Universitat de les Illes Balears

Visualization of Affect in Faces based on Context Appraisal

Defended by

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HACEN CONSTAR:

Que la memoria titulada *Visualization of Affect in Faces based on Context Appraisal* ha sido realizada por Diana Di Lorenza Arellano Távara bajo nuestra dirección en el Departamento de Matemáticas e Informática de la Universitat de les Illes Balears y constituye la tesis para optar al Grado de Doctor en Informática.

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To all who contribute to make this Thesis a reality.

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I can hardly believe I am writing this page, because it means it is finished.

First of all I would like to thank God & Co. for giving me all the strength through the hardest moments along these years, and for blessing me every day.

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Abstract

Virtual Characters are more than avatars capable of expressing emotions and interact with the users. Virtual Characters should be seen as a very reliable representation of a human being, capable of expressing all the possible affective traits after the appraisal and evaluation of what is happening around and inside them. They should feel and express what they are feeling, they should convince you they are "real".

To achieve this level of believability several researchers have proposed different computational and affective models, as well as graphical techniques to simulate expressions, gestures, behavior or voice. All this state of art has provided us with sufficient data and information to see what else needs to be done.

As a result, we propose a contextual and affective framework that allows the generation of the context that surrounds the character as well as the simulation of its psychological characteristics like preferences, standards, personality, or admiration for other agents. Moreover, the framework proposes novel and implementation independent techniques for the visualization of emotions and mood.

Through experimentation we come up with a set of head-position/eye-gaze configurations that are perceived as certain personality traits, we validate the generation of expressions for moods, and assessed the feasibility of the context generation through movie scenes, which translated into our system, triggered the same emotions and elicit the same facial expressions as in the movie.

This research is a step forward in the creation of more believable virtual characters, by pointing out other elements that should be considered when creating characters that can be used in affective HCI applications, storytelling, or virtual worlds for entertainment (e.g. videogames) or for therapies (e.g. in therapies with autistic children).

Key words: Virtual Characters; Context Representation; Facial Expressions; Psychology.

Resumen

Hablar de personajes virtuales implica hablar de mucho más que avatares capaces de expresar emociones e interactuar con los usuarios. Los personajes virtuales deberían ser vistos como una representación fidedigna de los seres humanos, capaces de expresar un amplio rango de rasgos afectivos después de haber analizado y evaluado qué ocurre fuera y dentro de ellos. Deben sentir y expresar lo que sienten de tal forma que logren convencer que son reales.

Para alcanzar este nivel de credibilidad gran cantidad de investigadores han propuesto diferentes modelos afectivos y computacionales, así como técnicas en gráficos para simular expresiones, gestos, comportamientos y voz. Todo este trabajo previo nos ha permitido obtener suficientes datos para analizar qué más se puede hacer en esta área.

Como resultado, proponemos una metodología que permite la generación automática del contexto que rodea al personaje, así como la simulación de sus características psicológicas como preferencias, estándares, personalidad, o admiración por otros agentes. Más aún, se presentan novedosos algoritmos independientes de la implementación para la visualización de emociones y humor.

Mediante experimentos y test que miden el grado de percepción en los usuarios asociamos un conjunto de configuraciones "orientación de la cabeza/dirección de la mirada" a rasgos de personalidad, y validamos el método para generar expresiones de humor. También evaluamos la fiabilidad de la generación de contexto usando escenas de películas, obteniendo el mismo set de emociones y expresiones faciales que en dichas películas.

Finalmente, cabe destacar que este trabajo de investigación es un paso hacia adelante en la creación de personajes más creíbles, ya que indica qué elementos deberían tomarse en cuenta al momento de crear personajes virtuales que puedan ser usados en aplicaciones Interacción persona-ordenador, cuentacuentos, o mundos virtuales destinados al entretenimiento (videojuegos) o fines médicos (terapias con niños autistas).

Palabras Claves: Personajes virtuales, Representación de contexto, Expresiones faciales, Psicología.

Contents

Chapter 1

Introduction

If we knew what it was we were doing, it would not be called research, would it?
Albert Einstein.

Since the creation of the first virtual character, a lot of research has been done to provide them with realism, believability, and empathy.

Nowadays, thinking of virtual characters means thinking of virtual worlds and videogames as L.A. Noire, Call of Duty, The Sims^{TM}, among many others. These characters are endowed with great realism and believability thanks to advanced technologies in Computer Graphics and Artificial Intelligence.

Nevertheless, these techniques might be computationally expensive and therefore, not very suitable to implement in real time interactive virtual worlds. From the AI point of view, they should interact with the user or other inhabitants, and have affective reactions to a series of events. From the physical point of view, they are human or animal representations with gestures, voices, and facial expressions that show their affective states in different instants of time.

These characters or avatars (virtual representations of a person) are not only limited to videogames or entertainment; they can be used almost in any interactive application as virtual presenters, educational tutors, instructors, or social network's avatars.

Nevertheless, to engage an audience, the characters must be believable, specially when it comes to their affective responses. In this regard, the field of ***Affective Computing*** has made great advances to give characters affective characteristics. *Affective computing* is a term coined by Rosalind Picard [123] that *relates to, arises from, or deliberately influences emotions.* Affective computing includes implementing emotions, and therefore aids to test different theories of emotions. It also includes giving a computer the ability to recognize and express emotions.

Given that our goal is to develop a framework for creation of believable characters capable of a wide range of facial expressions, elicited as consequence of their emotional reactions to the events in a changing virtual world, is one of the key fields in this research.

In this chapter, the nature of the problem, motivation, aims of research, and research methodology are introduced. Also, the significance of the chosen approaches and possible applications are identified. Finally, the thesis outline is summarized at the end of the chapter.

1.1 The nature of the problem

One of the main problems to face in Affective Computing is the lack of consensus in answers to questions like: "what are emotions?", or "what is personality?". As Picard stated, there is open debate about these topics, and *evidence lacks on all sides of the debates.* Like her, we have based our work on relevant theories, and how they have been used for creating believable characters.

But what is *believability*? Paiva et al. [121] observed that believability is one of the most debated properties of synthetic characters and the goal of researchers working on this area for many years now. The term was introduced by Bates' team [11] relating to characters that give the illusion of life, facilitating the user's suspension of disbelief. Believability has been intensively explored in literature, and it is still the Holy Grail of the synthetic characters' research area. Why are synthetic characters not believable? Is it too hard?

Moreover, the question "what makes a character behave in a believable way?" arises from the appraisal of situations and events that the characters experience. Therefore, a precise and complete description of what surrounds the characters and how they perceive it is necessary to make them react accordingly, and show the feelings they are experiencing.

Finally, how to evaluate the expression of affect in the character in a believable way can only be measured empirically and subjectively with a significant sample of subjects. To this respect the obtained results will be valid as long as the hypothesis formulated proves to be true, or false, depending on the case that wants to be evaluated.

1.2 Motivation - The Domain of Interest

The research presented in this thesis is motivated by the idea of having a platform where one can create interactive virtual characters and situations automatically and straightforwardly. To achieve this, **integration** is the key. Thus integration of semantics, affective computing and computer graphics is the basis of a system that allows the representation of what happens with the characters, how they feel, and how they express those feelings.

The first domain of interest is semantics, which help us to define context. The main reason for using context is stated by Kaiser and Wehrle [78] in the following paragraph:

The current, concrete meaning of a facial expression can only be interpreted within the whole temporal and situational context. In everyday interactions, we know the context and we can use all information that is available to interpret the facial expression of another person. Therefore, if we generate the context we can generate accurate facial expressions according to it.

