Representation of Emotions

Synthesizing of emotions in NPCS is not enough. These emotions have to be evident to the player, as these convey some information to him about the gameplay. This chapter will focus on discussing different ways of representing the emotion to the audience. .

Stern (1999), states some of the techniques relevant for the successful real time emotion expression in virtual characters to be the following:

- Emotion expression in parallel with action.

A character ought to convey an emotion for example using any emotive body posture, or any other physical means of expressing emotions, while performing actions at the same time. For example, a surprised character should be able to open their mouth ajar and jump at the same time. This kind of parallel expression makes the emotion more believable.

- Emotion expression at regular intervals

Characters should regularly be paused during execution of a behavior so as to express their current mood. This kind of conduct enhances the portrayal of the emotion. For example, an angry character, while charging after the player, may hit (or blow up) any obstacles that comes on its path, as a way of expressing their level of anger. This kind of behavior is quite different from a character who avoids all obstacles while chasing the player. In the first example, the character blowing obstacles may be viewed as being angrier.

Sengers (1998) concepts of behavior transitions can also be applied, such that when a character has finished with one behavior and is about to perform the next, then they can pause for a moment, giving the illusion of a “stop and think” moment. This would be at par with how humans behave sometimes.

- Prioritization of emotion expression

It is important to prioritize emotions such that when a character experiences simultaneous competing emotions, then the one with the highest priority should be the expressed one. For example extreme emotional states such as fear, hunger and fatigue can be given a higher priority in relation to emotions like happiness or sadness. This is a relevant fact when implementing an application where more than one emotion can occur at any given time. In such applications, conflict among the emotions is bound to occur. Thus the emotion with the highest priority should be the one expressed.

- Emotions expression through customization of behavior

Some behaviors have alternate ways of execution, depending on the emotional state of the character. This means that an action such as walking can be performed in different ways, such that, if the character is proud, then the walk should consist of trotting proudly with chest up, or if the character is afraid, then this should be reflected in their manner of running. Using alternative ways to perform a behavior deepens believability. Theatrical techniques such as position and angle of the character (whether the audience can view him in full or not), orientation of the character's face amongst many others, can be used as a means of customizing behavior. For example, if the character is facing downwards while walking, then this can be perceived as a conveyance of sadness.

6.5.1 Outward expressions

Observers may infer a person's emotions and attitudes from nonverbal behaviors (Ekman & Friesen, 1969). These behaviors communicate considerable emotions about a person's emotional state. They include facial expressions, gestures, body postures and gaze. For example, an angry person tends to align itself with the object of anger, a sad person may have an inward bent body posture with their face oriented towards the floor and a curious person may have raised eyebrows.

Thus, when creating virtual characters that convey emotional states, we must ensure that the agents' performance suggests a corresponding emotional state to the observer or risk creating confusion, resulting in disbelief (Gratch & Marsella, 2001a). Characters in a virtual world must portray the situations that they are facing at any given time. Consequently the behavior of the character at all times must reflect the current under-goings in the virtual environment. Furthermore, the behavior should be unique to the individual since humans do not behave in the same way. The behavior ought to be linked to the individual's personality as this is the factor that makes humans different.

At any given time, an agent's mix of non verbal behavior should appear emotionally consistent. This means that if a character is experiencing a particular emotion, then all communicative gestures should reflect this.

6.5.2. Behavioural (Emotional) Reactions and Decision actions

Stern (1999), states that if a virtual character cannot show an immediate emotional reaction, then it will not seem believable. Timing is critical. Emotional reaction here refers to mapping of emotions to actions such as walking, sitting, attacking, using objects etc.

In (Zhu & Thagard, 2002), the authors note that the relevance of emotions in action selection has been a widely ignored area. They state that there are two types of actions involved: behavioral action and decision action. This can also be termed as mapping from reaction to action. To illustrate this, the following fig 7 will be used:

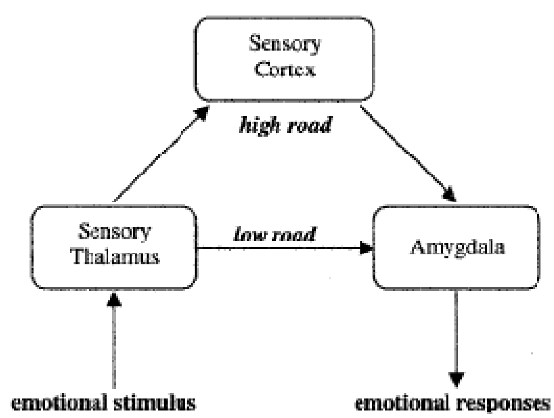


Fig 7: Showing two separate paths from sensory stimulus to emotional responses (adapted from LeDoux 1996 p.164)

From the above diagram, the low road is also known as the quick pathway which results in behavioral “instinctual” reaction. The responses from this path are automatic and involuntary, and they take place before the brain has had a chance to think about what to do.

The low level path involves autonomic, endocrine, skeletomotor and arousal systems mediated through the amygdala, and thus prepare the organism to cope with the situation involving significant change. The high road involves higher level information processing systems such of the brain, which are believed to be involved in processes like thinking, cognition, consciousness and reasoning. Thus the low level and high level roads are associated with tendency/readiness to act, and the decision to act respectively. Roberts (2003) defines reaction behavior as ranging from intentional action to non voluntary movement. The non voluntary movement can be equated to readiness to act, while intentional action is same as decision to act.

Different emotions correspond to different types of actions. For example, when confronted with fearful event, then the resulting action maybe to escape from a dangerous situation. Anger may cause some reaction to the target, and pain may cause physical withdrawal from the pain inducing object.

Shearer (1994) supports the above categorization. His theory maintains that emotions are an interface that mediates between environmental input and behavioral output. "*This interface has strong ties to motivational-implementation systems and helps ensure that the central needs of an organism are met"* (Lord and Kanfer, 2002)

Low level organisms meet such needs by hard wired responses which provide a rigid link between specific stimuli and behavioral responses. This is not the case for humans, since our emotional interface decouples stimuli and responses, thus allowing for greater flexibility which accrues from the combination of two processes. In the first process, emotions prepare and energize appropriate action tendencies. The responses are not immediately released thus providing a delay period for which alternative information can be processed and alternative responses considered. This can be deemed to be analogous to behavioral action and decision action stated by Zhu and Thargard (2002). The latency period is shorter for stronger emotions such as fear, leading to faster execution of emotional responses, as compared to less critical situations (with weaker emotions) which lead to continuous evaluation resulting in thoughtful choice of behavior.

Sheerer's studies show that an increase in the latency between the triggering stimulus and the response allows for a wider participation of cognitive and social processes in the emotional responses. As a result, the range of potential affective and behavioral reactions increases. This means that intense emotions produce behavior reliably and rapidly while less intense emotions produce more variable delayed behavior. This categorization has led some psychologists to propose that emotions can be defined and identified by different sets of action tendencies (Arnold 1960, Fridja 1986)

Such tendencies include associating anger with a preparation to advance in a threatening way, or associating fear with retreat (Fridja, Kuipers & Schure, 1989). Plutchik (1980) supports this categorization by equating different behavioral actions to emotions a shown on table 1 below:

Emotion	**Behavioral reaction**
Joy	Retain or repeat
Trust	Groom
Fear	Escape
Surprise	Stop
Sadness	Cry
Disgust	Vomit
Anger	Attack
Anticipation	Map

Table 1: showing mapping of primary emotions to reactions by Plutchik

Kismet (Breazeal, 2000), also propose the same scheme as the above whereby emotions elicit behavioral response such as approach, attack, escape etc, and associated displaying expression.

Lyons (1978: 410-418) differs from the psychologists regarding the above rationale. He states that there is no particular form of behavior which is characteristic of an emotion the way in which eating is characteristic of hunger. Fear for example can be assumed to have a characteristic behavior which is avoiding danger. However, this evasion of danger can be done in different ways for example, if the danger is an enemy then he could be avoided by running away or killing him, if the danger is fear of falling off a cliff, then one could move away from the cliff.

Bartneck (2002) warns that it may not be possible to base every mapping of an emotional state to actions on theoretical foundations. He states that in such an event the developer can invent his own mappings, but they should be thoroughly tested so as to ensure that they are not biased on the developer's experiences and opinions.Examples of emotional states which may be hard to map include pride and humility as they do not immediately excite individuals to action (Hume, 1960: 367)

Conclusion

From the above, it is clear that we can express emotions in two ways either by our outward physiological expression or by the actions that we take. The actions can be an unconscious process (a mere reflex) with highly cognitive processes not being involved or it can be a conscious process which involves the higher cognitive process. This difference results in behavioral and decision action respectively. Behavioral actions tend towards primary emotions which are entrenched in the limbic system, and tend to elicit action tendencies as stated by Fridja (1986) and Plutchik (1980).A designer of an emotional model should be aware of the following facts when mapping emotions to actions:

Decision actions tend toward secondary emotions as these require higher cognitive processing. Thus behavioral reactions may be similar in different individuals, but decision action may be different or unique to each individual. This may make the testing of decision actions to be a bit more difficult. Being that the behavioral actions are almost universal, then it is easier for the audience to identify with them by inferring on how they would react in the same situation. Decision actions on the other hand are subjective thus the complexity of mapping them. A designer of an emotional model should be aware of these facts when mapping emotions to actions.

Modeling of behavioral action needs only a rule base of “if then” statements since they already have predefined action tendencies. A finite state machine (FSM) could be a good solution for this.

Decision actions on the other hand requires simulation of the involvement of cognitive processes thus a necessity for algorithms that simulate how the final action will be arrived at. A good solution for this would be a combination of fuzzy logic and reinforced learning (RL). These algorithms were discussed earlier in chapter 4.

6.6. Role of emotions in decision making

Having described how to possibly simulate and represent emotions, the next possible question would be whether these created emotions affect the decision of an in individual. This chapter aims to answer that question by looking at the suggestions of several theorists with the hope of reaching to some sort of consensus.

Stuenebrink, Dastani & Meyer(2007) state that in psychological studies, secondary emotions refer to the emotions that influence the deliberation and practical reasoning of an agent. In their opinion secondary emotions shorten the deliberation process. This can be argued to be true since in the early days where machine thinking did not involve "emotional thinking", then machines reasoned using logic. Thus if a machine was assigned the task of finding a suitable baby sitter for a child, it would evaluate the different institutions, and individuals step by step, noting the pros and cons of each(as a form of cost benefit analysis). By then it was assumed that this was how human reasoning worked. It was all about rational[21] thinking. Such a process would end up being long and computationally expensive.

[21] Here rational refers to being based on reason.

If such a task is assigned to a human counterpart instead, their reasoning would almost be deemed irrational. Their decisions may be influenced by past memories as well as some arising biases from things that they have heard or what humans call “gut feelings”.

What makes the difference between how humans and machines make decisions is emotions. If we all reasoned as machines and only thought of the hard facts, then given certain situations, all humans would end up with almost similar solutions. An outcome that is not possible.

Deliberation of an autonomous agent in a game environment mostly involves selecting which action to take considering the current state of the environment, its feelings, goals and beliefs. Some theorists have labeled emotions as being the outcome of evaluation of a situation coupled together with a person's goals and beliefs. This definition implies that when making a decision, once an emotion has been felt, a decision can be made from there. Thus emotion would be a necessity for decision making.

Some theorists advance the notion that emotions are irrational, and as a result should not be involved in cognitive processes. Others are of the opinion that emotions are a prerequisite to decision making. This notion is supported clearly by Damasio's experiments (Damasio, 1994) which showed that patients with injury on the prefrontal cortex did not reason rationally, or process their emotions normally. Their personal and social decisions were irrational while they still maintained their ability to tackle the logic of a problem. This is also supported by early theorists like Aristotle as shown in section 3.3.1. Affect influences behavior coordination in humans through two modalities of emotions i.e. both the expected and the current emotions (Rank, Anjos, Petta and Aylett: 2005)

To support this notion Fineman (2003) describes a dilemma where a top executive has to fire one of his managers due to lack of performance. He is faced with background emotion (a gloomy mood), anticipated emotions (the executive’s thoughts of regretting his decision in the future) and task related feelings (which involve his discomfort at delivering the news). The decision in this case constitutes of shuffling and shaping ideas, hunches, dilemmas and actions. This scenario shows the different roles played by emotions in decision making.

Lerner & Lowenstein (2000) agree with this distinction of expected and current emotions. They explain the expected emotions as being the prediction about the emotional consequences of the decisions outcome. Decision making models such as the expected utility model work with this type of emotion. It assumes that individuals try to envisage the emotional cost associated with alternative courses of actions, and then selecting actions that maximize positive emotions while minimizing the negative ones.

The second type of emotional influence on decision making consists of immediate emotions experienced at the time of decision making. These have both a direct and indirect impact. The former occurs when the emotion instantly influences the action taken, while the later arises when the current emotion influences the generation of other emotions (either positive or negative), and they may also influence the way expected emotions are processed.

Proponents of rational thinking still try to convince the world about the head and the heart being two separate entities that are not related. In our day to day life this is an admirable aspect for top officials who have to show that all their decision making processes were based on some sort of cost benefit analysis.

Writers who try to explain economic behavior and decisions hold on to the ideal of rationality and regard emotion as being an interference to the cognitive processes. In the 1950's Herbert Simon did a study where he came up with the term "satisficing" which refers to the process of choosing some target criterion for one's decision. When this criterion is met, the decision making process ends as there is no need to explore further alternatives. Under this type of reasoning, rationality is seen as "bounded" since all the possibilities are not evaluated to get the maximum gain (Fineman, 2003).

Rationality is questionable in terms of its assumption that we can weigh all alternative solutions. Though possible in most problems, this maybe a time consuming daunting task which most humans would rather find a short cut through. The shortcut maybe in terms of making decisions based on previous experiences, habit, stereotyping and gut feelings, all of which contain an emotional element.

Damasio (1994) is against the idea of the dualism of the body and mind. He argues that the ideal of a rational decision maker is not appropriate for an organism that is continuously subjected with choices for which courses of action have to be taken. In such cases rapid decision making may be necessary. For this to happen, there is a necessity for a mechanism that provides a common measure for evaluating options in relation to their potential benefit. This mechanism is known as the somatic marker, which implies a link to physiological experience. Thus decision making calls for activating representations of similar events experienced in the past. If the events made us happy, and their consequences were positive, then we are likely to repeat them again. These experienced past events are known as affective memories. They allow humans to sift through options and narrow them down. Though this may not result in an explicit choice, but at least it constrains the playing field (Keane & Eyensck, 2000).

Keane & Eysenck(2000) give a description of detailed emotional decision making. They state that the limbic system(namely the orbitofrontal cortex) is necessary for the online rapid assessment of stimulus-reinforcement associations, as it is involved in learning to link a stimulus and action with its reinforcing properties. Such an assessment requires that the stimulus-reinforcement association reflects any new perceived information.

We conclude this chapter by paraphrasing Damasio (1994) who maintains that reasoning is guided by the emotional evaluation of an action's consequences. Our actions do not occur in an impersonal state as we are always aware that they have social and personal consequences. Thus the separation of the mind and the body can be viewed as a myth: the mind is a conscious entity of cognition.

6.7. Emotional models in AI

This chapter will describe some of the most successful implementations of emotional models in AI. This includes both theoretical as well as computer based applications. The theoretical models will be discussed first since the latter are based on them.

6.7.1 Theoretical emotional models in AI

These are psychological models that have described how to model emotions, and they have been used as the basis for many computer based systems for modeling emotions. Many models have been proposed in this field.

6.7.1.1. Ortony Clore Collins model (OCC, 1988)

It is also known as the OCC model, and it is by far the most popular. It was developed in 1988 and it consists of 22 emotions. The authors behind this model thought that it was not important for machines to have emotions but they believed that AI systems should be able to reason about emotions and integrate them in their problem solving, planning and natural language understanding.

The OCC theory assumes that emotions develop as a consequence of certain cognitions and interpretations. Consequently it concentrates on the cognitive elicitors of emotions. Cognition arise from events, agents and objects, thus an emotion arises from valenced reactions to situations consisting of events, agents and objects. This model works both with discrete as well as dimensions of emotions. When looking at the dimensions of an emotional feeling, its intensity is determined by three central intensity variables. These are desirability, praiseworthiness and appealingness.

- Desirability is linked with reaction to events and is evaluated in relation to goals.
- Appealingness is linked with reaction to objects and is evaluated in relation to attitudes.
- Praiseworthiness is linked with the reaction to actions of agents and is evaluated with regard to standards (Picard, 1997: 195-200)

When interpreted in a layman's term, an individual can be pleased or displeased about the consequences of an event, they can approve/disapprove the actions of an agent and they can like/not like aspects of an object. The 22 distinct emotions are generated by a rule based system. This model supplies no formalization for all their defined emotions but give only a few examples. The authors' postulate, however, that every emotion can be described using a formal notation, although with many emotions this is by far more complex.

An example of how joy synthesis occurs in this model is described below in formal language.

Example: using the OCC model to synthesize "joy"

> *Let D (p, e, t) be the function representing the desirability (D) of an event (e) for a person (p) at a certain time (t). The function returns either a positive value for a desirable event, a negative value for a not desirable event.*
>
> *Let I g (p, e, t) be a function representing a combination of global intensity variables(e.g reality, expectedness and proximity) and P j (p, e, t) the potential for a state of joy. Then an example rule for joy is:*
>
> *IF D(p,e,t) > 0*
>
> *THEN set Pj(p,e,t) = fj(D(p,e,t), Ig(p,e,t))*
>
> *The resulting function f j releases a further rule which determines the intensity for joy and thereby makes possible the experience of the joy emotion* (Picard, 1997).