The second domain of interest is driven by the context's affective approach, which constitutes one of the novelties of our work. By defining the affective traits of the character as part of the context, a more accurate affective state of the character, and thus more accurate facial expressions will be achieved.

The third domain of interest is focused on the character's facial expressions. Having a character whose facial cues evoke the facial behavior of human beings can be of great help to enrich the transmission of the context's affective message.

Therefore, we propose a three-layered model, where the first two layers, a semantic layer and an affective layer, are the ones that deal with the context. The semantic layer defines the context (at a character's internal and external level) and produces an affective output that is interpreted by the affective layer. The affective layer provides the psychological background to evaluate the emotions, mood and personality of the character, and transform them into a representation for facial expressions. The third layer deals with the visualization of emotions and moods, which constitutes one of the novelties of the work. So far emotions were the main affective traits to be shown through facial expressions. Nevertheless, mood is also an important affective trait that can be manifested in the face of a person.

Another affective trait that has been poorly researched when it comes to its facial expression is *personality*. Personality, by definition, is stable; but as Linda Edelstein said, *put a character in extraordinary circumstances, and certain traits come to the forefront* *while others recede* [40]. Nevertheless, people tend to show the same traits when placed in similar situations: A highly competitive man will likely show ambition in the office, or playing Monopoly with his family. The perception of personality based on observation has long been a subject of research in behavioral psychology. It is just until recently that this research has focused on facial actions. For this reason, as part of the third domain of interest and as a novel research, we explore some facial cues to express personality.

1.3 Aims of Research

This research focuses on the development of a contextual and affective framework that allows the creation of virtual characters, capable of expressing emotions, mood and personality through facial expressions.

The primary aims are to develop and implement:

1. **A new approach for context representation in virtual worlds**
    - A model that defines the concepts that are part of the context of the character (its outer (environment) and inner (psychology traits) world).
    - A methodology that allows the user to define and infer knowledge about the context, and to create new scenarios in a simpler way.
    - Psychology-based rules to produce emotional responses in the characters.
2. **A model to appraise and elicit different affective traits in virtual characters**
    - An affective model that uses psychology theories of affect to elicit new affective states in the character based on its felt emotions, personality and mood.
    - A mathematical representation of affective traits to be computationally tractable.
3. **A visualization module for novel representation of different affective traits through facial expressions**
    - Generation of facial expressions of universal and intermediate emotions.
    - Generation of facial expressions of mood to visualize the output of the Affective Module.
    - An exploratory study of visual cues for personality traits to make characters more believable.

1.4 Research Methodology

The research methodology in this thesis is a combination of analysis of previous works, experimentation of theories and implementation of new ideas to obtain a novel approach for a Computational Affective Model. The fields on which we base the research are Semantic Web and Ontologies, Psychology, Computer Graphics, and Artificial Intelligence.

The first step in our research is the study of psychological theories, computational models, and frameworks for virtual characters; so we know what has been done and acknowledge the missing features for a more automatic generation of virtual characters.

This previous analysis leads to the formulation of the following research questions:

- **Context Representation**
  1. What is the impact of context in virtual worlds
  2. Which are the context factors that needed to be taken into account for virtual characters in a virtual world?
  3. How context influences the emotional responses of virtual characters?
  4. Which techniques have been used to simulate context in computational systems?
- **Affective Model**
  1. Which emotional theories should be addressed to represent emotions?
  2. How can the mood of a character be represented?
  3. How do personality affect moods and emotions? How do these three affective traits interact with each other?
- **Visualization of Facial Expressions**
  1. How can we obtain facial expressions for universal and intermediate emotions?
  2. Which facial cues should be considered when expressing mood and personality?
  3. Do the physical characteristics of the face influence the recognition of an affective trait?

By doing the corresponding research to answer the former questions we will be capable of choosing the best techniques and methods to implement and validate the Computational Affective Model proposed in this thesis.

1.5 Significance and Potential Applications

This research examines the relation between context, affect elicitation, and facial expressions; all applied to virtual characters in virtual environments. The chosen approaches are significant steps towards providing more believable characters, or agents, whose affective behavior can be generated in a more automatic way. The approaches are the following:

(A) Simulating scenarios for interactive characters

By implementing a semantic representation of the context, we can translate daily situations into the computational model. Therefore, what surrounds the character can be appraised and evaluated according to its internal configuration (psychological parameters) and also according to a set of rules derived from the model. As a result, a set of emotional responses will be elicited. In this way, a number of simulations for HCI applications can be automatically generated like virtual students in virtual classrooms to train teachers, or virtual agents that help to improve communication skills in children with autism or Asperger syndrom.

(B) Fast storytelling with affective output visualization

Imagine a system that can tell the facial expression that a character will have based on a set of events that are part of a story. With our computational affective model we are able to represent those events, obtain the emotional responses to them, and visualize the character's facial expressions. Therefore, story designers and character animators can have a draft version of how the character should look like due to certain situation; and moreover, the corresponding facial parameters to control to achieve that facial expression.

(C) Visualizing mood and personality

Our study goes a step forward in the investigation of how mood and personality are expressed through facial expressions. Until now the study of emotions in the face has reached a point where little is left to be done. But what is the expression of certain mood, or certain personality trait is still a field to be researched, and that can contribute to create more believable affective characters.

1.6 Thesis outline

The remainder of this thesis is organized as follows:

Chapter 2 reviews a number of psychological theories and computational models of emotions, mood and personality; as well as other applications that deal with affective characters, which we will use as a reference for our research. The discussion focuses on the techniques, theories, and results obtained by each previous computational model, and how they serve as the basis for our own computational model.

Chapter 3 provides an overview of the framework for the computational affective module. The discussion aims to give readers a general vision of the whole model and guide them into the subsequent chapters in this thesis. In particular, the system architecture will be presented to shortly introduce the different modules to be developed.

Chapter 4 introduces the semantic model used to represent context. There it is analyzed the motivation for using context and the previous works that have researched on semantic techniques. We also present our requirements and methods for context representation, how to use this model to create “stories”, definition of characters, their environment and their emotional responses.

Chapter 5 explains the affective model used for the computation of the character’s emotional states from personality, mood and emotions values. It takes as input the character’s emotional responses generated by the semantic model, and produces a new mood using the character’s personality traits and previous mood. The chosen representation for these affective traits is based on psychological theories and affective models presented in Chapter 2.

Chapter 6 describes the visualization module which is used to generate facial expressions for the affective state of the character. For visualization of mood, which constitutes one of the novelties of this work, an in-depth explanation if offered so it can be replicated by future researchs. Finally, our contribution to the research on facial expressions for personality is described.

Chapter 7 reports the evaluation of the Computational Affective Model. It exposes the obtained results which validates not only the effectivity of the computational model, but the correct visualization and perception of the elicited facial expressions.

Chapter 8 summarizes our work, provides an outlook to its potentials and implications, analyses the limitations of the taken approaches and gives some directions for future work.

Chapter 2

Psychological Theories

Any emotion, if it's sincere, is involuntary.
Mark Twain

Psychology has been one of the base research fields in Affective Computing, because it provides the affective models and theories to be used.

As our main goal is to create believable and affective virtual characters, in the following we outline a selection of psychological theories focused on representation of affective components as emotions, mood, and personality. This selection has been guided by the importance and contribution of these works to the generation of virtual characters.