A summary of how the OCC model works is as follows

- The character evaluates a situation which can include an event, agent, action or object. The emotion itself is also taken as a situation and thus it can trigger additional emotions. This result in information about what emotional categories have been affected.

- The character calculates the intensities of the affected emotional categories. The result of this calculation is an emotional value which identifies whether the emotion is generated or not.
- This emotional value is mapped to an emotional expression and it can influence the behavior of the character.

The OCC model has not been fully implemented in AI systems, but it was the first model to guide the AI community into setting a framework for emotion synthesis. It has also become the default model for emotion synthesis in computers, though this was not the intention of its authors.

This model is appealing due to the fact that it's almost represented in a pseudo like code which is easy for programmers to work with. It has been used as a basis for electronic models like Oz and Elliot which will be discussed in detail in this chapter. Though, it may have a draw back when it comes to dealing with complex emotion synthesis.

It also does not provide for a history function, it lacks in terms of developing a personality for an agent(this can act as a means of making the agent more believable), and does not cater for interaction of emotions.

Though Bartneck (2002) defines the history function as being a valuable tool for calculating the likelihood and realizations of events, it can also be a good tool for calculating the mood of the character by keeping a history of the characters previous emotional states.

6.7.1.2. Roseman's Cognitive Appraisal model

In this model, Roseman developed a categorization of the evaluation people make about events that cause emotions. This was achieved by running a series of studies which involved subjects either recalling emotional experiences or answering questions intended to measure the appraisals that result in the emotions. In other studies subjects read brief stories of situations happening to protagonists, and answered questions about what emotion they thought the protagonist would feel, and its intensity.

This resulted in 200 written reports on emotional experiences. From these, they constructed a small number of appraisals which interact to give rise to seventeen [22] emotions. The six appraisals are defined below:

- Unexpectedness, which elicits surprise.

[22] This number seems to vary from 13 to 17 in different literature.

- Motivational and Situational states which elicit sadness or distress. Motivational states describe whether a person possesses a motivation to a desired situational state or a motivation away from an unwanted situational state. The dimensions of this states end up being either positive or negative, thus generating emotions such as sadness and distress. Inconsistent situations with an appetitive motive (not getting a reward) elicit sadness, while those with an aversive motive (getting punished) produce distress.
- Probability, i.e. certainty or uncertainty, gives rise to emotions such as fear, relief, distress and sadness
- Problem type which defines the difference between the emotions felt. For example, a negative event, depending on its cause may give rise to different negative emotions like disgust or frustration.
- Agency which describes the agent to which events are attributed to. The agent could be others or self (Picard, 1997: 207-208).

This approach is appealing due to its simplicity which infers that it can be quickly turned into rules that govern how emotions arise from event appraisals. It has been used as the basis for electronic models like BORIS and Dyer. Its main disadvantage lies on the fact that it does not account for how to deal with the possibility of multiple appraisals. These have the possibility of leading to a mixture of emotions (secondary emotions).

6.7.1.3. Model of Bates and Reilly (Oz, 1992)

In this model only an agent that is able to react convincingly to a variety of situations in an environment to which a human user belongs, is really accepted by the latter as a believable character. The Oz world consists of four important elements: a simulated environment, agents, an interface through which humans can participate and a planner that is concerned with the long term experience of a user. An agent structure of Oz is called Tok and it consists of modules for goals, behavior, sensory perceptions, and language analysis and language production. A module called Em is responsible for emotions and social interactions

The emotional system in Em is modeled after the OCC model, it generates primary emotions but it does not cater for intensity variables as postulated by OCC model. This is due to the fact that calculating intensities in OCC contains the complexity of one agent having the knowledge of another agent's goals and appraisal mechanisms (Reilly, 1996). In Em, intensities are influenced by the importance of the goal that generates them. Each emotion has a threshold, and an emotion is only generated when intensity exceeds this threshold.

Em also calculates mood (a factor that is missing in OCC) by summing the intensities of all negative and positive emotions separately. If the negative emotions are greater, then the mood is set to be bad, and vice versa. The model separates the recognition of emotion, and an agent's responce to it. Recognition occurs when an agent observes the emotional state of the other; it does not need to know the reason behind this state. This is contrary to OCC where an agent has to know why the other is in a certain state. Emotions like distress are also recognized in an easier way (Reubenstrunk, 1998).

Picard (1997: 202) criticizes Em for having hard coded cognitive and behavioral influences which must be changed by hand so as to adapt to new situations. This negates the process of a natural model of emotion where one would expect the agents to learn by themselves to adapt to changes within their environment.

6.7.1.4. Elliot's model

This is based on the OCC model and it shows how modeling personalities and social relationships for agents can interact with generation of emotions. The key feature of this model is social relationships between the agents. These include friendship, animosity and empathy. This model involves two main parts. The first deals with interpretation of events in relation to agent's goals and preferences, and the second part deals with how an agent reacts in response to an emotional state. This reaction is highly influenced by the agent's personality. Some agents may decide to respond externally by verbalizing their emotional state, while others may keep it internal (Picard, 1997).

This model is distinguishable from others due to three main factors which are:

- The agents keep an internal representation of the presumed ways in which others evaluate the world. This allows them to generate empathetic responses.
- They use forward logic based reasoning from presumed appraisals, and events to guess about the emotions of others.
- They use backward, case-based reasoning from facts about previous situations and expression of other agents to generate emotions.

One of the adequacies of this model is that it gives agent's personalities. This ensures that every individual agent is unique. This can be a major factor in increasing believability especially in games that involve more than one NPC.

Other notable models in this area include BORIS, OpEd and Thunder which use a content theory of emotions to aid in the understanding of text (namely inferring emotions from text). PARRY which is a system that attempts to model a diseased and limited mind. AMAL, which attempts to identify emotion eliciting situations, and ACRES, which attempts to model the dynamic utility of emotions.

Elliot (1992) defines most of these approaches as being quiet diverse, and they are only loosely tied together by the generic category of emotion research. This may be a valid statement as there seems to be a string tying all this models together, and that is based on the fact that one way or another they all try to simulate how emotions work in humans, be it in their synthesis, recognition or effects of not experiencing the emotions. However, it is not possible to heap the models under a specific emotion topic such as emotion synthesis or recognition. This makes it difficult to evaluate the models against each other.

Theoretical models like OCC and Roseman are easier to evaluate as they both focus on generation of emotions. Their pseudo like / rule based nature makes them simple and easy to use, especially for programmers who can quickly turn this into code.

The main drawback of these models is that they do not cater for the integration of emotions, i.e. accounting for when an event(s) generates two or more emotions what should happen. Another criticism is that they are only based on the cognitive aspect of emotion. This has been seen as the main drawback of OCC by Reilly (1996) and Izard(1992) who term it as being overly cognitive and thus needing some re-adjustments to cater for physical aspects of emotions.

The models of Elliot and Reilly have proven that though the OCC is operational as a computer model, it is advisable to extend it by additional functionality such as personality and social interactions.

6.8. Conclusion

Emotions play an important role in AI and games. This fact had emerged during the conclusion of the pre-analysis where a causal relationship was established between AI, emotions and games (in relation to believability). Discussions from this chapter show that emotions have brought in the "real human thinking" into modern AI thus revolutionizing it. Emotions are also a necessity of gameplay. The interaction of the player with the gameworld should produce emotions in the player. These emotions are the determining factor of the actions that the player takes within the game and whether he will keep playing or not. Thus the informal relationship that had been implied in the pre-analysis can now be formalized.

Emotions, a fundament of humans, are a necessity for AI and believability in games.

Unlike humans however, agents in a game cannot produce emotions on their own, thus the need for modeling these emotions. To do this, the agents have to be subjected to emotional inducing stimuli which may be scripted as events within the game world, or they can occur as the agent interacts with the environment. Once the emotions have been synthesized, just like in the case of humans, they should have an influence on the decision making process and thus control which actions an agent takes within a game scenario.

A new relationship seems to be emerging. Emotions are relevant for AI, believability and decision making. Believability had been previously described in terms of a believable character. A believable character is one that is both autonomous and emotive. Emotive meaning that it has the capability of synthesizing emotions and using these as a basis for their decision making (chapter 2).

To do this, the character has to evaluate different actions and choosing the best option depending on the situation. This is decision making. To simulate decision making in agents, AI algorithms have to be implemented. Thus AI, believability, emotions and decision making are interrelated. For a character to be deemed more believable, it ought to use an AI algorithm that incorporates emotions as a basis of its decision making process.

7. Related work

During research, the following related work were found, which show how emotions can be incorporated (using AI algorithms) into decision making as a tool for enhancing the believability of the character.

7.1. Flame (Fuzzy Logic Adaptive Model of Emotions)

This is a model that consists of emotional, learning and decision making components. It was developed by El Nasr et al (2000). The emotional component processes perceptions coupled together with expectations, event-goal associations and outcomes of the learning component to produce emotional behaviour. This behaviour is used in the decision-making component to select an action. The action is triggered in relation to the situation, the agent's mood, emotional states and emotional behaviour.

The authors of the paper do not give a detailed model of the decision making component since they are of the opinion that there are a number of planning or rational decision making algorithms that could be used (Russell and Norvig, 1995)

7.2. A behavioral animation system for autonomous actors

Becheiraz &, Thalmann (1998) built an emotional algorithm, that generated emotions based on perception. An emotion is generated if it reached a certain threshold which corresponded to the minimum intensity of the potential for an actor to feel that particular emotion. This emotion is then mapped to an animated behavior which includes facial expression, gestures, and change of walk styles.

7.3. Emotion based decision making

Velasquez(1998) has built an emotional model that deals with six emotions (fear, anger, distress/sadness, joy/happiness, disgust and surprise) and reactions that result from them. In this model some blends emerge of the co-activation of two or more basic emotions. When such a blend occurs, it is biased on one particular system, e.g. the perception or behavior system. The model also works with the influence of emotional memories on decision making and action selection. The model proposes but does not cater for explicit models for higher order emotions.

7.4 Emobot

This is an emotional agent implemented for Quake II using fuzzy logic (Hooley, Bart, Henry and Inoue, 2004). The model works with basic emotions and also the co-activation of them. It is only possible to have two emotions existing at any time, and when this occurs, the emotions are mapped, according to their intensity, to some kind of behavior. For example if the NPC is experiencing fear on an intensity scale of 0.7 and anxiety on a scale of 0.5 then the resulting action would be for the NPC to run. If the emotions are experienced on a lower intensity then a corresponding action will be taken. Though this model provides for the activation of at least two basic emotions at one time, it does not provide for the interaction of these emotions.

7.5. DER (Dynamic emotional response)

This was developed by Tanguy, Willis and Bryson (2005, 2007). It focuses on the role of emotions on action selection mechanisms. This model assumes other mechanisms for eliciting emotional responses from an agent's environment, but keeps track of emotional intensities changing and interacting over time. Each emotion has characteristic intervals of onset, sustain and decay values. In addition, each emotion may either excite or inhibit each other.

The application accounts for the interaction of basic emotion. When two emotions occur at the same time, the one with the highest intensity is the one chosen for expression (a process known as masking). E.g., if both fear and surprise occur at the same time, if fear's intensity is higher than surprise then the resulting facial expression will be that of fear. The emotional states are mapped into facial expressions.

7.6. Max

This project (Becker et al, 2008) is based on simulating secondary emotions on a conversational agent named Max.

This is achieved by embedding two separate modules, one for emotions, and another for cognition. These modules interact to produce complex emotions such as frustration and relief.

The production of the emotions is based on the famous OCC model, and depends on factors like intensity, and mood. The presence of the emotion is visible in Max's conversation.

7.7. Conclusion

The conclusion to the analysis stated that AI, believability, emotions and decision making are interrelated.

If we factor out the common denominator of this statement, then we can rephrase it to be that emotions are a prerequisite of believability. This fact is supported by Gratch et al (2002), studies by Prendinger, Becker, Ishizuka (2006) and also by the successful implementation of emotional systems in the above mentioned applications.In the early years, the biggest problem within emotion research was on how to generate discrete emotions. As a result there was a lot of emphasis, or models based on generating discrete emotions using different algorithms. This is evident in Roseman's and Fridja's models discussed earlier in chapter 6.

Having tackled that problem, some researchers have argued that incorporating emotions into a system is not a problem; the problem arises in depicting the right emotion at the right time (a factor that is a main requirement of believability).

To do this, different researchers have used different algorithms, with the most common being fuzzy logic. This is evident in Flame and Max described earlier in this chapter. These systems were mainly concerned with the expression of emotions by the agent. The timing of the emotional expression had to be realistic. The only drawback in these systems was that the expression of emotion was mostly restricted to facial animations.

Later models have gone a step further in their expression of emotions. They not only use facial expression and body postures, but behavioral reactions[23] as well. This is evident in emobot[24] and flame[25]. The mapping of emotions to behavioral reactions has been done by the help of algorithms such as fuzzy logic, reinforced learning and neural networks.

Despite of the above developments, there is still something missing within the believability of NPCs in video games. There could be several speculations into this. Authors such as Plutchik (1980) and

[23] Also known as emotional reaction, this was discussed in detail in section 6.5.2

[24] Quake II's emotional bot

[25] Fuzzy Logic Adaptive Model of Emotions

Izard (1977), have argued that human beings do not experience only one emotion at a time. We can be sad and afraid, or, happy and confused at the same time.

When we experience two or more emotions concurrently, then a higher order of emotions (secondary emotions) ought to arise. This is discussed in detail in section 3.4.4. These secondary emotions are only unique to humans; they are not experienced by animals (Beck, 2006). This fact has been supported in research by Leyens et al (2000, 2001) where they distinguish between primary emotions(fear, anger) which are considered to be common to both humans and animals, and secondary emotions(disappointment, resentment, shame, love) which are only attributable to humans.

Leyens, Paladino and Jeroen (2002) state that since secondary emotions are uniquely human, then people who express themselves in terms of these emotions are implicitly seen as more human. Thus it can be argued that modeling secondary emotions would be closer to modeling how the human emotional system works. However, this aspect of emotions does not seem to be a vastly researched area.

The most famous research done in this area involves DER and Max (discussed earlier in sections 7.5 and 7.6 respectively), with Max being the most successful implementation. Apart from the successful integration of basic emotions to produce secondary ones, Max's other strong points lie on the fact that he is a conversational agent, and that his perception of the world involves reading actual human emotion data via biometrical sensors. As a result of this, he is more suited to applications that interact with real humans "face to face". Thus he has been adapted as a museum guide, and a poker player.

Tests conducted during a poker game termed Skipbo where humans played against Max, concluded that when Max expressed empathetic emotions then test subjects felt that they were playing with a co-equal human. This may lead to theorizing that one of Max's strongest characteristics i.e. the successful integration of emotions, may be adapted for his video game counterparts as a way of increasing their believability.

Martin et al (2006) who worked with using blended animations to represent secondary emotions question the possibility of classifying and representing secondary (complex) emotions. They state that the externalization of non verbal behaviors play an important role in the perception of emotions. They further say that though there has been a lot of research on expression of basic emotions via facial expression, vocal expression and expressive body movements, the same does not hold for secondary emotions. Their solution to this problem is to blend animations of the different primary emotions which constitute a secondary emotion, as a way of expressing the secondary emotion.

Clearly there is no much research in this area. The same also applies to the concept of secondary emotion and action selection. Though authors like Fridja (1986) and Plutchik (1980) have stated the related action tendencies to basic emotions, there is no much research on how secondary emotions affect action selection. We have stated that secondary emotions require the involvement of cognitive processes, thus the action selection involves decision making on the part of the agent. But this is just a speculation, not a fact.

As a consequence this thesis aims to focus on the importance of interaction between emotions, and, the role of this interaction in NPCs believability.

7.8. Defining the problem

The initial problem of this project was to investigate how we can incorporate emotions into games using AI so as to enhance the believability of NPCs behavior. After the detailed research on the relevant areas of AI, emotions and believability, we try to narrow down the initial problem formulation with a focus on secondary emotions since despite their importance in human rationality; they do not seem to be a highly researched area. Also, a lot of work on believability has been focused on the outward expression of emotions as opposed to action selection, which is a believability essential that is affected by emotions. As a result the final problem is stated below:

"We wish to investigate the role of secondary emotions in action selection, and how this affects the believability of a character"

7.8.1. The proposed system

To test the above problem, a mod will be developed based on “2 minutes of Mayhem”. The term mod refers to modifying an existing game by giving it extra functionality. “2 minutes of Mayhem” is a First Person Shooter (FPS) game developed on Virtools game engine. It consists of the player, trying to kill his enemies, and at the same time collecting items from the environment. The player has a certain amount of time within which he is supposed to accomplish his tasks. The enemies are made as a copy of one of the NPCs. They have four basic animations assigned to them; walk backwards, run shoot, stand shoot and run. This game was chosen due to the fact that our initial research on believability gave examples of criticism of the actions of NPCs in FPS games. Thus, we thought that they would be the best foundation on which to test our hypothesis on.

The mod will consist of adding an action selection mechanism to the game. This mechanism will rely on secondary emotions as being one of its major inputs. The secondary emotions will be produced by combining two primary emotions. The primary emotions that will be used are fear, anger, sadness, surprise, anticipation and joy

The presence of emotions will be visible in the character's emotional behavior. This behavior will arise from a decision action, thus a simulated decision making component will be used to select an appropriate action under each situation.

To be able to test the problem, the following will be implemented in the mod:

- Scripting events that will act as emotion evoking stimuli
- Generation of primary emotions using finite state machine. An emotion will only be generated if it reaches a certain threshold.
- Generation of secondary emotions when more than one primary emotion is produced. This will be done using fuzzy logic
- Simulation of a decision making process which will use finite state machine, nash equilibrium[26] and reinforced learning
- Selection of actions as a result of the decision making process.