2.1 Psychological Theories of Emotion

The study of emotions is a challenging area, since emotions can be analyzed from different perspectives. This has originated a number of theories and models that intend to explain what they are, as well as how and why they are appraised and elicited. This section attempts to classify and overview some of the theories that have been used in the computational field, thus we have: Categorical models, Dimensional models, and Appraisal models.

2.1.1 Categorical Models

Categorical models claim the existence of historically evolved basic emotions, which are universal and can be found in all cultures. In these models, or theories, emotions are labeled and considered as families instead of individual emotions.

Darwin

Charles Darwin's work is so relevant because he made major contributions to the study of facial expressions in a way that had not been done before. In his book *The Expression of Emotions in Man and Animals* [33], he stated that facial expressions and involuntary movements are based on three principles: *serviceable associated habits* (certain movements are done even when they are not necessary, e.g. scratch one's head when thinking or when being confused); *antithesis* (perform movements of a directly opposite nature when having a directly opposite state of mind, e.g. move the arms to wave away a person even if that person is not close enough); and *direct action of the nervous system* (certain expressions are influenced by physiological reactions).

By means of multiple observations in several countries using as subjects infants, people with dementia, Duchene's studies, art works, and people from different cultures and races, he studied how people behave when experiencing different affective states. For example when suffering; in anxiousness, pity or despair; when feeling happiness or devotion; and so on. For example, he observed that laugh or smile were expressions for the state "high spirits" in a deaf and blind person, a normal person and idiots (medical term).

Darwin grouped emotions in categories according to shared characteristics and movements, focusing primarily on the face. He grounded the idea that facial expressions of emotion are universal and gestures are culture-specific conventions, also seen in other species, which evolved serving once particular functions (e.g. baring teeth in anger to prepare for attack), becoming useful when communicating these emotions to others.

Ekman

Paul Ekman, inspired by Darwin's approach [46], studied the universality of emotional expressions and developed a methodology to describe these expressions based on muscular movements, the *Facial Action Coding System - FACS* [48].

From his experiments, Ekman confirmed Darwin's theory of universality [45], claiming that the same emotion might be elicited by different circumstances, but its expression could be found across cultures. He provided a set of characteristics as distinctive universal signs, physiology responses, automatic appraisal, brief duration, and so on, which distinguish emotions from other affective phenomena.

He proposed six basic emotions (anger, fear, joy, disgust, sadness and surprise) [42], which were extended to fifteen in later works: amusement, anger, contempt, contentment, disgust, embarrassment, excitement, fear, guilt, pride in achievement, relief, sadness/distress, satisfaction, sensory pleasure, and shame [44].

Plutchik

Robert Plutchik proposed a theory based on biological natural selection, distinguishing "eight basic prototype functional patterns of behavior", or primary emotions [125].

His model arranges emotions in a cone-structure, based on bipolarity and similarity. For example, anger and fear are bipolar because anger leads to attack and fear to withdrawal. Consequently these two primary emotions lie on opposite sides of the emotion cone as shown in Figure 2.1 [12].

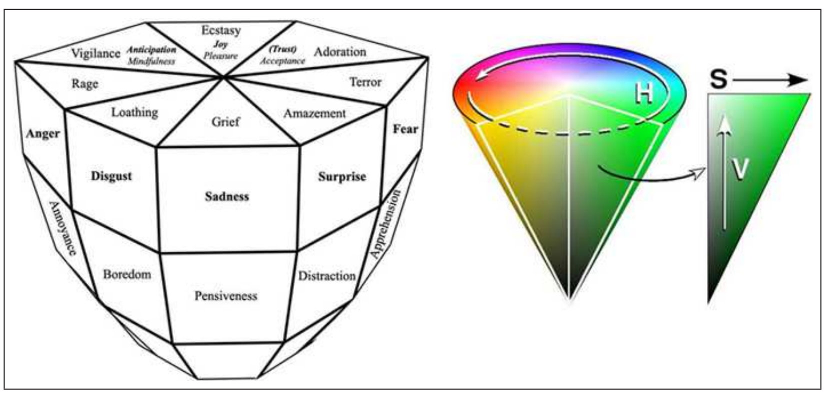


Figure 2.1: Plutchik's dimensions of emotions (Fig. 2.2 from [12])

Plutchik also accounts for emotions that are either combinations of two or three basic emotions, or one basic emotion experienced at a greater or a milder intensity. He called this combination *dyad*, e.g. joy and acceptance produce love. Although Plutchik was aware that some combinations might never occur at all, he stated that his model covered all aspects of emotional life. However, the model is questionable when trying to classify concepts as anticipation or surprise.

2.1.2 Dimensional Models

Dimensional models, or dimensional theories of emotions, assume the existence of two of more major dimensions which are able to describe different emotions. The idea originated from the observation that some emotions share characteristics that can be seen as different degrees of the two dimensions (or more). Therefore they do not need to be labeled and categorized, constraining their study and measurement.

Whissell

Cynthia Whissell provided a list of emotional terms compiled in her *Dictionary of Affect in Language* [153]. It includes approximately 4000 English words with affective connotations, where each word is described along the dimension of Activation (or Arousal) and along the dimension of Evaluation (or Pleasantness).

Whissell's work is used for measuring emotion, and though its lower reliability in the Activation dimension, it has been proved to work better when applied to passages or lists because it allows the evaluation of the affective tone of the entire passage or list.

In practice, the *Dictionary of Affect* can be applied to both short-term and long-term responses (mood description, personality description, reaction to immediate situations, and analysis of texts or diaries). As words are rated along a two-dimensional space, Whissell observed that the classification of words as *emotional* is related to their distance to the origin.

Russell

Another theory based in a two-dimensional bipolar space is the one proposed by Russell [135]. Based on previous experiments performed by colleagues, Russell also found that there are three properties of the cognitive representation of affect: the pleasantness-unpleasantness and arousal-sleep dimensions; the bipolarity of dimensions that describe affect; and that any affect word could be defined as a combination of the pleasure and arousal components.

As a result, a two-dimensional space was evaluated with the horizontal dimension corresponding to pleasure-displeasure, and the vertical corresponding to arousal-sleep. Russell also observed the lack of need for a third or more dimensions, because having extra dimensions would only account for a tiny proportion of the variance and are limited to subsamples of emotion words. Figure 2.2 shows the eight affect concepts in a circular order.

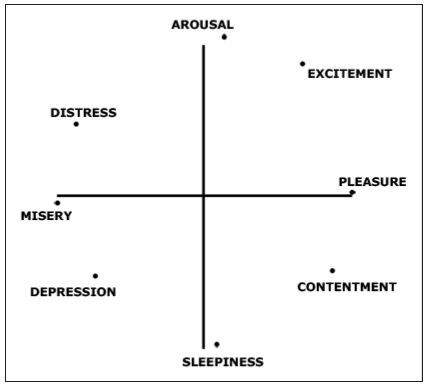


Figure 2.2: Eight affect concepts [134]

In recent works, Russell [133] proposed a framework that weds bipolar dimensions to discrete categories. He presented a set of concepts that intended to re-arrange knowledge from previous models to make a consensus among them. The first set of concepts are "technical terms" which define various emotion-related events: *Core affect*, *Affective quality*, *Attributed affect*, *Affect regulation* and *Object*. The second set of concepts bridge the gap between the "technical terms" and folk concepts, leading to a more familiar manner of speaking: *Mood*, *Empathy*, *Displeasure motive*, *Prototype*, *Emotional episode*, *Prototypical emotional episode*, *Emotional meta-experience* and *Emotion regulation*.