7.8.2. Comparison with other projects

Though DER's implementation (see section 7.5) closely relates to what this project intends to do, the difference lies in the following:

Though based on integrating emotions, DER works by mapping their result into facial expression. Instead, the present project aims to map emotions into the actions taken by the player by adding a decision making component.

[26] This is a set of game strategies, one for each player so that no player has incentive ot unilaterally change her action.

Secondly, DER does not rely on an appraisal module. It receives emotional impulses and translates them into an ADSR (Attack Decay Sustain Release) envelope using predefined pulse responses. On the other hand, this project intends to transform emotional impulses into different intensities. The duration of the impulse will be based on a weight attached to the intensity, with higher weights being given to emotions with higher impulses. The weight assigned to the emotional state will determine its duration. This will be achieved by using fuzzy logic.

Thirdly, DER mainly deals with masking of the secondary emotions while this project intends to work with both masking and superimposition of different emotions.

Lastly, DER does not have a learning mechanism which this project intends to implement as part of the cognitive processes that are involved in decision making.

7.8.3. Notes on the planned testing

To test this problem we have to be aware of the following findings during the research

- There is no clear theoretical foundation for physical expression of secondary emotions or their mapping into actions. This may imply that it may be hard for the audience to perceive these emotions.
- Secondary emotions involve cognitive processes and thus affect decision making
- Some secondary emotions are purely cognitive and as a result they are not perceivable physically. Thus the action selected by the character may be the only means of judging the presence of the secondary emotion.
- Believability is a merging of both autonomous and emotive characters. Thus the character ought to be able to synthesize emotions that will influence the actions that he takes within the game.

PART 2

8. Design

This chapter will describe the design process of the project. It will start by describing initial surveys that were conducted to provide needed guidance during this phase. Later, a general design of the system will be outlined, and a detailed description of the given design blocks will follow. The chapter will end with a conclusion to the design.

8.1. Designing Initial Surveys

To be able to have a clear understanding of the design logic, initial surveys were conducted. These were helpful in clarifying the design. These were inform of open ended questionnaires handed to at least 30 persons. We assumed that since we were dealing with a relatively new research area, it was important to find out how people related to it. The results of these surveys were expected to not only improve the logic of the design, but also the methodology chosen for the final testing. The surveys conducted were as follows:

Survey 1. Awareness of secondary emotions

An initial survey was designed to check if people were aware of the existence of secondary emotions. This survey would later prove if the final tests results for the project would be biased or not. It would also offer guidance on which secondary emotions the project should focus on.

The test was designed based on the third task of MEIS which asks people about their understanding of feelings, and this may include questions on blends of emotions (Forgas, 2000). MEIS (Multifactor Emotonal Intelligence Scale) is a test for measuring emotional intelligence. It was developed by Drs Mayer, Salovey and Caruso. The test consists of 4 parts. The first deals with identifying emotions in others. The second deals with the ability to use emotions. The third works with the ability to understand complex emotions, and how they transit from one stage to another. The last deals with the ability of managing emotions in self and others.

This first survey was based on the third part of the MEIS test i.e. the ability to understand complex emotions. The survey was conducted using two questionnaires. The first questionnaire stated two scenarios giving rise to two different basic emotions. The test person was then asked to list the resulting secondary emotion. An example is shown below:

You are expecting something to happen and at the same time you become surprised. What is your final emotional state?

a. Confused
b. Happy

c. Nervous
d. None of the above

In the second questionnaire, a secondary emotion was stated, and test persons were asked to state the primary constituents of that emotion. An example of a question is shown below.

Please state which two emotions resemble the mixed emotion given

Alarm?

a. Fear + Anger
b. Fear + Surprise
c. Surprise + Disgust
d. Sadness + Joy

Survey 2. Secondary emotion/Action selection

For this survey, people were asked about their behavioral reaction when they experience a secondary emotion. The aim of this study was to see if it was possible to relate actions to secondary emotions. This test was designed as there is no available material on the mapping of secondary emotions to actions. As discussed in section 6.5.1, Plutchik (1980) and other theorists have only been able to map primary emotions to actions.

Survey 3. Initial game trial

For this survey, people were asked to play the original game “2 minutes of Mayhem”, and then specific questions were asked about the NPCs. The aim of this survey was to check on the level of believability of the NPCs in the original game, and then compare this with the “more believable” npcs that were to be implemented later.

Samples of the questions were as follows:

- Did you perceive any kind of emotions from the NPCs? If yes, please state them?
- What served as a clue to the existence of these emotions?
- Were the NPCs believable? State why if yes or no.

A detail description of all the surveys and their results are attached as part of appendix 1.

The results of these surveys will be discussed in the following sections of this chapter since most of the design work is based on these results.

8.2. Overall system design

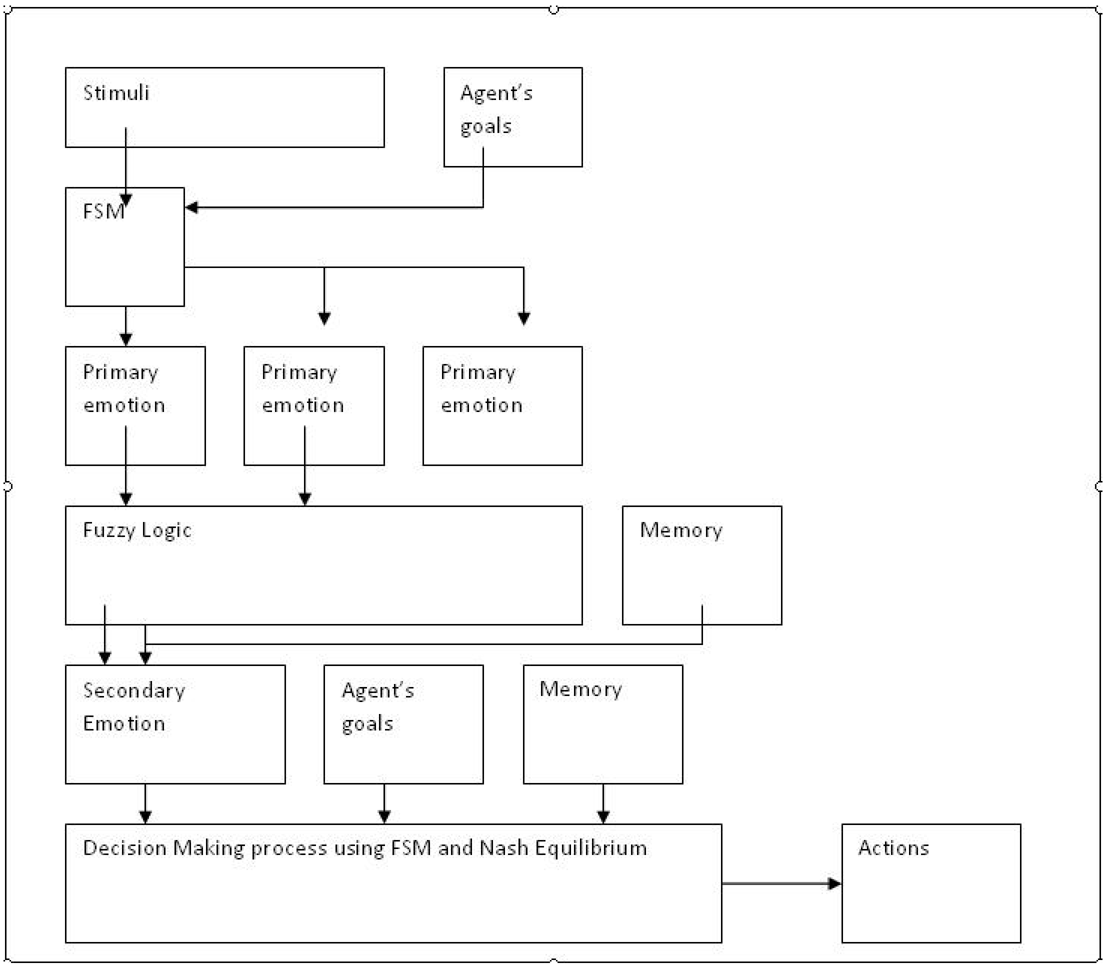


Fig 8: Showing the final system design

8.3. A complex emotional model including secondary/complex emotions and action selection

From fig 8, the system starts by the agent perceiving stimuli. Using a simple FSM, this stimulus is transformed into primary emotions. The production of primary emotions will be based on both traditional and physical approaches. The traditional approach will be in terms of an agent perceiving stimuli and generating an emotion as a result. However the value of this emotion will be altered by cognitive factors which will be represented inform of the agent evaluating the emotion evoking stimuli. This evaluation will result in the emotion value being changed. This evaluation ensures that we do not end up with the same emotion values if two entities appear at the same time and within the same distance. It also ensures that depending on the circumstances, each stimulus will evoke a different threshold for emotion. The assumption here is that an innocent passer-by and a bomb explosion should not generate the same emotion values.

For example, an agent perceives a new entity and assigns it an initial surprise value of 60. The agent will then re-evaluate this value according to its goal. The goal in this case is to kill the player. Thus the agent will evaluate his situation as follows:

"I am surprised with a value of 60. My goal is to kill the player. What is causing this surprise? Is it an entity? If yes, how does this entity affect my goal? Will he make it Harder? Easier? "

The agent then has to evaluate if the new entity makes his goal harder, or easier. This is done by checking on factors like whether the entity is armed, or attacking the NPCs. This evaluation results in a weight which is added to the surprise value, thus raising or reducing it accordingly. If two primary emotions occur at the same time, then fuzzy logic is used to determine the resulting secondary emotion. Only three basic emotions will be taken into consideration. As mentioned before, these are fear, surprise and anger

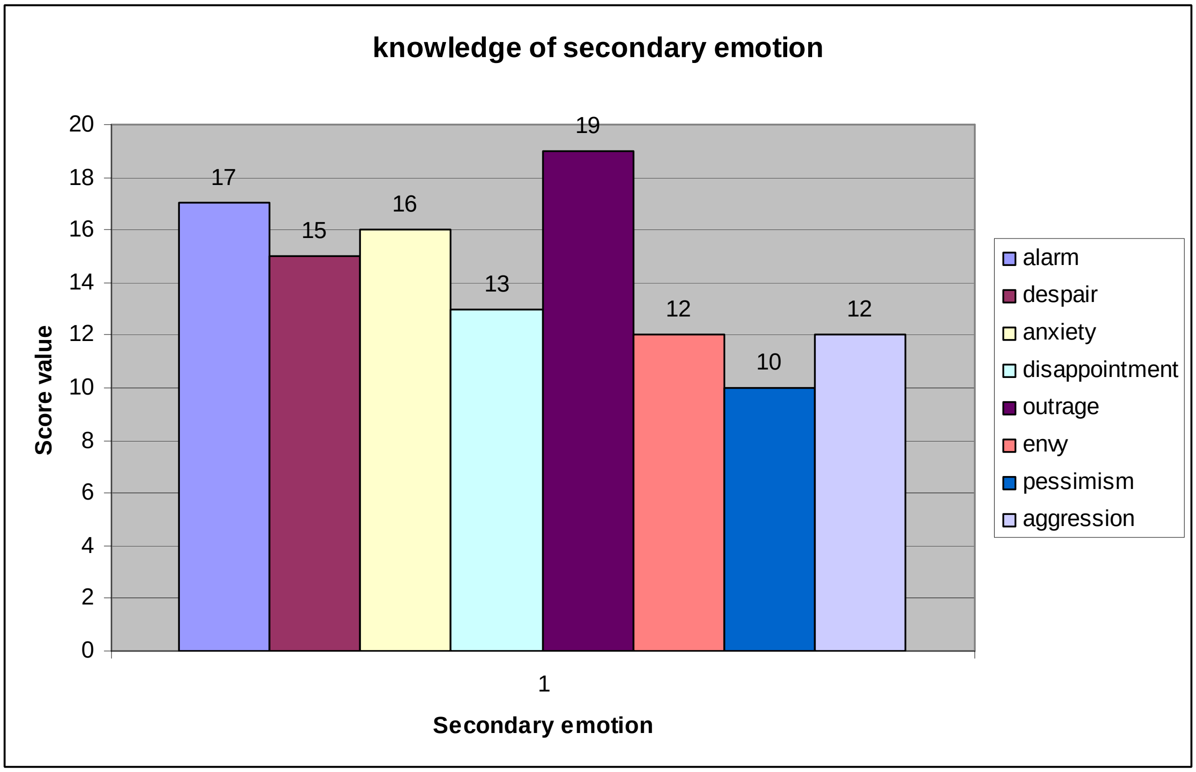
The final secondary emotion value is then fed into the decision making process, together with the agent's goal and memory. The decision is made using FSM (Finite State Machine) and RL (Reinforced Learning). The decision making block work is to help the agent take some kind of action.

For simplicity purposes, there will be no feedback loops in the above system.

FSM has been chosen due to its simplicity. Fuzzy logic is a good algorithm for simulating emotions since they never have clear boundaries, especially as will be shown in this project where it is easy to move from a simple basic emotion to a secondary one.

RL is chosen for simulating memory in the agent. This is due to its rewarding nature. Thus the items in the agent's memory will have either a positive or negative value. These correspond to good and bad action respectively. Actions which have not been encountered yet, will be denoted as neutral by assigning them a "0" value.

Only three primary emotions and their secondary combinations will be taken into consideration. This is due to the results of an initial test carried out during the design test. The objective of the test was to identify if people are aware of secondary emotions, and also, which secondary emotions are more popular. This test involved stating a secondary emotion and asking people what its primary constituents were. This is similar to the MEIS test described earlier in this chapter. The results of the tests were as shown in the following graph1:



Graph 1: showing the knowledge of secondary emotions among 30 test persons.

The tests were conducted on 30 individuals between ages 24-30. The average score on the knowledge of secondary emotions was 4.75. From the above table, the most common secondary emotion was outrage followed by alarm.

These secondary emotions are a combination of primary emotions as done in Plutchik's model discussed earlier in section 3.4.4. Secondary/Complex emotions, and shown in the below table:

Primary emotions	**Secondary Emotions**	**Occurrence**
Fear + Surprise	Alarm	Often
Surprise + Anger	Outrage	Sometimes
Fear + Anger	Conflict	-

The mixture of fear and anger was chosen as they are both constituents of alarm and outrage, and they are also easy to elicit within a game environment.

The mode of occurrence of these emotions should determine the threshold needed to generate the secondary emotion. An often occurrence means that the emotion can be generated with a low threshold of between 20-40%. For a sometimes occurrence then the emotion threshold has to be between 40-60%.For a seldom occurrence, the emotion threshold has to be above 70%. Whenever a conflict occurs when two emotions are mixed, as is the case between fear and anger, then the emotion with a higher threshold will dominate.

8.4. FSM design

This algorithm was chosen due to its simplicity. It will rely on game variables as the inputs of changing from one state to the next. There will be only two states, emotionless and "having some emotions". The game variables that will act as inputs are shown below:

Emotion	**Game variables**
Fear	perception of player
	Ammunition left
	Distance between NPC and player
Surprise	Perception of a new character
	Distance to the new character
	Number of new characters
Anger	Perception of obstacle
	Distance to obstacle

The state of "having some emotions" will involve either being in a state of fear, surprise and anger. The detailed explanation on how the states change will be discussed in section 9.1 on the implementation of FSM.

8.5. Fuzzy system design

This section will discuss how fuzzy logic will be designed in relation to game variables, fuzzy sets and defuzzification.

Fuzzy logic will be used because it is a good tool in modeling to include how two or more inputs (in this case, basic emotions) can interact to form a unified output (secondary emotions). Fuzzy sets will be used to represent emotions, while fuzzy rules will be used to represent mappings from events to emotions.

Fuzzy parameters

The variables that represent FL parameters are divided according to the emotional states as follows:

Emotion	Emotion variables	Game Variables (FSM)
Alarm	Fear	Perception of player
		Distance between player and NPC
		Ammunition left
	Surprise	Perception of a new character
		Distance to the new character
		Number of new characters
Outrage	Anger	Perception of obstacle
		Distance to obstacle
	Surprise	Perception of a new character
		Distance to the new character
		Number of new characters
Mask fear/Anger	Fear	perception of player
		Distance between player and NPC

		Ammunition left
	Anger	Perception of obstacle
		Distance to obstacle

From the above list, the emotion variables are the ones that are fed into the fuzzy logic system. The third column with game variables, simply show the variables that were used in FSM to generate the emotion variables. This detailed table has been used so as to show the relationship between the FSM and fuzzy variables. Each of the fuzzy variables will be represented in either Gaussian or trapezoidal membership functions. These functions will help in coming up with the rules for the system. There are 3 main rule based systems. Mamdani, Sugeno and Koskos. These were discussed earlier in section 4.4. For this project, the rules will be based on Madmani due to its simplicity, universality and intuitiveness[27]

<u>Fuzzy design in Matlab</u>

The original membership functions were designed in Matlab to give a rough idea of what should be done during the implementation phase in C++. In Matlab, the primary emotions were given as inputs, with their specific membership functions. An output, the secondary emotion, was then designed from these inputs. The output had three membership functions which were Gaussian. Gaussian functions were chosen due to their smooth transitions.