Cochrane

Thomas Cochrane [29] proposed an eight-dimensional model to map the conceptual space of emotions as faithfully and efficiently as possible. We included this model due to its potential to be used in computational applications given that it offers a useful tool for researchers, regardless of the theory of emotions that they hold. It applies equally to whatever component of emotion (appraisals, emotion language, subjective feeling, physiological changes, expressive behaviors, action tendencies or regulation strategies), integrating different approaches by capturing the meaning of the emotion at an abstract level.

The eight proposed dimensions are: *Valence (attracted-repulsed)*, *Personal Strength (powerful-weak)*, *Freedom (free-constrained)*, *Probability (certain-uncertain)*, *Intentional focus (generalized-focused)*, *Temporal flow (future directed-current-past directed)*, *Temporal Duration (enduring-sudden)*, and *Social connection (connected-disconnected)*.

After mapping emotional terms in his model, Cochrane proved that even terms related to emotional subclasses can be differentiated, and none of these differences would be captured by the traditional valence or arousal dimensions.

2.1.3 Appraisal Models

According to the appraisal theory of emotions, the emotional responses results from a dynamic evaluation (appraisal) of needs, beliefs, goals, concerns, environmental demands that might occur consciously or unconsciously. Therefore, this type of theories has become one of the most active, and attractive approach in the domain of emotional psychology.

OCC Model

One of the most used model of emotions in the computational field is the one proposed by Ortony, Clore and Collins [120], known as the *OCC Model*. This model is of a cognitive nature, and intends to explain people's perception of the world and how it causes them to experience emotions.

For Ortony et al., emotions cannot be arranged in a low-dimensional space; rather they should be organized in groups. They found representative clusters identified by "eliciting conditions", under which emotions are triggered. Also, inside each emotion group, each emotion type is seen as a family of closely related emotions.

The assumption of the model is that there are three major aspects of the world, upon persons can focus: *events, agents*, or *objects*, which elicit different types of emotions. When one focuses on events is because of their consequences, when one focuses on agents is because of their actions, and when one focuses in objects is because of their aspect or properties. The structure of the OCC model is shown in Figure 2.3, where individual groups of emotion types are enclosed in boxes, with the group's name in the bottom part of the box.

The intensity of emotions for each group is given by a number of variables that depend on the appraisal of the event, agents or objects. For instance, FORTUNES-OF-OTHERS, there are four variables that affect the intensity of its emotions: *desirability-for-self*, *desirability-for-other*, *deservingness*, and *liking*.

Regarding the OCC model, Bartneck [9] [10], reflected on the missing features (extensive amount of knowledge to categorize the affective response, history function to keep track of previous events, extensive number of emotions to be represented) and the lack of context handling of the OCC model when creating believable characters. Nonetheless, Ortony

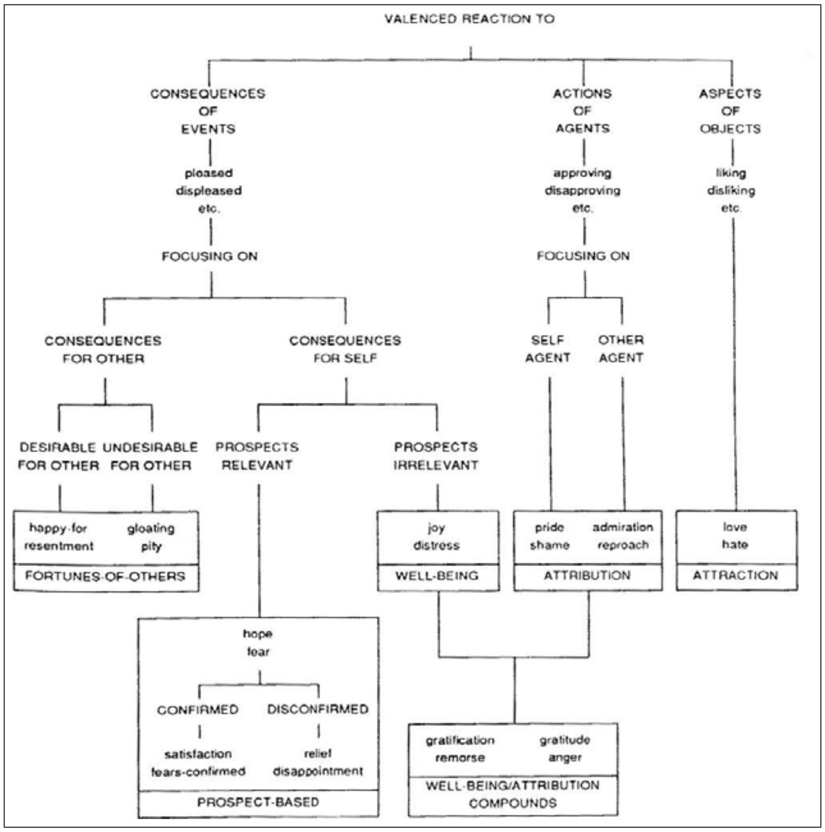


Figure 2.3: OCC Model - Global structure of emotion types [120]

and colleagues presented their awareness about these issues, and they stated that the OCC model is a basis model to define human emotions with a cognitive and individual approach. Therefore, the problems that Bartneck explains are details that need to be handled in a separate way or as a component of the OCC model.

Scherer's Model

A model that does not deal with categories but with processes is the *Component Process Model* (CPM), proposed by Klaus Scherer [140]. The CPM is a dimensional dynamic model that defines emotions as adaptive reactions to events driven by processes of the organism, which consists of five components corresponding to five distinct functions: (1) Cognitive: evaluation of objects and events; (2) Peripheral efference: system regulation, (3) Motivational: preparation and direction of action, (4) Motor expression: communication of reaction and behavioral intention, and (5) Subjective feeling: monitoring of internal state and organism-environment interaction.

The CPM also explains how emotional states can be differentiated as a result of a sequence of specified *stimulus evaluation* (or appraisal) *checks* (SECs). SECs are based on four appraisal objectives: **(1) *Relevance Detection:*** evaluates the stimulus according to the event's probability of occurrence, level of pleasantness, and importance or relevance for the organism's goals or need; **(2) *Implication Assessments:*** evaluates the consequences of the event for the self; **(3) *Coping Potential:*** determines the type of responses for an event, and their consequences; and **(4) *Normative Significance:*** how the individual and the society evaluate an action and the significance of an emotion-producing event.

The importance of the work of Scherer is that it is a representation of human appraisal, without being limited by objects, goals and other agents, as the OCC model. The CPM also gives the necessary information to visualize the emotional appraisal by giving a set of cues (in face, body, voice and internal systems) and parameters that can be manipulated in a virtual character.

Frijda's Theory

Nico Frijda proposed an appraisal theory of emotions based on the term *concern*. According to Frijda, a concern is what gives a particular event its emotional meaning. *Emotions arise in response to events that are important to the individual's goals, motives, or concerns* [60].

For him an emotion is defined by six characteristics that describe its function: (1) Concern relevance detection, (2) Appraisal, (3) Control precedence, (4) Action readiness changes, (5) Regulation, and (6) Social nature of the environment. On the other hand, the emotion process can be described with three lines: the core process (leads from stimulus event to response), the regulation line (processes that intervene in the core process) and the line of inputs other than the stimulus event. The outputs are: the overt response and physiological changes [59]. It is depicted in Figure 2.4.

The advantage of Frijda's model is that it can be formalized in such a way that form the basis of a computational model, as used in the architecture of a computer agent [109].