Rules were then generated using the input and output membership values. Sample of the rules included :

- 1. If (fear is low) and (surprise is medium) then (output1 is low) (1)
- 2. If (fear is medium) and (surprise is low) then (output1 is low) (1)
- 3. If (fear is high) and (surprise is low) then (output1 is medium) (1)
- 4. If (fear is high) and (surprise is medium) then (output1 is high) (1)

Matlab allowed the possibility to give in actual values for the two primary emotions, fear, and anger. These were fuzzified, and then later using Mamdani inference, they were defuzzified to a crisp value. This gave an idea of which values to expect when programming. A sample of Matlab files for membership functions and rule sets can be found in appendix 10.

[27] This statement is supported by Matlab fuzzy logic library

8.6. Reinforced learning design

This is achieved by the NPC keeping a table of actions taken and the result of these actions. The NPC is only interested in whether a new entity attacked him or not, as this would refrain him from achieving his goal of killing the player. Thus after a new entity has appeared, and the NPC has taken an action, it checks whether this action deterred its goals. If yes, then it is given a negative value, if not, then it gets a positive value.

Example:

New entity	Action to him	Action to us	Value (and reason)
Pierre	Attacked him	Did not attack back	-1(valuable time wasted)
HammerC	attacked him	attacked us too	1(danger to us)
Eva	did not attach her	did not attack us	1(saving time)
Trooper	did not attack him	tried to attack us	-1(posing danger to us)

Thus from this table, when the NPC encounters the same characters the second time round, he will not attack Pierre again since that gave him (the NPC) a negative value. He will attack the HammerC again since that gave a positive result, and he will not attack Eva. However, he will attack the trooper since not attacking him the first time round ended up being a danger to the NPC, thus the negative value. These new actions will be given values, and for this second time as well, the ones with positive values will be repeated but not the ones with negative values. The NPC will keep on updating this table every time it takes an action towards any of the new entities.

8.7. Designing the emotional stimuli in game scenarios

For fuzzy logic to be able to work, some game scenarios may need to be added so as to provide the game variables stated in the previous section. These scenarios are designed to create complex emotions when they interact with other scenarios or entities. This is a technique discussed in section 6.4 whereby different storylines are made to converge so as to generate complex emotions.

There are several new game scenarios that will be introduced so as to be able to elicit the different basic emotions. The induction of these emotions will be based on the theories provided by Plutchik

(1980), Brazael (2000), and Roseman's model. These were described earlier in sections 3.4.4. Secondary/Complex emotions6.7.1.2. Roseman's Cognitive Appraisal modelrespectively.

The new scenarios are:

Surprise scenarios´

The surprise scenario is based on stimulus that Roseman's model describes as unexpectedness. That is the introduction of a new unanticipated stimulus into the environment. In this system, it will be achieved as follows:

Scenario 1: This involves an innocent passerby who is jogging around the park.

This scenario will be designed to provide a scene in which an innocent passerby comes into the game environment where the player and the other NPCs are fighting. The purpose of this will be to see the level of emotions generated in the NPCs when an innocent harmless character comes into the scene.

Scenario 2: Introducing a new army into the scenario.

This ought to result in a scene in which a different army joins the original NPCs to fight the player. The purpose of this would be to see the level of emotions generated when a new group of characters that could either be "friends" or "foes" of the NPCs come into the scene.

Scenario 3: A scared ally who appears into the scene without any weapon

This scenario introduces a friend of the player's who appears into the scene from time to time but without any weapon.

Fear scenario

This is based on Plutchik's and Brazeal (2000) work, where fear is expected to be produced by a threatening stimulus. In this mod, the threatening stimulus will be the player, and any new armed character that may come into the scene. As soon as the NPC perceives any of these characters, fear will be evoked depending on how far/close the new entity is.

Surprise-Fear-Anger scenario

This scenario involves having a character that comes into the scene and produces actions that induce surprise, fear and anger from the NPCs. This character ought to act as an obstacle to the

NPCs in achieving their goal of killing the player. This is based on Plutchik's work where anger is the result of an obstacle or delay that makes it difficult to achieve a goal.

8.8. Designing emotional reactions

Sloman (1999) states that the majority of work on emotions is based on the fact that the emotion can be expressed outwardly. This however does not hold for purely central secondary emotions (these are emotions that cannot be expressed by bodily reactions). These are the emotions that this project will be based upon. The term emotional reaction used in this section refers to an action.

An initial idea had been to work with partial peripheral secondary emotions (those than can be expressed both internally and externally) but this would have involved a lot of animation which was not the main focus of this project. Since purely central secondary emotions involve cognitive processes such as planning and decision making, expression of emotion in this system will be via the action taken by the NPC. These involve actions like walk backwards, attack, attack fiercely and evade. These will be assumed to be the type of decisions that the NPC has to make to achieve his goal of killing the player. To be able to design these emotional reactions, an initial test was done to find out how people react when they experience different emotions. The test was made up of open ended questions so as not to limit the answers that the test persons would give.

Though eight secondary emotions were tested, only results of the two that are the focus of this project will be discussed. These are as shown on table 2 below. They are alarm and outrage. The rest of the results for the other secondary emotions can be found on appendix 1.

Emotion	Action
Alarm	Run, Halt, Jump up in confusion, React to alarming element, Sharpen senses, Freeze, Change orientation towards situation, be "why" faced, try to calm down, try to get an overview, be more careful, stress out, try to solve the problem.
Outrage	Speak out, Yell, Confrontation, Cry, Get angry, Fight, Loss of overview, Scream, Complain, Be angry yet surprised.

Table 2: showing results of initial test on mapping secondary emotions to actions.

It is interesting to observe that some of the actions stated in the above table, reflect on the mappings provided by Plutchik (1980) to the basic emotions that constitute the above secondary emotions. His mappings discussed earlier in section 6.5.2. Behavioural (Emotional) Reactions and Decision actions, describe fear as being mapped to escape, surprise to stop, and anger to attack.

The initial idea was to use results from the above table coupled together with Plutchik's mapping model as a basis for the initial mapping for actions in this project. This meant that we had to create extra animations for actions such as halting, confrontation, change in orientation, running away from player and attacking. However due to software problems this could not be achieved. As a result we ended up with only eight possible actions that the NPCs can take. These are: walk backwards, stand shoot, run forwards, run shoot, call for backup, pause, change orientation and back away slowly while firing.

8.9 Designing action selection mechanism

Initially, action selection had only been based on secondary emotions. This initial mapping was based on the results of the initial test discussed in the previous section 8.8, and on Plutchik's model. Thus the initial mapping was as follows:

Alarm-> change in orientation, halt, walk backwards, back away slowly while attacking, call for backup

Outrage-> Stand and shoot, Run towards player and shoot

However later we decided that it was not enough to just map a bunch of actions to a secondary emotion. How exactly would the NPC know which action to take out of the whole bunch? To answer this, we divided each secondary emotion into four levels of intensity. The intensity could either be low, Medium low, Medium High or High. From this, each intensity level of the emotion was mapped to an action as shown on table 3 below:

Alarm emotion value	Action Weight	Back off	Attack	Call for backup	Change in orientation	Halt, without action	Backaway slowly while attacking	Nothing
Low	0.3				1.0			1.0
Medium low	0.5		1.0					
Medium high	0.7	1.0				1.0		
High	0.9			1.0			1.0	

Table 3: showing emotion action mapping

From the above table, a low intensity of alarm can result in two actions, either do nothing or change in orientation. A medium low alarm results in attacking. A medium high alarm results in backing off and halting without action. A high alarm results in calling for backup or backing away. Each action taken is multiplied by the action weight. For example, the action weight for any low alarm value will be 0.3. This is multiplied by 1, still resulting in 0.3. Thus in the end all the actions end up having the value of the action weight.

As stated earlier, a rational agent acts by doing some sort of cost benefit analysis of its future actions. The NPCs in this mod ought to be able to do this. As a result, an event evaluation action table was created. The NPC uses this table to evaluate every new entity that comes into the game. This table is based on fictitious game, a technique based on finding the Nash equilibrium[28] in a game as shown below in table 4. Nash equilibrium is a game theory concept involving two or more players. Each player is assumed to know the equilibrium strategies of the other players and no player has anything to gain by changing only his strategy unilaterally.

	Back off	Attack	Backup	Nothing
New entity	0.0	0.0	0.0	1.0
Has weapon	0.5	0.7	0.0	0.0
Attached to player	0.3	0.6	0.0	0.0
Blocking our path	0.5	0.8	0.0	0.0
Already attacking	0.0	1.0	0.0	0.0
More than one entity	0.0	0.0	1.0	0.0

Table 4: Game event (variable) - Action table

In section 6.2. Role of Emotions in AI and in games of the analysis, we explained the role of emotions in decision making. This role has to be incorporated into our action selection mechanism. So far there is a table showing how to map from emotions to actions, and another showing how to map from game event to actions. To be able to incorporate emotions into the action selection, the two tables had to be combined. An initial idea was to use an “AND” operation as done in fuzzy logic, where the greater value of two variables is taken.

8.11. Conclusion

This chapter has given a detailed overview of the design of the functionality that will be required for the implementation phase. The design described here, is what we view as the necessary elements for us to be able to implement an effective affective system for action selection. The design blocks identified here, i.e. Finite state machine, fuzzy logic, Reinforced Learning, emotional evoking stimuli, emotional reactions and action selection are passed on as inputs to the implementation phase.

9. Implementation

This chapter will outline the implementation of the project. It will start by giving an overview of the implementation in Virtools and Visual Studio C++, followed by a more detailed explanation of the different parts of the implementation. More focus will be given Fuzzy logic as it is the main algorithm that the implementation is based upon.

9.1 Implementation flow diagram

Figure 9 shows an overview of some of the main blocks that had to be implemented in C++ so as to be able to have a functioning system.

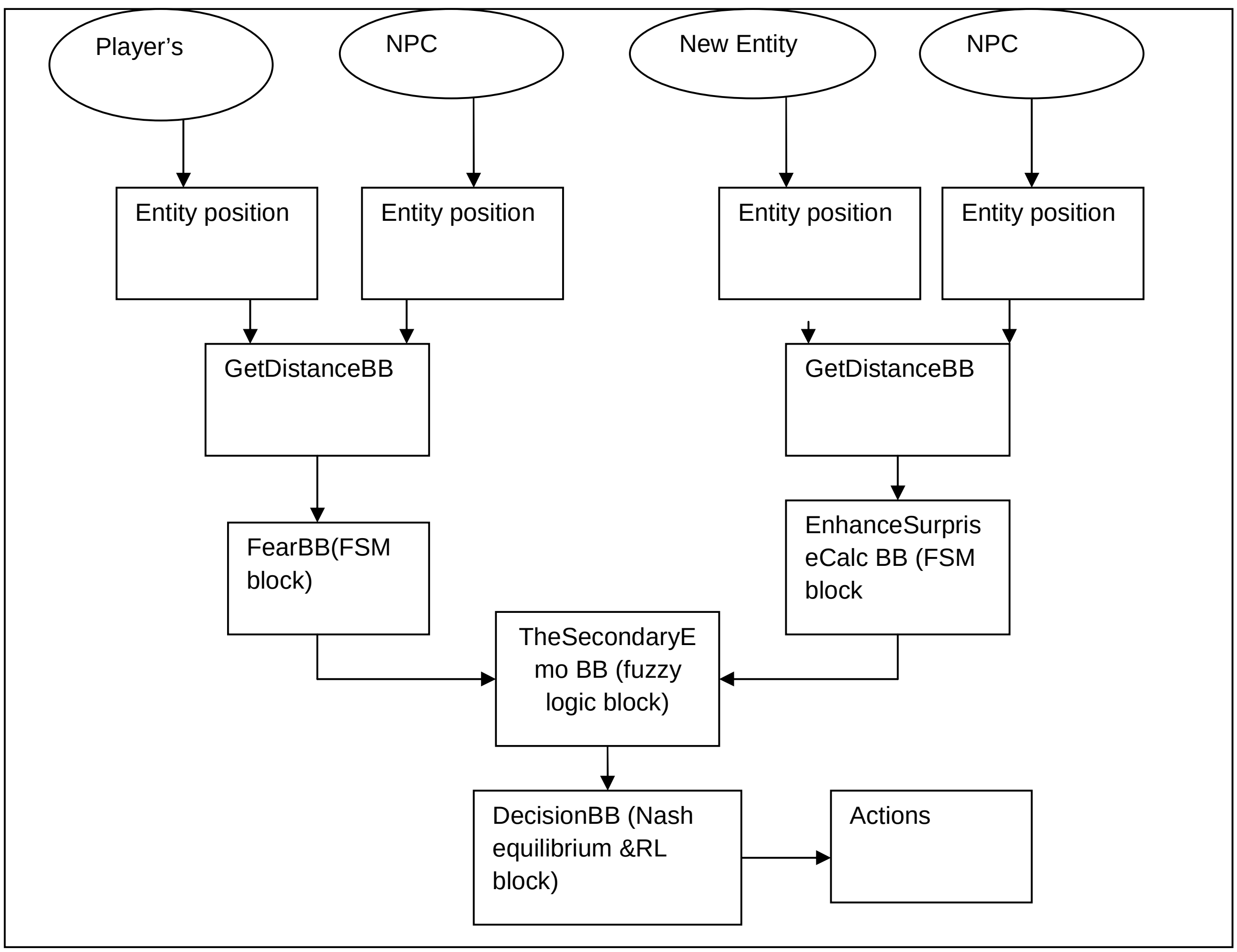


Fig 9: showing the main building blocks programmed in C++ that offer the needed functionality to the system.

The circles in the figure represent entities (characters) while the boxes represent building blocks. These building blocks are a product of the design figure shown on the previous chapter. Most of thesedesign blocks are implemented as Virtools Building Blocks[29] (from now on will be referred to as BB) created in C++.

A quick overview of how the implementation works is as follows: The NPC perceives the player or a new entity in his environment. He calculates the distance between himself and the player/new entity. This distance serves as the input that is later transformed into a basic/primary emotion value. If two of these basic emotions occur, they are fed into a block that combines them using fuzzy logic to come up with a secondary emotion. The secondary emotion is then fed into a decision block that evaluates which action should be performed.

This implementation will be discussed in detail the next few sections. Only small sample of the Virtools scripts will be shown in different parts of the implementation discussion. This is due to the fact that the script that implements the main part of the NPCs action selection mechanism is too vast to be copied into this document. As a result, these scripts, together with others that aid in the functionality of the mod are attached as appendix 7.

9.2 Implementing emotion evoking scenarios

In order to simulate emotions, we need to evoke them first. This is achieved by introducing new “emotion evoking” characters into the scene. The implementation of these characters was based on the emotion evoking scenarios described in section 8.7. These characters evoke fear, surprise or anger.

The new characters introduced into the scene were:

Character1: Eva

Eva is a character from the Virtools game engine. She represents an innocent passerby who has to run around the park. Only two main animations are attached to her, run and stand. She keeps running until she meets an obstacle which may include the player or the other characters. When this happens, she stands until the characters move out of her path. When she meets immovable objects, she makes a 90 degree turn and continues running. This ensures that she is always running around park. Every once in a while (though rarely), she runs out of the park.

[29] This is a block in Virtools game engine that defines the functionality that should be given to any object that its attached to.

Character2: Pierre

Pierre is also a character from the Virtools game engine. He represents an unarmed ally of the player. He appears in the game at certain intervals. This is achieved by activating and deactivating his script at certain intervals. His activation/deactivation is inversely proportional to HammerC, the other character that will be discussed briefly. He is programmed to imitate the player, but with varying distances. Sometimes he is besides the player and other times he is far way. So every time the player moves, so does Pierre. He walks on his knees every time the player fires. This is a way of indicating that he is scared.

Character3: HammerC

This character is made as a copy of the player's character, i.e. the Hammer. This is done by creating a duplicate of the Hammer. He represents an armed comrade of the player who appears at random intervals to aid him in fighting the evil NPCs. He has the same movements as the player, and these are walking, jumping and shooting. He is programmed to imitate the player, so he mimics the player's moves but at a certain distance. He is translated by -1 unit on the z axis so as to ensure that he can be viewed from the third person camera being used in the game. He is able to attack the NPCs. This is as shown in the screenshot below.

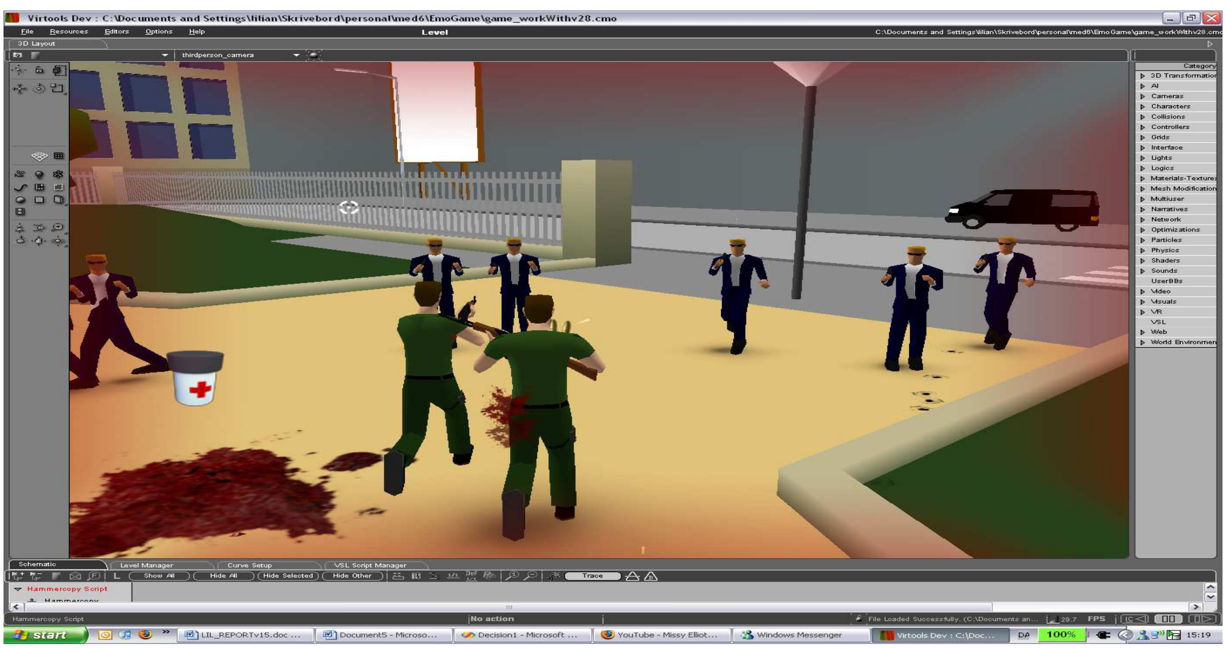


Fig 10: Showing the player and his comrade HammerC attacking the NPCs

HammerC and Pierre are programmed to appear / disappear from the game environment at certain intervals. This behavior acts to evoke different emotions at different times.