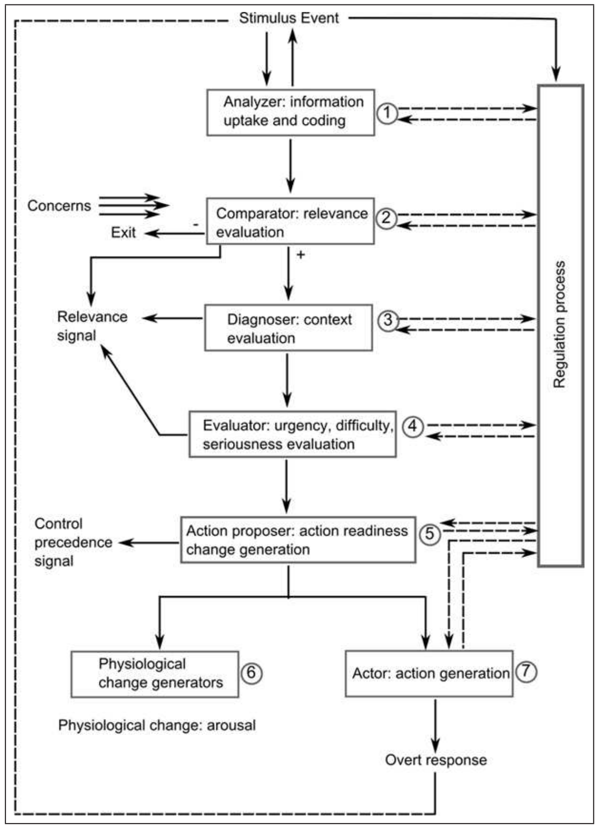


Figure 2.4: Frijda's emotion process. Adapted from Fig. 9.1. in [59].

2.2 Psychological Theories of Personality

Concerning personality, theories happen to be very different among them. The state of the art theory is the Five Factor Model, or Big Five, which proposes five almost independent dimensions providing a very clear definition of personality. Nevertheless, it is not clear (psychologist are still doing studies) how these dimensions can be related between each other. Another theory based on FFM factors is the AB5C model, proposed by De Raad. The advantage of this theory is that it allows to combine two factors, obtaining all the corresponding adjectives needed to define a character's mixed personality.

2.2.1 Eysenck Model

Hans Eysenck proposed one of the earliest personality theories. He called it temperament, and it was based primarily on physiology and genetics, firmly believing that most fundamental personality traits are inherited. On the other hand, his theory also supported the fact that environment determines behavior [21].

Eysenck's original research found two main dimensions of temperament: Neuroticism (N) and Extraversion-Introversion (E). However, after factorial and other empirical studies a third dimension emerged which was named Psychoticism, (P), which was conceived as a set of correlated behavior variables indicative of predisposition to psychotic breakdown [52].

Neuroticism, or Emotionality, is a dimension that ranges from normal, fairly calm people to one's that tend to be quite "nervous". It is characterized by high levels of negative affect such as depression and anxiety, originated at the sympathetic nervous system.

Extraversion-introversion is a dimension found in everyone, produced as the balance of "inhibition" and "excitation" in the brain. Extroversion is characterized by being outgoing, talkative, high on positive affect (feeling good), and in need of external stimulation.

The Eysenck Personality Questionnaire (EPQ) [51] is a questionnaire to assess the personality traits of a person, and it is still used by psychologists nowadays.

2.2.2 Five Factor Model

McCrae and Costa [97] proposed a hierarchical organization of personality traits in terms of five basic dimensions: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience. The Five Factor Model (FFM), or Big Five, shares two traits with the Eysenk's model (Extraversion and Neuroticism). Table 2.1 presents a description of each trait.

Factor	Description	Adjectives
Extraversion	Preference for social situations	talkative, energetic, sociable
Agreeableness	Interaction with others	trustworthy, friendly, cooperative
Conscientiousness	Organized, persistent in achieving goals	methodic, organized, efficient
Neuroticism	Tendency for negative thoughts	insecure, emotionally unstable
Openness	Open, interest in culture	imaginative, creative, explorer

Table 2.1: Five Factor Model traits [85]

The traits were found in self-reports and ratings, in natural languages and theoretically based questionnaires, in children, college students, and older adults, in men and women, and in English, Dutch, German, and Japanese samples. All five factors were shown to have convergent and discriminant validity across instruments and observers, and to endure across decades in adults [97]. It provides the model with two advantages: universality and applicability.

Regarding universality, the FFM is strongly rooted in biology, and it has been found that each of the five factors is heritable [98]. Regarding applicability, the FFM can be used in different branches of psychology: industrial, organizational, clinical, educational, forensic, and health psychology. Another advantage of the model is that any personality type can be represented through the combination of the five traits, because they are found to be independent from each other.

Although the FFM is the most used personality model to date, some psychologists criticize the methodology, and the number of traits. Some say that five factors are too many factors, but studies demonstrate that five factors are "just right". Others say that five factors are insufficient to summarize all that we know about individual differences in personality. To this respect, the authors reply that they merely represent the highest hierarchical level of trait description.

2.2.3 Circumplex Structures

The motivation for circumplex models is that they provide much more opportunity for identifying clusters of traits that are semantically cohesive.

Wiggins Model

Wiggins et al. [155] reoriented the *Interpersonal Circumplex*, or IPC, which defines a broad set of interpersonal traits that are directly related with affective and cognitive behavior. The IPC has sixteen dimensions that were reduced to eight, where each octant is a combination of the dimensions: Dominance/Passiveness and Affect/Hostility. The octants that are adjacent to each other share attributes and the ones that are opposed are inversely related. Figure 2.5 shows the circumplex.

Traditionally this circular structure has been used to define interpersonal relations and to explain user's trustworthiness in collaborative virtual environments and telemedicine [23]. The advantage of this model is that allows a fine-grained definition of personality traits.

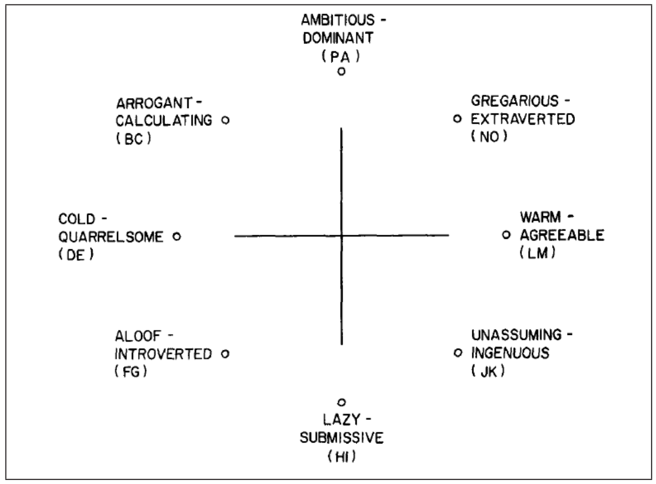


Figure 2.5: Wiggins - Two-factors: Dominance/Hostility and Affect/Hostility (Fig. 2. from [154])

AB5C Model

The Abridged Big Five Dimensional Circumplex (AB5C) [74] taxonomy of personality traits consists of 10 circumplexes that were obtained by the pair-combination of FFM traits. Hofstee et al. found that by blending the FFM traits by pairs, a much tighter conceptual structure that seems to work in practice was achieved. On the other hand, the model is less restrictive than simple-structure models and two-dimensional circumplex models, like the Wiggins model [155]. Figure 2.6 shows one of the ten circumplexes that combines Extraversion or Surgency (Factor I) with Emotional Stability (Factor IV).