Character4: Trooper and his army

These are three characters from Virtools game engine. They are, the trooper, traitor trooper (who is a copy of the trooper), and Jane. The trooper is oriented to always be facing the player. Mostly, he is either in front of or behind the player. He keeps calculating the distance between himself and the player, and comparing this to an approach distance. If the distance is less than the approach distance, then a message is sent for the trooper to walk. If it's higher, then the trooper has to rethink his actions, and while doing this, he shoots at the player.

Jane is a female character with only three animations attached to her. Those are running, defending and kicking. She is programmed to mimic the trooper, and always stay beside him. This is done to indicate that they are a team.

Character5: Traitor trooper

He is a part of the trooper's army, but he is separated from them due to the fact that at some point he leaves their army and decides to join the player. He represents a character that acts as an obstacle to the NPCs. The animations attached to him are the same as the trooper's. However, he has two scripts attached to him. Initially the first script controls his movements and as a result he mimics Jane's actions. As a result, his movements, those of Jane and the trooper are almost similar. However unlike the trooper, he is not always facing the player, he keeps looking around. This is supposed to act as a clue that he may switch sides. When he decides to join the player's army, his original script is deactivated, and the second one is activated. In the second script, we make him mimic the player but he is translated by 2 units so as to be ahead of the player. This gives the illusion that he is protecting the player from the enemies. This is shown in the screenshot below.

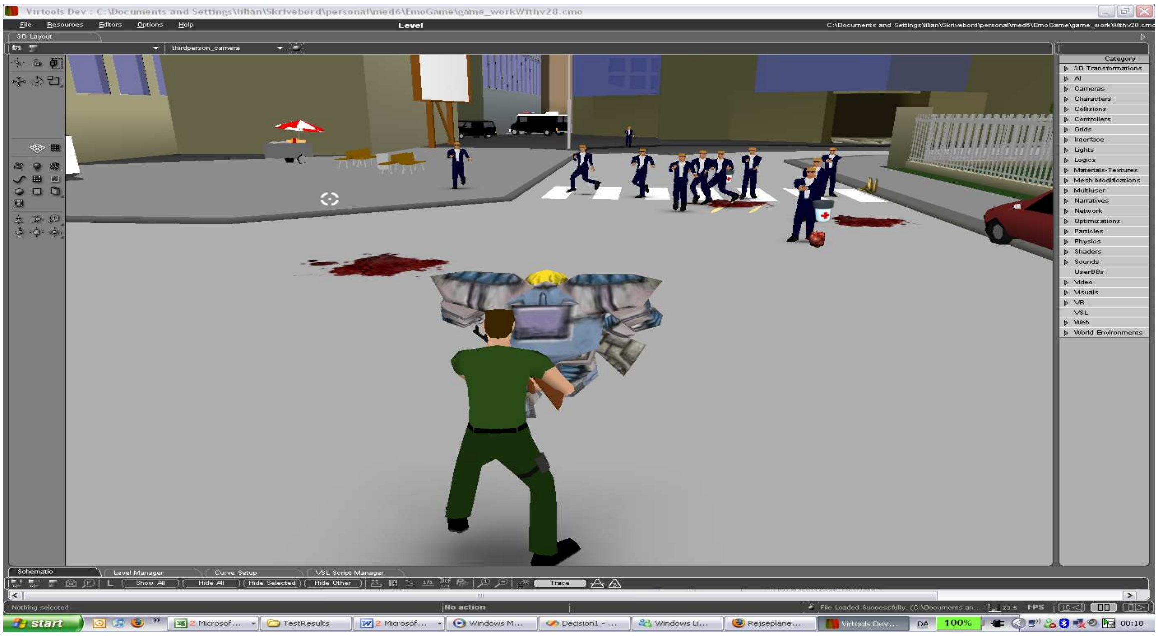


Fig 11: The traitor trooper offering protection to the player while the NPCs run away

9.3 Finite state machine

This was implemented in form of if-then commands. When in an emotionless state, if the character comes across a game variable that should evoke some emotion, then if the required threshold is reached, the character's state changes from emotionless to "having some emotion". The emotion value is either directly or indirectly proportional to the variable that causes it.

NPC's initial state	**Game variable**	**NPC's final emotional state**
Emotionless	Player's distance	Fear
Fear	new entity	Fear + Surprise
Fear	obstacle	Fear + Anger
Emotionless	new entity	Surprise
Surprise	Obstacle	Surprise + Anger
Emotionless	Obstacle	Anger

The resulting mixed emotions Fear+ surprise, fear+ anger and surprise + anger, are the ones that are passed on to the fuzzy block for further processing to give an estimated value for the secondary emotion.

The player's distance is inversely proportional to fear, the closer the NPC is to the player, the more scared he gets. Thus if distance between the player and the NPC is 1(very low), then this results in a high fear value of 90. This is because every one unit in distance represents ten times itself subtracted from 100. The figure 100 is taken to be the saturation level for any emotion. This is in agreement to Picard's description of some of the variables that make an effective affective system (Refer to appendix 4 for more information on this). The rule for the transition is if distance is high, fear is low, and vice versa. To be able to get this distance, two building blocks were implemented in C++. The first, EntityPosition is used for getting the entity's position. Here entity refers to any of the characters in the game. Another building block is used to get the distance between the two entities. This is done by getting the distance between the two character positions which are represented as vectors. This distance is what is translated into the fear value.

Surprise occurs when a new entity (namely, a new character) comes into the scene. When this happens, the NPC calculates the distance between itself and the new entity. If the entity is close, then the surprise value should be higher and vice versa. This initial surprise value is given to a building block "EnhancedSurpriseCalc" which enhances its value. This is done by checking which new entity has entered the scene, it evaluates the harm factor of this new entity to the NPC by checking if the new entity is armed, if it's attached to the player, if it's attacking, and also the number of new entities in the scene. This evaluation gives a final altered surprise value that is fed to the block that calculates the secondary emotion.

Anger occurs when there is an obstacle in the NPCs path. The amount of anger is determined by the amount of time that the obstacle stays in place. If it stays for only a second, then the anger intensity quickly vanishes. However, if the obstacle stays for a long time, then the anger value rises. A new building block that acts as a counter is used to calculate how long the obstacle stays in place.

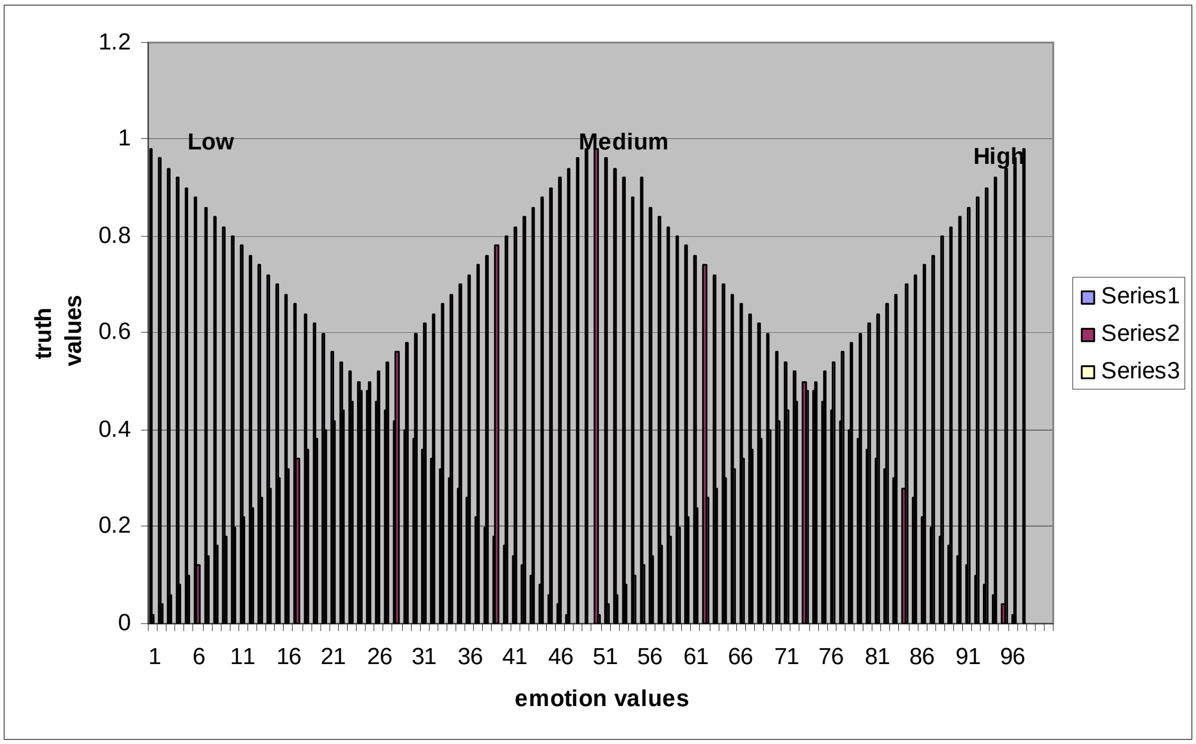
9.4. Fuzzy logic

To do this, we tried to emulate Mamdani's model discussed in section 4.4. Fuzzy Logic whereby we first fuzzified the input values, and later on defuzzified the output to get a final crisp value.

A fuzzy class was developed in C++. To emulate membership functions, an array was created. This was a dimensional [100] [3] array. This array is initialized to represent membership functions. The three columns of the array contain the truth values (weights) for the low, medium and high membership functions. The low column is filled with truth values ranging from 1 and decreasing by 0.02. The medium and high columns are filled with truth values ranging from 0 and incrementing by 0.02. The low truth values go from row 0 to 50, high starts from 50 to 100, while medium runs from

0 to 100 but initially in an increasing, and then decreasing order. The implementation of this array was an emulation of the output membership function designed in Matlab as shown in appendix 10.

The resulting figures from initializing the array with truth values were copied in Excel, then a chart was drawn to see if our membership functions were trapezoidal as desired. The resulting membership functions are as shown below on graph 2:



Graph 2: showing our membership functions initialised as an array in C++ and then drawn in excel

The specific code for the initialization of the array in C++ can be seen as part of appendix 6.

This array(representing the membership functions) is passed as a parameter to the fuzzyifying and defuzzifying functionalities which are carried out in two functions. For fuzzyifying, when an input value of any of the primary emotions is given, it is turned into an integer. From there, a loop is run to check which row the emotion input value corresponds to in the membership array. When the row is found, its corresponding truth values for the low, medium and high functions are extracted. These are multiplied with constant values assigned to low, medium and high functions. A low value of 20 was assigned to the low function; medium was 60, and high 80. Thus for a fear value of 80, the resulting out put would be 0.0 on low, 0.3 on medium, and 0.4 on high. The fuzzication for the 80 value of fear would be

WeightedAve=(0.0*20+0.3*60 + 0.4*80)/(0.0+0.3+0.4)

=71.4

The same is done for a surprise value. To calculate the final defuzzified value, we get the average of the two crisp values. This is assumed to be equivalent to the centroid value taken by mamdani's inference. The exact specifics of the code can be found in appendix 6. The final output of the fuzzification, is then passed to the decision making building block. This is as shown in the Virtools patch on fig 12 below:

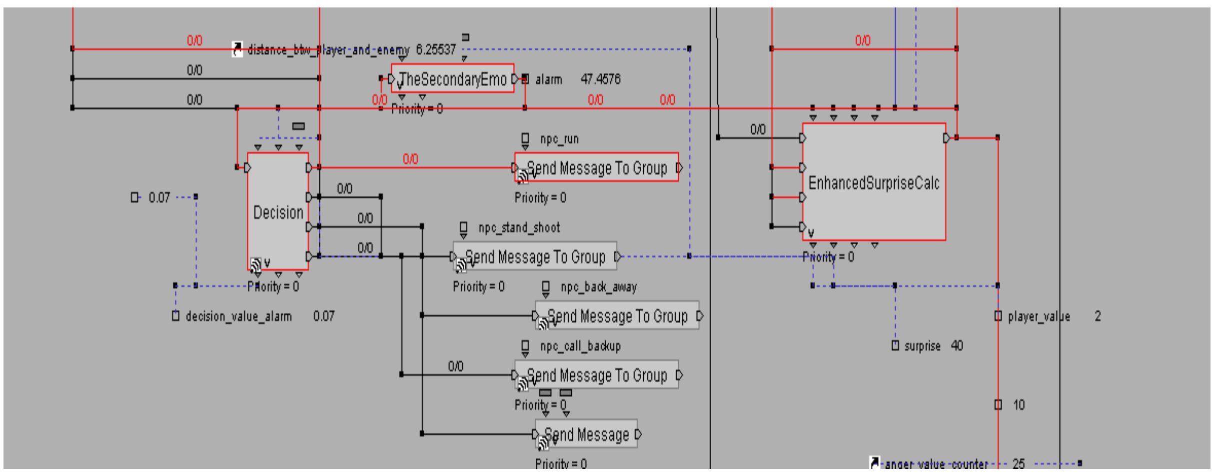


Fig. 12: showing an alarm value of 47.45 from Eva's appearance. This is the result of a surprise value of 40 and fear value of 50.

The mixture of fear and anger however is however calculated differently. This is because the combination of these two normally results in a conflict. In such a case, after calculating the fuzzification values of the two emotions, instead of getting the centroid value, we take the higher of the two values. This is seen as a masking of one of the emotions. This was discussed in section 3.4.4. Secondary/Complex emotions as one of the ways of creating secondary emotions. For the two values we simply give them to a function that returns the higher value between the two variables.

9.5. Decision making

The decision making class is designed after the emotion-action and game event-action tables described in the design chapter in section 8.9 Designing action selection mechanism. These tables are designed inform of if-then statements. The decision class relies on receiving two inputs for it to act. The first is the secondary emotion value, and the second is the identity of the character who invoked the emotion. Once it receives these values. It assigns action weights to the emotion values. This is done by dividing the possible emotion values into ranges and assigning them action values as follows:

Low range is for emotion values that are >0 but <20. Action value is 0.3

Medium low range is for emotion values that are >20 but <40. Action value is 0.5

Medium high range is for emotion values that are >40 but<60. Action value is 0.7

High range is for emotion values that are >60. Action value is 0.3

For the game event action table, 3 extra functions are used for evaluating. These are: hasWeapon(), attached_to_player() and already_attacking(). These are used for checking if new entity has a weapon, is attached to the player or is already attacking. These checks return Boolean values. Once these checks have been performed, weights are assigned as follows:

If only hasWeapon() is true, action value is 0.7.

If only attached_to_player() is true, action value is 0.6.

If only hasWeapon() and already attacking() are true, action value is 0.7+1/2.0.

The rest of the weight assignment can be seen in appendix 6 as part of the code

These action values from the game event and emotion tables are then combined as a product sum.

The product sum was chosen because this way then the emotion value will actually have an influence on the action. If we had chosen to take one of the action values, then that would mean excluding the other. This product sum value is our way of showing how the emotion value is biasing the decision of the NPC either positively or negatively. This final action (decision) value is what determines what action the NPC will take.

To be able to achieve the enabling of different actions, the decision BB has four output pins. Thus depending on the final decision value, one of the output pins is activated. These output pins act by sending messages that specify the exact actions that the NPCs should carry out.

9.7 Conclusion

The above chapter has fully described the functionalities that were implemented so as to be able to have a functioning mod. Apart from RL which was not implemented due to time limitation, the rest of the algorithms seem to work as expected. The implementation of fuzzy logic was challenging at first especially in relation on how to design membership functions. However, once this was achieved, the rest of the algorithm's implementation went smoothly. A minor draw back of this system is that it did not provide for what should happen when two secondary emotions occurred at the same time. This factor had not been anticipated during the design phase, and as a result it caused some weird behavior in the NPCs as they were not aware of which emotion to evaluate. Later, it was decided that if such an occasion occurs where two secondary emotions occur simultaneously only one of them would be picked randomly. This seemed to work ok but we were aware that it may cause some problems during the testing phase. It was decided not to pay any more attention to this problem as it was not the main focus of the project.

Thus having this system in place, the next logical step was to use it as a means for testing our theories.

PART 3

10. Testing

This chapter will introduce and discuss the tests carried out in the thesis. Reasons will be given for why these tests were chosen, and what is expected out of them. Results will be presented, followed by an evaluation on whether the test was successful or not. A final conclusion will be reached at the end of the chapter.

10.1. Test methodology

A total of ten tests were carried out during the duration of this thesis. Three in the pre-implementation phase as discussed earlier in section 8.1. Designing Initial Surveys and seven in the post implementation face. A total of sixty participants were tested in both the pre and post implementation tests. All the post implementation tests were written in form of questionnaires, which used a Likert scale of 1-7, and 1-8. The reason for this will be discussed later in this section.

From the final problem formulation

"We wish to investigate the role of secondary emotions in action selection, and how this affects the believability of a character"

We divided the problem into two and came up with relevant hypotheses to be tested as follows:

To test "***the role of secondary emotions in action selection***", the following hypotheses were developed:

1. Action selection is recognizable as one of the main ways that a character can express its emotions
2. The actions taken by an NPC can be linked to the presence of secondary emotions
3. The emergence of new secondary emotions should result in noticeable changes in action selection

To test "**how *the role of secondary emotions in action selection affects believability***", the following hypotheses were developed:

4. It is possible to map secondary emotions to actions in a believable manner
5. The addition of secondary emotions as a tool for action selection increases the level of believability in a game

6. The addition of secondary emotions as a means of action selection, should act as a way of randomizing the NPCs behavior

Test set up

The participants for all the post implementation tests were of the age group 20-40. All the tests set ups consisted of the game being shown in an IBM R52 laptop. Scheinheiser headphones were attached to the computer so as to be able to provide audio feedback to the test participants. In addition, a mouse was supplied for extra navigation in the game.

For each of the above hypotheses, tests were developed. These were as follows:

Test 1: Action selection is a means of expressing emotions

This was to test hypothesis 1:

"Action selection is recognizable as one of the main ways that a character can express its emotions"

This test was designed to assess if players acknowledge action selection as a way in which a character can express its emotions. The research on emotion expression in virtual environments had indicated that most work is normally put behind expressing emotions in terms of facial expression and body posture. Thus for this test to be successful, test persons had to be able to acknowledge action selection as a viable way of expressing emotions. The results of this test were to be used to test for biasing in the remaining tests on the game. This is because if people were not at all aware of action selection as a means of expressing emotions, then it would be hard to test them on a game that relied on this concept.

Test procedure:

The test persons were given a small questionnaire with five questions. This had to be filled before they were told anything about the game that they would play. They had to fill in a likert scale of 1 to 8 what they thought was the most important means of expressing emotions in characters in a virtual game. The choices were: facial expression, body posture, actions taken during the game, gesture and voice.

Test 2: The linking of actions taken by NPCs to secondary emotions

This was to test hypothesis 2:

"The actions taken by the NPC can be linked to the presence of secondary emotions"

This test was designed to examine if players can relate the actions taken by the NPCs during game play to the presence of secondary emotions. This was based on the fact that a decision action ought to arise from secondary emotions as discussed in section 6.5.2. For this hypothesis to be valid, the test persons ought to be able to relate the NPC actions to emotions.

Test procedure:

Each participant was given a written game synopsis, together with screenshots and definitions of the characters that they would meet during their game play. A verbal explanation was given on the aim of the game, and way of navigation within the gaming environment. After that, the participants played the game for about 5 minutes. This was the average time of play for them to be able to meet all the different characters who act as the emotion evoking stimuli. Participants who were still a bit confused with the game due to its dynamicity and complexity were allowed to re-read the synopsis and play the game a second time. When done with playing the game, the participants were given a questionnaire that consisted of 14 questions where they had to rate the emotions they thought caused the different actions within the NPCs. The questionnaire was rated on a 1 t0 8 likert scale that will be discussed in detail later in this chapter.

Test 3: The emergence of new secondary emotions and change in action selection

This was to test hypothesis 3:

"The emergence of new secondary emotions should result in noticeable change in action selection"

This test was designed because, due to the dynamicity of the game, the secondary emotions change quite fast, thus it is important that these changes are also noted within the action selection mechanism.

<u>Test procedure</u>

After playing the game, the test persons answered a questionnaire which asked them to rate the changes that they noticed in the actions of the NPCs with the arrival of each new character into the scene. The arrival of each character into the scene acted as a way of evoking the primary/secondary emotions. The rating of this questionnaire was done on a blank slider with "unindicated" values of 1 to 8. A slider was chosen instead of a Likert scale, as it was viewed that this would actually force some of the test persons to think before placing a value, and it also eradicates the choice of a neutral (median) number, as it is quite hard to choose this on a slider.

<u>Test 4: Mapping of secondary emotions to actions</u>

This was to test hypothesis 4:

"It is possible to map secondary emotions to actions in a believable manner"

This test was designed to check for possibility of mapping secondary emotions to actions due to the fact that the discussions in sections 6.5.2, and 7.7 showed that there is no theory supporting the mapping of secondary emotions to actions. It was stated therefore, that the designer of a system that uses secondary emotions should try to base the initial mapping on intuition and test as much as possible while doing the mapping, and maybe use the results to adapt the mapping to be more believable.

<u>Test procedure</u>

This test was conducted on only one group. After playing the game, the test persons answered a questionnaire which asked them to indicate on a likert scale of 1 to 7, whether the NPCs reaction on the emergence of new emotion evoking characters was intuitive or not. This scaling of "not intuitive" to "very intuitive" was used instead of the term believability as this could have been confusing to test persons. This is because this term does not have a clearly stated definition within the gaming/emotional realm thus its meaning may have been subjective to test persons.

<u>Test 5: To test the believability of the initial game versus the new mod</u>

This was to test hypothesis 5:

"The addition of secondary emotions increases the level of believability in a game"

This test was designed to check if the addition of secondary emotions as an action selection mechanism had increased the level of believability in the game. This was a "further development" on the initial test on the original game to assess its level of believability. It was modeled after

Turing's test (Livingstone, 2006) which states that AI should be tested by testing the game with and without the AI component.

Test procedure:

This test was conducted on two groups of test persons. The first group played the original game without the secondary emotions or action selection mechanism. The second group played the mod with the secondary emotions and action selection mechanism. Afterwards they were asked to fill in a questionnaire where they had to state if they could predict the NPCs actions beforehand. If they could, then they were asked to state the clue that helped them make this prediction. The level of predictability was indicated a likert scale of 1 to 7, but stating the reasons of the prediction was an open ended question where the participants indicated the clues in their own words.

Test 6: Randomization of NPC behavior by adding secondary emotions as a tool for action selection

This was to test hypothesis 6:

"The addition of secondary emotions as a means of action selection, should act as a way of randomizing the NPCs behavior"

This test was designed to check if using secondary emotions as a basis for action selection would impact on the predictability of NPCs behavior. This was based on the fact that randomization acts as a means of enhancing believability as it makes it harder for the players to know what the NPCs will do. Thus it is important that the choice of action selection based on secondary emotions adds some randomization to the behavior. This test was also modeled after the Turing test mentioned earlier in test 5.

Test procedure

This test was conducted on two groups of test persons. The first group played the initial game without the secondary emotions or action selection component. The second group played the new mod with the secondary emotions and action selection components. After that, the test persons were given a questionnaire to answer. This questionnaire asked them to rate the randomness of the behavior of all the characters in the game. Only the "guys in blue"(the NPCs) are taken into account as they are the characters that are common under both scenarios. The rest of the characters are only available in the new mod with secondary emotions and decision components.

Questionnaire design

The idea of using a Likert scale arose from a previous semester project (Juma, Ravn and Sahaf, 2007) where we found out that we could evaluate the presence of emotions by using a scaling system. It was also inspired by Dror (2001) where he described the use of numerical scales for representing emotions as this is a good way of helping machines to process and evaluate emotions.

The Likert scale was based on the PANAS (Positive And Negative Affect States) system developed by Watson et al (1988). This system measures emotional states. It consists of twenty items. Ten of the items measure positive affect while the other ten measure negative effect.

For each item, participants indicate “To what extent they feel an emotion” on a scale of 1 to 5. Where 1 = very slightly or not at all, and 5= extremely. In our tests however we decided to change this scale from 1 to 8 so as to have a wider range. From previous tests, it had been noted that when given a scale with odd numbers, most test people choose the median. Thus an even scale of 1 to 8 was chosen to avoid this.

(1) = Very slightly or not at all	(2) = A little	(3) = Moderately	(4) = Quite a bit	(5) = Extremely

Table 5: The original PANAS scale

From the above PANAS scale, ours was adapted to look as follows:

1	2	3	4	5	6	7	8
Not at all	Very slightly	A little	Moderately	Slightly above moderate	Quite a bit	A lot	Extremely

Table 6: Our emotion measuring scale

The emotions to be evaluated on this scale were fear, anger, surprise, alarm and outrage. For each question, a secondary emotion together with its primary constituents, are given as possible answers. This is due to the fact that our initial tests showed that only an average number of people are aware of secondary emotions. Thus during the evaluation of the test results, an answer stating the existence of the only the basic emotions that form a secondary emotion, or the secondary emotion itself will be taken to be correct.

The PANAs scale has been used successfully in emotional research in works like studying of the role of emotions in affect by Jundt, Dustin K, Hinsz Verlin B(2002) and in the study of self esteem and emotion by Brown and Marshall (2001)

Questions design

Demographical questions consisted only of asking for the test person's name, age and gender. These were seen to be the only factors that could affect the results. This is due to the fact that the game being tested was a totally new concept, and thus there was no need of asking people about their previous gaming experience, as this would have no effect on the tests.

It was assumed that mostly people in their early twenties and above were able to complete the task of this test successfully. This was as a result of the initial tests whereby when testing on the knowledge of secondary/mixed emotions, most of the test persons of ages 18 and below had no clue what that term meant. Thus it was assumed that the age limit for this test was 20 and above. Gender was noted to see if there was a difference in the perception of emotions between male and female due to the myth that "women are more in touch" with their emotions.

The quantitative questions were based on rating emotions on the likert scale. For every test, there was at least one question which acted as a control question. The control question was one in which the AI component of the system would not work, and thus "non AI" neutral results were expected from it. These control questions were to be used later as the hypothesized sample against which the actual results would be measured. This method was used because the original game did not have any of the new characters that were brought into it by the mod. Thus if test participants played the original game versus the mod, then for all the new characters, there would be nothing to compare against since they do not exist in the original version. Therefore to counter this, for every question, we have scripted a scenario where we simulate the AI as not working. Such a scenario mostly includes the NPCs not reacting to the characters. That is the control scenario.

Open ended questions were only used in one test (test no.5), and they were used to check on what acted as a clue in informing the test persons about the actions that the NPCs were going to take. Thus for these questions, the test persons were free to use their own words when giving their answers. The test questionnaires are available as part of appendix 2.

10.2. Test results

This section will present the tests results. For clarity purposes, the following terms have to be explained since they appear on each test result.

Df=degrees of freedom, Std dev=Standard deviation, N=no of samples.

N is the number of subjects tested. Mean represents the average score for the test persons. The Standard deviation shows how every sample differs from the mean. The Df is simply N-1 when dealing with one group. This Df is used for statistical calculations when getting a tValue. The tValue shows whether the difference between two samples is statistically significant. For this to be valid, the tValue of the two means must be greater than the tValue given in a t-table for statistics. Finally, the pValue defines whether the test is statistically significant or not. For the test to be significant, its pValue has to be less than 5%.

Test 1: Action selection is a means of expressing emotions

Test question: In which of the following ways do you think that a character should show its emotions?

- Facial expression
- Body posture
- Actions taken in the game
- Gesture
- Voice

These were rated in a 1 to 8 Likert scale. A one sample t-test was used to analyse the test results since only one group was tested. The sample population was assumed to have a normal distribution and thus a hypothesized mean of 4.5 was used for the evaluation.

H0 (Null hypothesis): There is no difference between the hypothesized mean and the expected mean of action selection

H1: There is a significant difference between the hypothesized mean and the expected mean of action selection

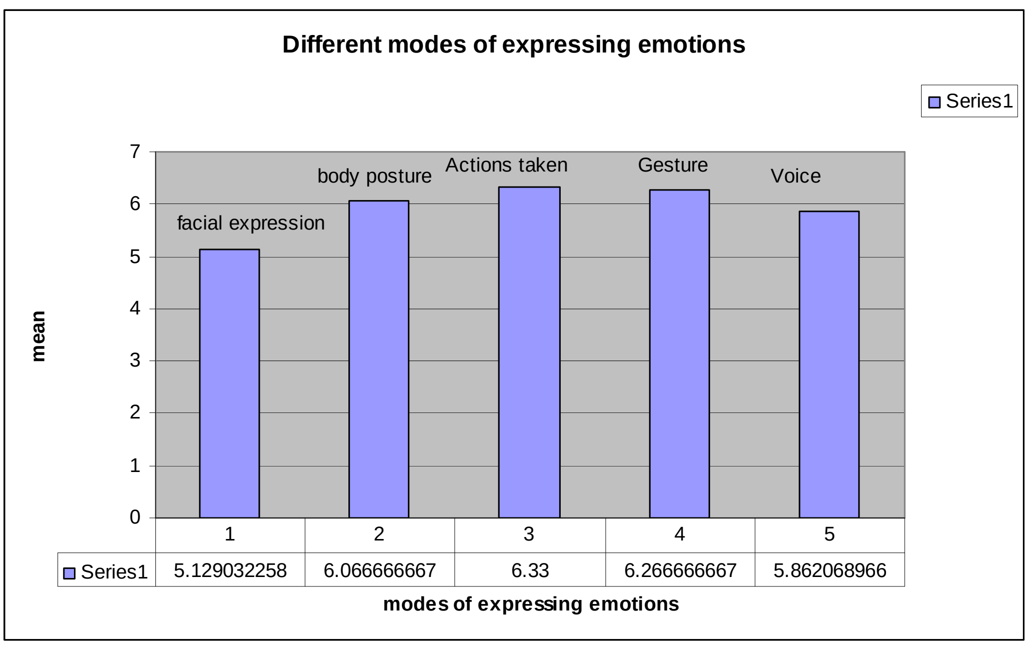
The desired results for this test were to get an actual mean that is significantly higher than the hypothesized as this would imply that action selection is a recognisable way of expressing emotions.

The results were as follows:

	Facial	Body posture	Actions	Gestures	Voice
Mean	5.13	6.07	6.33	6.27	5.86
df	30	29	29	29	28
tValue	1.9042	5.7823	5.7428	5.9826	3.55
pValue	0.0665	<0.0001	<0.0001	<0.0001	0.0014
N	31	30	30	30	29

Table 7: showing results of test 1 on whether action selection is a means of expressing emotions

From the above table, a positive t-value implies that the actual mean of action selection is higher than the hypothesized mean of 4.50. The pValue is <0.0001 meaning that the results are statistically significant. Thus the actual mean of action selection is significantly higher than our hypothesized mean of 4.5. The mean value shows the average score for all the test persons. This is depicted in graph 3 shown below:



Graph 3: representing the mean results for test 1

<u>Test 2</u>: <u>The linking of actions taken by NPCs to secondary emotions</u>

To analyze this test, the questions were evaluated against each other, with one acting as a control question. This was explained in section 10.1 of this chapter. The questions that acted as control were the ones without any action being taken. For these questions, we did not expect the test persons to infer any emotions, or if so, then the value was supposed to be very low. Thus the control question set included scenarios where the player moves towards the guys in blue and they do not move backwards and Eva comes into the scene and the guys in blue do not react. These were questions 1 and 6 respectively. Thus the non reaction to the player was tested against all the conditions where the guys in blue were expected to back away, or call for backup, as this was supposed to be an indication in the increment of alarm. The non reaction to Eva is evaluated against all the conditions where the guys are expected to attack as this was supposed to be an indication in the increment of outrage. Thus an unpaired t-test was used for this analysis. For all the tests, the control questions work as group1.

Test Question: State which emotion you think caused the following actions in the guys in blue?

The emotions to be chosen from were fear, anger, surprise, alarm, anxiety and outrage. The expected result was that people with knowledge of secondary emotions would recognize alarm, while those without would recognize the individual constituents of surprise which are fear and surprise. The same applies to outrage, where people with knowledge of secondary emotions are expected to identify it, while those without, are expected to recognize its individual constituents which are surprise and anger.

The expected results for each action are matched to the mapping done in the decision making-action selection algorithm. For each analysis in this section Q refers to Question. Thus Q1 is Question 1 and Q2 is Question 2. These are indicated to show which question acted as the control. The control question (either Q1 or Q6) are always indicated as being group1.

Action 1: Backing away

The expected results for this question was that fear and surprise would be produced thus leading to a secondary emotion of alarm. Therefore, only those three emotions should give statistically significant results. The same does not apply for anger.

	Group 1(Q1)	Group2(Q2)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	3.20	5.74	1.63	-5.79	<0.0001
Anger	3.40	3.46	1.86	-0.125	0.9
Surprise	3.36	3.96	1.70	-1.29	0.2
Alarm	3.56	4.93	2.01	-2.47	0.017

Table 8: Showing the results of the test on linking secondary emotions to the action of NPCs backing away

The results in the above table 8 show that only fear and alarm had statistically significant values with pValues that are <0.05. The same was expected of surprise but it produced a high pValue of 0.2.

Action 2: Running towards player

The expected results for this are that surprise and anger are produced thus leading to the secondary emotion of outrage. The value for fear should not be significant.

	Group 1(Q6)	Group2(Q3)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	2.32	3.48	1.77	-2.32	0.024
Surprise	3.29	4.25	1.91	-1.80	0.077
Anger	2.58	5.23	1.92	-5.06	<0.0001
Outrage	2.42	4.61	1.49	-5.30	<0.0001

Table 9: Showing the results of the test on linking secondary emotions to the action of NPCs running towards player

The results in table 9 show that anger and outrage had extremely low pValues of <0.0001 while surprise had a pValue that was not statistically significant.