Virtue and Dynamism Dimensions

De Raad and Barelds [128] used two factors, Virtue and Dynamism, to organize the Big Five variables in a circumplex model. The advantage of using this model is that the positions of the trait-variables relative to each other become clear. This organization is shown in Figure 2.7, where variables can be read focusing on two sets of opposite clusters.

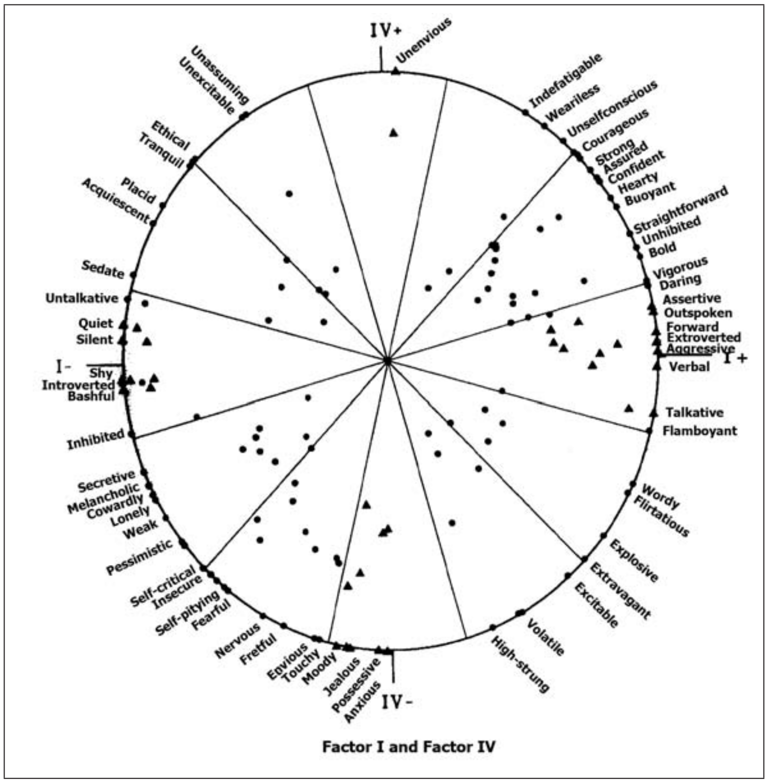


Figure 2.6: AB5C - Extraversion (I) and Emotional Stability (IV) (Fig. 1. from [74])

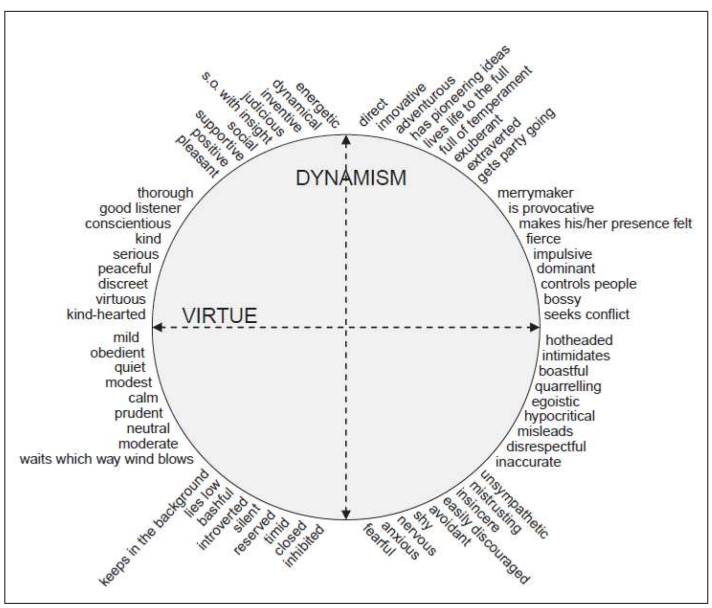


Figure 2.7: Circumplex - Two-factors: Virtue and Dynamism (Fig. 8.4. from [127])

2.3 Psychological Theories of Mood

Mood represents the overall's view of the internal state of an individual. The difference between mood and emotion depends on three criteria: temporal, expression and cause. Moods last longer than emotions, and they might not associated with a specific expression or cause. The main functional difference is that, emotions modulate actions while moods modulate cognition [148].

2.3.1 Ekman

Ekman [43] distinguished mood from emotions in terms of their time course (moods last for hours or days) and of *what should be found in the neural circuitry that directs and maintains each of these affective states.*

Most of the times, laypeople use the same word to refer to a mood or to an emotion. For instance, the word "irritable" would mean low-intensity anger or a long-lasting state. Another criterion is that moods seem to lower the threshold for arousing emotions; as if the person is *seeking an opportunity to indulge the emotion relevant to the mood.*

Ekman also stated that moods do not have their own unique facial expressions, while emotions do. Another characteristic of mood is that usually people cannot recall what situation brought them to a certain mood, while they can do that with emotions. Internal chemical changes can also change the mood, for instance, lack of sleep or food.

2.3.2 Pleasure-Arousal-Dominance Space

Albert Mehrabian proposed a framework for definition and measurement of different emotional states, emotional traits, and personality traits in terms of three nearly orthogonal dimensions: Pleasure, Arousal, and Dominance; which define the PAD Space.

There are two PAD Scales. One for definition of emotional states, or emotions (PAD Emotion Model); and the other for definition of temperament (PAD Temperament Model). Both the PAD Temperament Model and the PAD Emotion Model allow us to predict the correlation between any two traits (temperament) or states (emotions) for which PAD components have been experimentally identified. In this way, an agent would be infused with "personality characteristics", or emotions, that appear to have life-like quality. For example, an agent that is configured to be *neurotic* would thus manifest related characteristics (e.g. anxiety, proneness to binge eating, depression, or even panic disorder). On the other hand, based on the correlation among traits, this *neurotic* agent would not be likely to exhibit extroverted or nurturing traits [103].

During the past few years this model has been used in computational model for representation of **mood** in virtual characters [4], [63], [80]. The reason for using a temperament model as a mood model is given by the fact that in the PAD space a set of different affective values are produced depending on the values of pleasure, arousal and dominance, which in turn change over time. As the combination of these three dimensions produce eight different octants, then we can assume that these octants are moods.

In [105], "Emotional States" refer to transitory conditions of the organism (e.g. feeling alert vs. tired, happy vs. unhappy), which can be seen as emotions and/or moods. "Temperament" refers to an individual's stable emotional characteristics (i.e. emotional traits or generalized emotional predispositions). More precisely, temperament is an *average of the states of pleasure, arousal, and dominance across representative life situations.*

2.3.3 UWIST Mood Adjective Checklist

The UWIST Mood Adjective Checklist (UMACL) is a tool for measuring mood. Matthews et al. [96] defined mood as an emotion-like experience lasting for at least several minutes.

Some of the previous mood models they studied to obtain their final scale were the one proposed by Mehrabian and Russell [106], which used three bipolar factors: *pleasure-displeasure*, *arousal*, and *dominance-submissiveness*; Zevor and Tellegen's [157] two factors-model: *positive affect* and *negative affect*; Thayer's [145] that also obtained these two factors, but he labeled them *energetic arousal* and *tense arousal*; and Mackay et al.'s [90] who identified bipolar dimensions related to hedonic tone or feeling of *pleasantness-unpleasantness*, and *arousal*.

In the end, Matthews et al. proposed a three-dimensional model of mood: energetic arousal, hedonic tone, and general arousal. It is of great importance in clinical research, because of its apparent ability to discriminate between depressed (low hedonic tone) and anxious (high tense arousal) mood states.