Action 3: New blue guys coming into the scene

For this test, it is expected that fear, and surprise were produced, forming up to create alarm. Thus it is expected that the test persons will be able to infer these three emotions significantly, but not anger.

	Group 1(Q1)	Group2(Q4)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	3.20	5.29	2.07	-3.67	0.0006
Anger	3.40	4.31	1.56	-2.14	0.037
Surprise	3.36	4.79	1.73	-3.00	0.0042
Alarm	3.56	5.27	1.97	-3.20	0.0023

Table 10: Showing the results of the test on linking secondary emotions to the action of new blue guys coming into the scene

The results in table 10 match the expected results with the exception of that anger also has a statistically significant value, though its much lower than for the other three emotions.

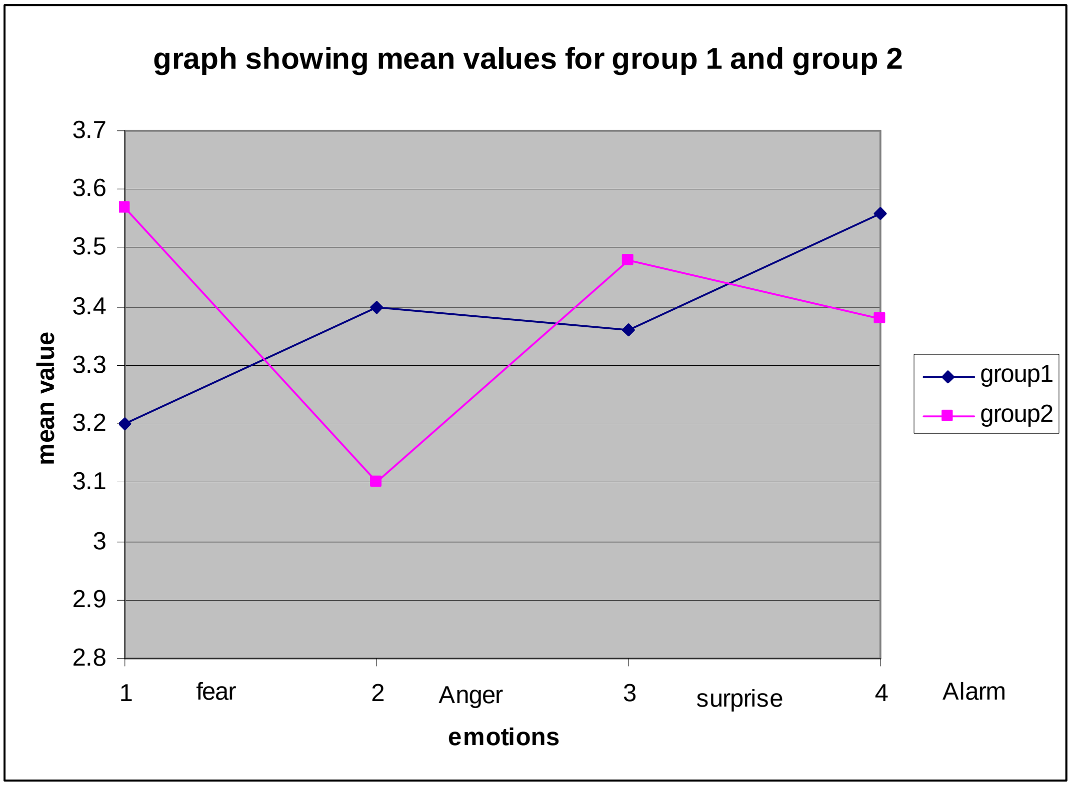
Action 4: slight orientation towards Eva

For this action very small insignificant values were expected to be recorded for the different emotions. This is due to the fact that the guys in blue observe Eva sometimes as being harmless to them and thus the secondary emotions formed result to very little or no action.

	Group 1(Q1)	Group2(Q7)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	3.20	3.57	1.75	-0.716	0.48
Anger	3.40	3.10	1.68	0.614	0.54
Surprise	3.36	3.48	1.73	0.227	0.82
Alarm	3.56	3.38	1.87	0.324	0.75

Table 11: Showing the results of the test on linking secondary emotions to the action of a slight change in orientation towards Eva

The results here as shown in table 11 match the expectations as all the pValues are statistically insignificant. The mean values for this action vary very little when compared to group 1. This is as shown on graph 4.



Graph 4: showing the mean values for group 1 and group 2

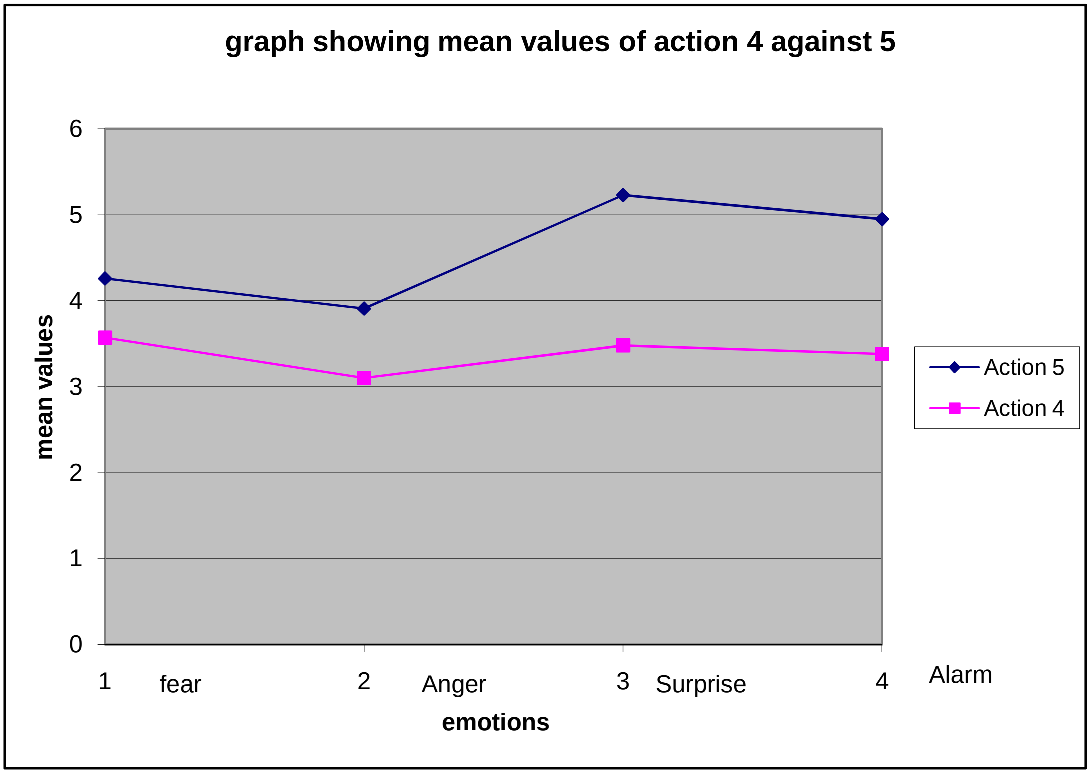
Action 5: shooting vigorously towards Eva

For this action, slightly larger values than for action 4 were expected, and the values for fear, surprise and alarm were expected to be significant.

	Group 1(Q1)	Group2(Q8)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	3.20	4.26	1.88	-2.12	0.04
Anger	3.40	3.91	1.78	-0.981	0.33
Surprise	3.36	5.23	1.68	-3.79	0.0004
Alarm	3.56	4.95	1.78	-2.68	0.010

Table 12: Showing the results of the test on linking secondary emotions to the action of NPCs shooting vigorously towards Eva

The results for this action as shown in table 11 match the expected results as all the emotions apart from anger have pValues that are less than 0.05, and the mean values for group2 here are higher than the mean values for group 2 in action 4. This is as shown in the graph 5.



Action 6: the guys in blue pausing without action when Pierre comes into the scene

This action was expected to infer some action as it resulted from emotions that were slightly above average.

	Group 1(Q1)	Group2(Q9)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	3.20	3.33	1.90	-0.246	0.81
Anger	3.40	2.67	1.66	1.55	0.13
Surprise	3.36	4.00	2.02	-1.11	0.27
Alarm	3.56	3.71	1.78	-0.291	0.77

Table 13: Showing the results of the test on linking secondary emotions to the action of NPCs pausing without action when Pierre comes into the scene

This result was not successful at all since all the pValues were not statistically significant.

Action7: The guys in blue shooting at Pierre sometimes when he comes into the scene

The results for this action were expected to be that fear, surprise and alarm are recognized with a significant statistical value. The mean values from this action were supposed to be slightly lower than for action 7. However due to the failure of action 6, their mean values will not be compared.

	Group 1(Q1)	Group2(Q10)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	3.20	4.91	1.86	-3.81	0.0026
Anger	3.40	4.3	1.77	-1.76	0.084
Surprise	3.36	4.50	1.85	-2.11	0.040
Alarm	3.56	4.52	1.91	-1.74	0.088

Table 14: Showing the results of the test on linking secondary emotions to the action of NPCs shooting at Pierre when he comes into the scene

Action8: The guys in blue backing away when one from the trooper's army joins the player's army and offers him protection.

The expected results for this test were that the test person's would notice the presence of fear and surprise which will combine to form alarm. However, anger is not supposed to provide any significant result.

	Group 1(Q1)	Group2(Q11)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	3.20	5.17	2.09	-3.29	0.0019
Anger	3.40	3.50	1.56	-0.225	0.82
Surprise	3.36	5.08	1.81	-3.34	0.0017
Alarm	3.56	4.96	2.06	-2.38	0.022

Table 15: Showing the results of the test on linking secondary emotions to the action of NPCsw backing away when traitor trooper joins the player's army

The results from this action as shown in table 15 were as expected since all the emotions apart from anger have a pValue that is statistically significant.

Action 9: The guys in blue reappearing but hiding.

For this question, fear and surprise were expected to be recognized, and thus resulting in alarm. The same does not apply for anger.

	Group 1(Q1)	Group2(Q13)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	3.20	5.09	1.84	-3.55	0.0009
Anger	3.40	4.13	1.72	-1.47	0.15
Surprise	3.36	4.57	1.79	-2.33	0.024
Alarm	3.56	4.87	1.90	-2.38	0.021

Table 16: Showing the results of the test on linking secondary emotions to the action of NPCs reappearing in the scene but hiding from the player

Table 16 shows that the results were as expected.

Action 10: The guys in blue reappearing and attacking

For this question, a low value is expected for fear, surprise and alarm. However, significantly higher values are expected for anger.

	Group 1(Q6)	Group2(Q14)			
Inferred emotion	Mean	Mean	Std dev	tValue	pValue
Fear	2.38	4.14	1.91	-3.13	0.0031
Anger	2.58	5.36	1.96	-4.81	<0.0001
Surprise	3.29	4.36	2.03	-1.79	0.081
Alarm	2.59	4.73	1.84	-4.04	0.0002

Table 17: Showing the results of the test on linking secondary emotions to the action of NPCs reappearing and attacking the player

From the table 17, the results show that even though anger has a high mean that is very statistically significant, the pValues for fear and alarm are also <0.05. This was not expected.

Test 3: The emergence of new secondary emotions and change in action selection

This test was only conducted on one group and thus a one sample t-test with a hypothesized mean of 4.5 was used. The expected results were that for every time that a secondary emotion is recognized, and then the change in action selection had to be visible. For this to happen, the mean value for the change in action selection had to be significantly higher than 4.5.

		Group1	Group2			
Character	Actions	Mean	Mean	Std dev	tValue	pValue
Pierre	Running to player	4.50	5.05	1.85	0.2814	0.78
	Running/Shooting player	4.50	4.61	N/A	N/A	N/A
HammerC	Running to player	4.50	4.96	N/A	N/A	N/A
	Running/Shooting player	4.50	5.11	1.95	1.39	0.17
	More blue guys joining	4.50	5.93	2.45	3.09	0.0046
Trooper& army	More blue guys joining	4.50	4.72	2.65	0.4145	0.68
Traitor Trooper	Running away from player & trooper	4.50	5.89	1.91	3.18	0.0052
	More blue guys	4.50	4.95	2.57	0.7585	0.4579
Player	Change in orientation & run towards player	4.50	5.39	2.54	1.8575	0.0742
	Slight change in orientation	4.50	4.84	N/A	N/A	N/A
	Running/Shooting at player	4.50	5.66	2.08	2.92	0.0071
	More blue guys joining	4.50	5.37	2.42	1.056	0.0730

Table 18: Showing the results of the test on change in action with the emergence of new secondary emotions.

The results in table 18 were not as expected as there was no significant change in actions for Eva and Pierre.

<u>Test 4: Mapping of secondary emotions to actions</u>

This test was conducted on one group, thus its analysis was done using a one sample t-test with a hypothesized value of 4.5(which is used as the mean for group1). The expected results were that all the mappings would have a significantly higher mean value than the hypothesized one. The values for actions towards Eva were not evaluated as they were way below the hypothesized mean with values of 2.20, 4.48 and 4.44.

		Group1	Group2			
Character	Actions	Mean	Mean	Std dev	tValue	pValue
Pierre	No action	4.50	2.21	1.50	8.248	<0.0001
	Shoot at	4.50	4.80	1.69	0.9424	0.3389
HammerC	Shoot at	4.50	6.00	1.64	5.0096	<0.0001
	More guys in blue	4.50	6.40	1.75	5.9338	<0.0001
Traitor T	Back away	4.50	6.03	2.03	4.0781	0.0003
	Attack	4.50	4.97	2.38	1.0521	0.3017

Table 19: Showing the results of the test on mapping secondary emotions to actions

From table 19 it is visible that the mapping for Hammer C, and Traitor trooper back away were better as they all have mean values that are significantly above 4.50 since their pValues are <0.05.

<u>Test 5: To test the believability of the initial game versus the new mod</u>

Since this test was conducted on two groups, its analysis was done using an unpaired t-test. The first group had played the original game while the second played the new mod. They had to state whether they could foretell the actions of the blue guys or not. The questions asked will be reviewed briefly. The expected results are that the values from the original game should be significantly higher than those from the mod since the 1 to 7 scale goes from not at all to very much.

Question:

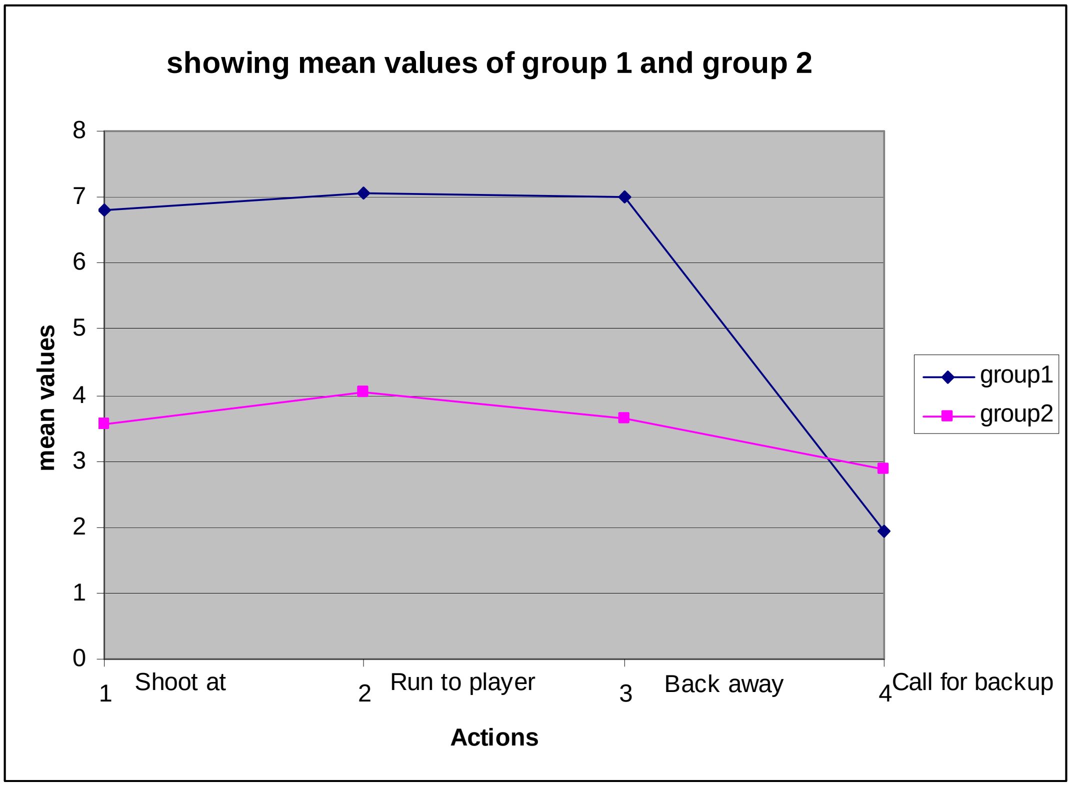
Did you know beforehand that the guys in blue were going to perform the following actions?

	Group1	Group2			
Actions	Mean	Mean	Std dev	tValue	pValue
Shoot at	6.81	3.57	1.80	7.01	<0.0001
Run towards player	7.06	4.04	1.85	6.28	<0.0001
Back away	7.00	3.65	1.49	8.45	<0.0001
Confusion	N/A	2.12	N/A	N/A	N/A
Call for backup	1.94	2.88	1.61	-2.18	0.034

Table 20: Showing the results of the test on believability of NPCs actions in initial game versus the mod

All the results shown in table 20 were as expected since group1 values are significantly higher than groups 2 with a really low pValue of <0.0001. However, despite the fact that the action “Call for backup” seems to be having a slightly higher significant pValue as compared to the rest, the results are not as expected. That is despite the fact that the pValue is <0.05, the value for group1 is much lower. The opposite was expected. This means that it was harder to foretell when the NPCs were going to call for backup in the original game.