2.3.4 Positive and Negative Affect

David Watson [150] proposed an alternative mood model to the Pleasantness-Unpleasantness/ Activation one. It focuses on the general dimensions of Negative and Positive Affect. The Negative Affect dimension represents different types of negative mood as feelings of nervousness, sadness, irritation, and guilt. The Positive Affect reflects the experiencing of some type of positive mood as feelings of joy, energy, enthusiasm, and alertness.

The model classifies positive and negative moods in four basic types: high positive/low negative (e.g. feeling happy), high positive/high negative (e.g. mixture of fear and excitement in a roller coaster), low positive/high negative (e.g. feeling depressed), and low positive/low negative (e.g. disengaged state while watching television).

Watson and Clark [152] developed their own mood inventory named PANAS-X, which is an extension of the original PANAS (Positive and Negative Affect Schedule). It consists of 11 scales that assess specific types of affect: 4 basic negative affects (fear, sadness, guilt and hostility), 3 basic positive affects (joviality, self-assurance and attentiveness), and 4 other affective states (shyness, fatigue, serenity and surprise).

2.4 Summary

In this chapter we have reviewed some psychological theories of emotions, mood and personality that are relevant in the field of Affective Computing. From Darwin, who studied the universality of facial expressions, to Thomas Cochrane, who proposed a novel theory for the implementation of appraisal, several psychologists have come up with different ways to study emotions. Categorical, dimensional, and appraisal models of emotions are the three types we have overviewed, being the OCC model the most used in computational models to date. Regarding personality, the Five Factor Model, or Big Five is still the state-of-art personality model. One reason is its replicability along different studies. Another reason is that its five dimensions allow the description of any type of personality. Finally, the study of mood is becoming more and more important in the Affective Computing field. Therefore, efforts are being directed to its representation in computational models, going from bi-dimensional representations (good mood and bad mood) to the 8-moods PAD Space.

Chapter 3

Related Work in Affective Computing

Dr. Walter Gibbs: Ha, ha. You've got to expect some static. After all, computers are just machines; they can't think.
Alan Bradley: Some programs will be thinking soon.
Dr. Walter Gibbs: Won't that be grand? Computers and the programs will start thinking and the people will stop.
TRON (1982).

Thanks to the efforts in the fields of Affective Computing, Artificial Intelligence, Computer Graphics, and Cognitive Sciences, the creation of virtual characters has been improved and enriched through the years.

Some researchers have proposed computational models based on psychological theories to elicit different affective traits and behaviors in the characters. Others have focused on studying which behaviors are perceived as manifestation of different affective traits. While the first ones aimed for a character that "feels" and react accordingly to those feelings; the last ones aimed for cues that make a character "looks like" feeling.

In the following we will review previous works grouped by those that propose computational models of affect for Embodied Conversational Agents (ECAs), and those that studied the perception of affect in the face and head. Finally, a summary of the section is provided.

3.1 Computational Models of Affect

According to Danny Hillis, vicepresident of Disney Imagineering in 1997, there are 4 "holly grail" items concerning entertainment agents: a computable science of emotion, virtual actors, agent evolution, and computable storytelling [50].

To achieve these goals, many researchers have proposed and implemented computational models for the generation of affect, as can be seen in the State of Art reports in [148] and [79]. In the next subsections we outline the objectives, main contributions and visualization methods of the most cited and relevant works in the Affective Computing Field.

3.1.1 Cathexis

Juan Velásquez [147] presented Cathexis, one of the first distributed, computational models that represented the dynamic nature of emotions, moods and temperaments, as well as their influence on the behavior of synthetic autonomous agent. The architecture of the model presented two components: the *Emotion Generation System* and the *Behavior System*.

The emotion generation system used appraisal theories with other emotional theories based on physical reactions. The implementation was based on proto-specialists agents provided with sensors to monitor internal and external stimuli, allowing the elicitation of family of emotions (e.g. Fear, Fright, Terror, etc.). Emotions could be basic or blended/mixed (e.g. Grief, a combination of sadness and anger).

Moods were defined from a psychobiological perspective as levels of arousal that influence the activation of emotions. Temperaments were different values of thresholds that controlled the intensity and arousal of emotions. To compute the intensity of emotions, Velásquez took into account its previous level of arousal, the contributions of each emotion elicitor for that emotion, and the interaction with other emotions.

The behavior system decided which behavior to display given the agent's emotional state. Each behavior contained two major components: one for generation of prototypical facial expressions, body postures and vocal expressions; and other for identification of motivations for behaviors and action tendencies (e.g. fighting, insulting, biting, etc.).

The system was implemented in an object-oriented framework. The ECA was Simón, a synthetic agent representing a baby. The users interacted with Simón through an interface, providing external stimuli that caused him to react emotionally. Our model is similar to Cathexis in the sense that we also took into consideration internal and external stimuli. The difference is that our external stimuli is provided by events happening inside the virtual world, and we do not consider physiological elements to elicit or manifest affective phenomena. Figure 3.1 shows the facial expressions of Simón.

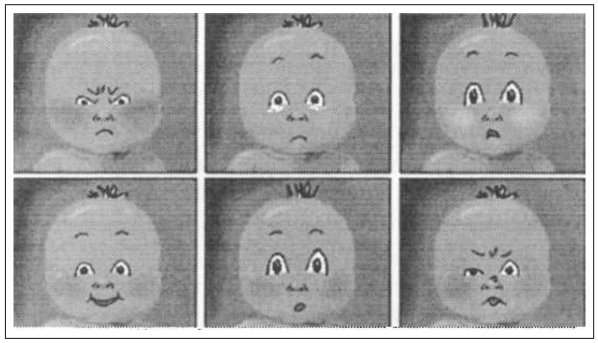


Figure 3.1: Simón's facial expressions (Fig. 3. from [147])

3.1.2 The Affective Reasoner

The Affective Reasoner (AR) [50] was a platform where agents were able to reason about events and other emotional episodes in other agents' lives, reacting with emotions and emotion-induced actions.

In the AR situations were evaluated by the agents according to their individual concerns and affective state, producing different interpretations. Each interpretation elicited emotion types and some variable bindings, according to the Emotion Elicited Condition Theory (EEC), proposed by Ortony et al. [120], which was represented in a separate database as a set of high-level emotion rules.

Agents' temperament was defined with respect to agent's idiosyncrasy and response to a situation. Once emotions arose, temperament regulated how these were going to be manifested (from somatic responses like turning red to highly intentional responses) through processing modules that chose compatible action responses (expressions) or took into account the state of the world. Emotions' intensities depended on variables such as degree of importance to the agent, "surprisingness" of the action, temporal proximity, and so forth. Finally, moods changed the thresholds for interpretations of situations and altered the activation of expression channels.

The AR was found to be useful for generation of stories with emotional content. It was also the first model to use all the OCC emotions, allowing agents to reason about one another's concerns. The virtual actors were talking-heads (either computer or human) expressing facial emotion content with speech, and in some cases, music [49]. The main difference of our model is that we do not represent physiological responses. Elliott modeled mood as the factor that changed thresholds for emotion activation, while we used the PAD model [105] to represent it. Finally, memory was a factor that Elliott took into consideration using databases, while we relied on ontologies to reuse already existent knowledge, but so far we do not deal with memory.

3.1.3 Virtual Puppet Theater (VPT)

André et al. [3] presented one model that integrated personality and emotions to create interactive virtual characters. In the Puppet project, children were intended to gain a basic understanding on how emotional states change, as well as to comprehend how physical and verbal actions in social interaction can induce emotions in others.