The action “confusion” could not be tested in group1 as this was not a part of the original game. This action had been added to add unpredictability since in the original game, the NPCs always knew where the player was. The appearance of NPCs looking initially confused seems to have the lowest mean for all the questions in group2 with a value of 2.12. These results are depicted in the following graph 6.



Graph 6: Showing mean values for different actions for group 1 and 2

Test 6: Randomization of NPC behavior by adding secondary emotions as a tool for action selection

Since this test was also conducted on two groups, its analysis was done using an unpaired t-test. The first group had played the original game while the second played the new mod. They had to evaluate the randomness of the different characters. However since the original game had only the NPCs as the other characters in the game (i.e. besides the player), then they are the only ones that will be evaluated.

The expected results are that the NPCs in the mod should have a significantly higher random value than in the original game.

Results:

	Group 1	Group2			
Character	Mean	Mean	Std dev	tValue	pValue
Guys in blue	1.45	4.59	1.31	-9.12	<0.0001
Player's army	N/A	5.14	N/A	N/A	N/A
Trooper's army	N/A	4.34	N/A	N/A	N/A
Eva	N/A	4.70	N/A	N/A	N/A

Table 21: Showing the results of the test on randomization of NPC behavior by adding secondary emotions as a tool for action selection

The results in table 21 turned out as expected with the randomness value in the mod being significantly higher with a pValue of <0.0001. However, when judging the randomness of the blue guys in relation to the new characters added in the game, it seems the player's army and Eva are more random than the guys in blue.

10.3. Test discussion

In this section a review of the individual tests will be performed leading to an overall conclusion for the whole test. The individual review is done due to the fact that quite a number of tests were conducted, and as a result it may be confusing to discuss all of them at once. However, a general conclusion to all the tests will be given at the end of the chapter.

Test 1: Action selection is a means of expressing emotions

The results for test 1 were unexpected, as previous research had emphasized facial expression as being the most used/recognizable means of expressing emotions in virtual characters.

It is interesting to observe that for the other four modes of representing emotions the pvalue is <0.0001, while the one for facial expression is not statistically significant. From previous research, we would have assumed that facial expression would be the most recognizable as it seems to be the most used way of expressing emotions by virtual avatars. It is remarkable to see that action selection (one of the least used methods in expressing emotions) has the highest mean of 6.33 as compared to the rest.

Our hypothesis for this test, "Action selection is recognizable as one of the main ways that a character can express its emotions" holds since the pvalue is <0.0001. A criticism toward the results of this test could be that people were not asked to state why they think a particular mode of expressing emotions is better than the other. This would have given an overview of what it is that animators and others may be missing when focusing on expressing emotions through facial expressions. The results of this test however could be related to the initial survey done (described in section 10.1) whereby when people were asked which actions they take when experiencing a certain emotion, most people described the action in terms of a decision e.g. “ I cry”, “I yell”. Only one test participant answered in a way that relates to facial expression. This may be due to the fact that most of the times facial expression is an unconscious action. Thus we can speculate that the way in which we express emotions is by the actions that we take, most of the times.

Test 2: The linking of actions taken by NPCs to secondary emotions

This test will be evaluated as a general conclusion to all the 10 different actions assessed under this test. The individual evaluation of the test on each action is given in appendix 3. For this test, action1 (backing away) proved to be successful. This is because the test persons noted the presence of fear, surprise and alarm as expected.

Action 2(Running towards player) was a partial success since people noticed one extra emotion (anger) which was not expected to arise from the scenario. This result could be a fault on the mapping part, since the action of approaching an enemy cannot be the result of fear. This is quite intuitive. Thus this mapping will be taken as a malfunction on the part of the system.

Action 3 (new blue guys coming into the scene) provided partially successful results due to the fact that people noticed the presence of anger, even though this was not a part of the scenario. Once again, it was speculated that this findings may have been due to bad mapping on the design part. This speculation however would be confirmed by test 4 on mapping.

Action 4(slight orientation change towards Eva) produced the expected results by producing low mean values which had pValues >0.05. Action 5(shooting vigorously at Eva) also gave the expected results but this time with all the mean values apart from anger being <0.05.These values were also higher than for action 4 as expected. This is observable in graph 5 which depicts the mean values of action 4 against action 5. This meant that action 4 was a result of lower emotions being registered as compared to action 5.

Action 6(The guys in blue halting when Pierre comes into the scene) was a failure due to the fact that it ´produced emotion values with very low pValues. The mapping of this action was based on the production of emotion values that were in the medium high level. Thus the mean values for these emotions were expected to provide pValues that were statistically significant. We have to note that during testing, two of the test persons asked if it the halting of the NPCs was a malfunction of the system. They did not notice the relation of this halting reaction to Pierre's presence. As a result this mapping proves to be a failure.

Action 7(the guys shooting at Pierre) was a partial success due to the fact that despite recognizing the individual components of alarm, the alarm emotion itself got a pValue of 0.088. This is not statistically significant. The results for action 8 (the guys in blue backing away when the traitor trooper join's the player's army) were that fear, surprise and alarm were recognized with statistically significant pValues. Action 9(the guys in blue reappearing but hiding) had the same results as for action 8. These two actions were successful. Their success may be attributed to the fact that the emotion evoking stimuli(the traitor trooper) was well designed, thus making it possible for people to relate his appearance to the emotions produced and actions taken.

It is clear that the actions which failed completely were related to Pierre. This means that the mapping given on reacting to his presence must be completely wrong. This fact will be evaluated further in test 4 on mapping.

From the above discussion of the results of testing the ten actions that make up test2, we can conclude that we have only two actions that completely failed, three partially succeeded and five completely succeeded. The final results are as shown in table 22.

Action Value	Action description	Hypothesis 2: "The actions taken by the NPC can be linked to the presence of secondary emotions " result
1	Back away	True
2	Running towards player	Partially true
3	New blue guys coming into the scene	Partially true
4	Slight orientation change towards Eva	True
5	Shooting vigorously at Eva	True
6	Pausing without action when Pierre appears	False
7	Shooting at Pierre	Partially true
8	Blue guys backing away due to Traitor trooper	True
9	Guys in blue reappearing and hiding	True
10	Guys in blue reappearing and attacking	False

Table 22: Showing the different actions taken and their effect on hypothesis 2

Thus we can conclude that the hypothesis partially holds in relation to this test.

The major criticism for the test is that instead of indicating secondary emotions by their names only in questionnaires, we should have indicated which basic emotions form the secondary one. This is due to the fact that during the testing at least two test persons asked what “alarm” and “outrage” were. Thus it would have been a good idea to indicate that alarm constitutes of surprise + fear. This would have averted answers where we had people being able to recognize the primary emotions, but not the secondary ones.

Test 3: The emergence of new secondary emotions and change in action selection

For test 3 results, all the values indicated for the actions under Eva were too low. The mean values were 3, 3.36, 3.59, 3.86 and 2.18. These were way too low in comparison to 4.50, and thus the actions towards this character in relation to new secondary emotions were a failure. For Pierre, at least the actions of running to player, shooting at player and backing were expected to produce pValue <0.05 but they did not. Thus the actions for Pierre with the emergence of new secondary emotions were a failure.

For HammerC, only one action was significantly recognized with a pValue of 0.0046. This was the action of more blue guys coming into the scene. The actions of running towards and shooting at player were also supposed to give significant values.

For the Trooper and his army, none of the actions was supposed to be recognized significantly since apart from the traitor trooper who will be reviewed shortly, the rest of the army does not evoke any emotions. For traitor trooper only the action of running away from player was supposed to be significant, and it was with a pValue of 0.0052.

For the player, the values for change orientation & run towards player, running & shooting at player, and more blue guys joining were supposed to give significant values. But only running and shooting at player did with a value of 0.0071. It can be speculated that the test persons did not notice more blue guys joining in because only 5 characters are spawned when the player is on his own, as compared to the 25 who are spawned when the player's comrade HammerC appears. Thus the entry of 6 NPCs two at a time, as compared to the entrance of 25 NPCs in one go may not be noticeable.

To review the results for this test, the actions generated for Eva, Pierre, and HammerC failed to be recognizable with the emergence of new secondary emotions. Only the results of Trooper’s army and Traitor Trooper were a success. As a result, the hypothesis that the emergence of new secondary emotions should be noticeable in the change in action selection does not hold. Part of the failure of this test can be the fact that by the time the testers had to fill out the questionnaire, most of them complained that they could not remember all the actions taken with the arrival of every new character. Some test persons also complained that the use of a slider instead of a likert scale was confusing to them.

Test 4: Mapping of secondary emotions to actions

The expected results were that all the mappings would have a significantly higher mean value than the hypothesized one of 4.5. The mappings were being evaluated on a likert scale ranging from "not intuitive" to "very intuitive". The values for actions mapped towards Eva were not evaluated as they were way below the hypothesized mean with values of 2.20, 4.48 and 4.44. The values for actions mapped for Pierre were a failure because though the action of NPCs halting got a pValue of <0.0001, its mean of 2.21 was lower than the hypothesized mean. It should have been higher. The pValue for shooting at Pierre was >0.05.

The mappings for Hammer's actions were the most intuitive with both of them giving pValues that were less than 0.0001, thus very statistically significant. The two actions mapped to Hammer's entry to the game environment were either to shoot at him, or call for back up(i.e. the spawning of more NPCs into the scene). The mappings for Traitor Trooper were partially intuitive, with the action of backing away getting a pValue of 0.0003. However the action of attacking him only gave a value of 0.3017.

Thus from this test, it is visible that only mappings towards two character's were ideal, and that is HammerC, and Traitor Trooper. Therefore, though the result of Hammer's mappings show that it is possible to map secondary emotions to actions, the hypothesis as a whole does not hold due to the failure of mapping correct actions to Eva and Pierre. It had been speculated at the end of test 2 that failure in the reactions towards Pierre may be due to poor mapping. The results here confirm this speculation. It is interesting to note that the mappings for Eva failed in this test, while they seem to be successful when they were tested as action scenarios in test 2.

The failure of this test may be due to the fact that by asking people if the mapping was intuitive then a lot of the answers were going to be subjective. Maybe some players had expected the NPCs to shoot at any new character in sight without any kind of evaluation since it's a fast paced shooting game. However this assumption could have been proven if more open ended questions had been added to the test asking people to state why they thought the mapping was intuitive or not. That would have given a more concrete answer instead of making speculations.

Test 5: To test the believability of the initial game versus the new mod

This test was conducted on two different groups. The idea was to test the predictability of the actions taken by the guys in blue. The expected results were that the values from the original game would be much higher since the Likert scale was ranging from "not predictable" to "very predictable". The actual results were as follows, the mean values for the original game were 6.81, 7.06, 7.00 and 1.94 for the actions "shoot at", "run towards", "back away" and "call for back up". The values for the mod were 3.57, 4.04, 3.65 and 2.88. This resulted in the first three actions having very low pValues of <0.0001 while "calling for backup" had a pValue of 0.034 which is still statistically significant. As a result of this, hypothesis no. 5 (The addition of secondary emotions as a tool for action selection increases the level of believability in a game) holds.

The success of this hypothesis could be attributed to the fact that the new mod tries to randomize the way the actions are taken. This idea of randomization is discussed in the next test results.

Test 6: Randomization of NPC behavior by adding secondary emotions as a tool for action selection

This test was also conducted on two different groups. They had to play the original game and the mod , and then evaluate the randomness of the different guys. But the main evaluation of this test will be based on the guys in blue (the NPCs) since the other characters are not available in the mod. The expected results were that the NPCs in the mod should have a significantly higher random values than in the original game. The actual results reflected on the expectations. The mean value for the guys in blue from the mod was 4.59 as compared to the value from the original game of 1.45. This results in a very low pValue of <0.0001 thus proving these results to be very statistically significant. This result is quite interesting because the problem of not being able to add new animations to the game restricted us to only the four initial actions which were there in the original game. Thus it had been assumed that to randomize the NPCs behavior using only these four actions would be a challenging task.

10.4. Test conclusion

From the above discussion of each individual test, we can conclude that we had 3 successes, 1 partial success and 2 failures. These results in our hypotheses values looking as shown on table 23.

	Hypotheses	Hypotheses result
1	Action selection is recognizable as one of the main ways that a character can express its emotions	True
2	The actions taken by the NPC can be linked to the presence of secondary emotions	Partially True
3	The emergence of new secondary emotions should result in noticeable changes in action selection	False
4	It is possible to map secondary emotions to actions in a believable manner	False
5	The addition of secondary emotions as a tool for action selection increases the level of believability in a game	True
6	The addition of secondary emotions as a means of action selection, should act as a way of randomizing the NPCs behavior	True

Table 23: showing the final values for the thesis' hypotheses

The first three hypotheses had been in relation to mapping secondary emotions to actions. Due to the fact that one test was true, one false, and the last was partially true, we can say that we partially succeeded in mapping secondary emotions to actions. These hypotheses arose as a subpart of our main problem formulation. We could not investigate the role of secondary emotions in action selection without doing some kind of mapping and testing it.

The final three hypotheses were in relation to investigating to how the role of secondary emotions in action selection affects the believability of a character. This was our main problem formulation. Two of these hypotheses turned out to be true and only one failed. Thus we can conclude that we succeeded in investigating how the role of secondary emotions in action selection affects believability. The success of hypothesis 5 and 6 prove that the addition of secondary emotions as a means of action selection increases the level of believability in NPC behavior. This increase in believability arises from randomization of the action selection mechanism.

From the above we can see that the mapping was not as successful as it should have been. Going back to the research, we had stated that mapping should be tested, and changed every time to reflect the results of the tests. We were not able to do this before performing the final tests, and as a result, this could be the leading factor for the failure of the mapping of the secondary emotions into actions.

On the other hand, the testing as a whole was a success. Despite the failure in the mapping test, at least two of the characters had their mapping correct. It is interesting to note that the characters with the right mapping were the armed ones, while the unarmed ones had wrong mapping. This may be due to the fact that the game is a fast paced action game so people have subjective opinions on how the NPCs should react to unarmed characters. For the armed ones, they would intuitively expect the NPCs to either attack or back way, or do something in between.

The other tests on the enhancement of believability, and randomization of behavior turned out to be true.

11. Conclusion

As stated previously, the aim of this project was to investigate the role of secondary emotions in action selection, and how this affects the believability of a character. This statement was reached after doing extensive research ending up in identifying an area that has not been widely researched. A mod for a FPS game was developed in order to investigate the research area. The development of this mod was in relation to previous theories discovered during analysis. Tests were carried out to examine six hypotheses arising from the stated final problem formulation. At least three of the hypotheses turned out to be true, and one was partially true. The success of these hypotheses proves that it is possible to use action selection as a means of expressing emotions. The fact that some of the hypotheses did not hold means that further testing needs to be carried out, as well as making changes in the mapping of emotions to actions. It had been stated previously that this mapping is quite a challenging task that needs to be tested several times while being altered. The results of this project show that this is true. Due to time issues, we were not able to change the mappings to reflect the final test results.

The success of the test that measures the acknowledgement of action selection as a means of expressing emotions brings a new concept into virtual worlds. This is due to the fact that most of the previous work on expressing emotions had been focused on using facial expressions. The results from this test may infer that maybe focus ought to be shifted from physiological expression of emotions to internal expression. This kind of expression of emotions would be ideal for fast paced games like FPS or racing games where the players never have the time to observe the physical changes of the NPC.

The success of using secondary emotions instead of primary emotions also sheds new light into enhancing believability. So far most of the research out there had focused on only using primary emotions. It had been stated during analysis that some researchers believe that humans who express themselves using secondary emotions can be termed as being “more human”. From our test results we can paraphrase this statement to be that artificial agents who express themselves using secondary emotions can be termed as being “more believable”.

This project can be seen as having set a foundation for a research area that had been widely ignored. The results of this project can be used in further research to find out how the modes of expressing emotions can be expanded so as not to rely on only one modality, and also how secondary emotions can be worked with further to enhance the level of believability . We stated in the conclusion of the implementation chapter, that an unaccounted for scenario occurred where two secondary emotions arose at the same time. This is a fact that can be worked on further and tested to see if having more than two secondary emotions occurring at the same time can enhance believability even further. Emotions are very dynamic states and thus this ought to be reflected in

NPCs at all times. This may mean that further work on the interaction of secondary emotions may be an interesting research area.

We started on this project by asking if the gaming and AI industry could borrow some of the techniques used by animators to enhance believability. We ended up taking some of those techniques, and enhancing them to a degree that made our application semi-successful in terms of enhancing believability.

Further development for this project would involve adding more actions so as to have a wider range of actions that the NPCs can select from. The fact that the game only relied on four major actions limited it in a way. Also, as stated previously, this work can be enhanced further by coming up with a solution on how to deal with the interaction of two secondary emotions and testing to see if this can enhance the level of believability. It would also be ideal to have a working memory algorithm as this ought to have an influence on decision making by the NPC. We had set out to build a memory function, but due to time limitations, this block could not be made into a working functionality.

Finally, the lack of animation limited the dynamicity of the characters that we introduce to the game as “emotion evoking stimuli”. The levels of emotion would have varied even more significantly if the characters were more dynamic, i.e. if their behavior could be changed every time that they came into the game. This would have added even more randomness into the game. Thus, it would be ideal to add extra animations so as to provide more dynamicity and complexity into the game, and see how these affect the level of emotions produced, and observe how these emotions would in turn affect the believability of the NPCs behavior.

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