The architecture considered deliberative planning (goals) and reactive plans (intentions), built on a BDI framework. They considered a knowledge base (database that contains the world model), a plan library (collection of plans to be used by the agent to achieve its goals), an intention structure (internal model of the current goals or “desires”, and instantiated plans or “intentions”), and an interpreter (resolves conflicts, select a plan and execute it). Events might be elicited from the virtual environment, or from the user input. They also introduced body states (hunger, fatigue, boredom).

The modeled emotions were: anger, fear, happiness and sadness. These could be elicited through OCC rules, or by the child interacting with the system. Regarding personality, they considered two traits from the FFM, extraversion and agreeableness. Interaction could be performed in three ways: the child controlled one avatar and interacted with others, the child observed the interaction of the avatars, and the child was like the director of the theater controlling the behavior of all characters.

Visualization was done through 2D cartoon-like characters that form part of a farm: a farmer and a animals. We chose to explain the Puppet project because as it did, we are considering a model of the world, also named knowledge base, which is modeled through ontologies. The main difference is the planning behavior, which we do not consider, because we are interested in visualizing affect through facial expressions.

3.1.4 Multi-layer personality model

Kshirsagar and Magnenat-Thalmann [85] proposed a multi-layer personality model for creation of affective characters. Instead, of focusing on event's appraisal, they enabled a complete design of personality that caused deliberative reactions that change the mood, and it affected (and was affected) by momentary emotions.

For personality, they combined all the dimensions of the Five Factor Model (FFM) [99]. Regarding emotions, they used the categories proposed in the OCC model [120], but not its cognitive processing. For visualization, they re-categorized the 22 OCC emotions, plus Surprise and Disgust, into 6 expression groups corresponding to the six basic expressions proposed by Ekman. Mood was the layer that linked personality with emotions, and it could be *good, bad* or *neutral*.

To implement the architecture and to model the uncertainty of human behavior, Kshirsagar and Magnenat-Thalmann used Bayesian Belief Networks (BBN). They created one BBN for each basic factor of personality, defining prior and transition probabilities for mood change. Then, this probability of mood change was computed for each elicited emotion. To implement the influence of mood on emotions, they defined matrices with probabilities of transitions between emotional states.

The output of the model were facial expressions synchronized with speech movement. The main similarity of this model with our work is the consideration of mood as an intermediate layer between mood and personality. Figure 3.2 shows the a character with resultant moods.

Figure 3.2: Facial Animation (Fig. 6. from [85])

3.1.5 Greta

Rosis et al. [35] designed and prototyped Greta, a 3D Embodied Conversational Agent (ECA) provided with *Mind* and *Body* to enhance in the user the impression of communicating with “a specific person”.

The mind of Greta was designed based on a BDI (Belief-Desire-Intention) model [130] considering: temperament and personality, social context, dynamics of the agent’s state, response decay, and multiple emotions. It means that her mind has a representation of the beliefs and goals that elicit emotions and the decision to display them or not. They also combined emotions and considered intensity changes with time, and how each of them prevails according to the agent’s personality and social context of the conversation.

The body of Greta used a repertoire of signals to be employed during communication like facial expressions, head movements or gaze direction. In recent versions of Greta [93], the agent also produced gestures (arms and hands movements) and upper body movements.

To implement Greta’s mind, they used Dynamic Belief Network (DBN). To keep Greta’s mind independent of her body, they defined a mark-up language (Affective Presentation Markup Language - APML [34]) to associate semantics to the natural language utterances.

One of the advantages of this system was its multimodality and domain-independence. By not using emotional and personality models they built a fine-grained cognitive structure, in which the appraisal of events was represented in terms of the agent’s system of beliefs and goals. The problem arose with the use of DBNs, because the number of nodes increases considerably with the number of modeled emotions. The difference with our model is the implementation of the “mind” of our system, which was done through ontologies, and the interaction between affective phenomena that, in our case, was done using the PAD Space. Figure 3.3 shows the first attempts on creation of facial expressions using Greta.

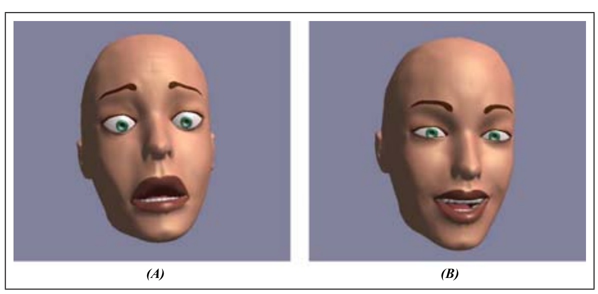


Figure 3.3: ***(A)*** Greta’s Fear and ***(B)*** Greta’s Joy (Fig. 36. and 37. from [122])

3.1.6 Generic Personality and Emotion Model

Egges et al. [41] described a personality, emotion and mood simulation model, based on appraisal theories.

The model of appraisal they used was the OCC [120]. However, as it did not consider personality traits, they included them as the selection criteria to indicate *what and how many goals, structures and attitudes fit with the personality*. For instance, Conscientiousness influenced how soon goals are abandoned and new goals are adopted [41].

Personality was represented through a vector with the intensities for each trait. It is worth noting that any personality model could be simulated. Emotions were considered as emotional states that changed over time, represented through vectors with the intensities of the 22 emotions of the OCC model. They had an emotional state history that kept record of the emotional states over time. Finally, mood was represented as a bi-dimensional or n-dimensional vector. For interrelation of these affective elements, first they defined matrices with the influence values of one element on another (Personality-Emotion, Emotion-Mood, Personality-Mood, Mood-Emotion). Then, they defined functions that used the values from these matrices to compute the changes in mood and emotions.

As in the Multi-layer personality model 3.1.4, the visualization was done through facial expressions and dialogs in virtual characters. The importance of this model is the addition of personality as a key element in the appraisal process, which we have followed in this thesis. Figure 3.4 shows the visual output of the model.

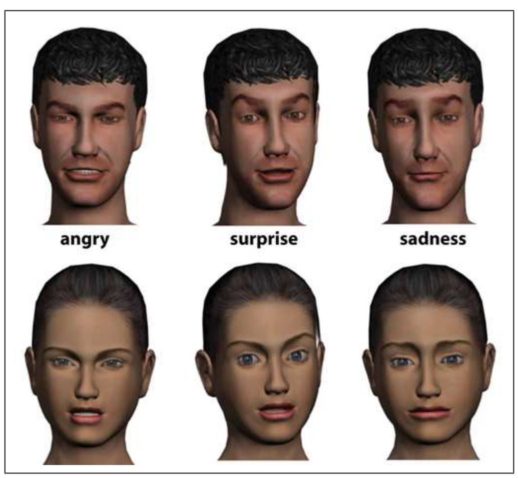


Figure 3.4: Facial Expressions for Anger, Surprise and Sadness (Fig. 7. from [41])

3.1.7 ALMA

Gebhard [63] proposed ALMA (**A** **L**ayered **M**odel of **A**ffect) to simulate the interaction of emotions, mood, and personality. The model used OCC emotions and the FFM personality model. These elements were mapped into the PAD Space [104] to represent moods.

Elicited emotions were represented in the PAD space as vectors and were condensed in a center of mass, influencing the mood and "making it jump" from one octant to the other of the PAD model. Personality was defined as a default mood using a set of equations provided by Mehrabian [105]. It influenced emotions by giving an initial offset to those related to the activated personality traits. Finally, mood updated personality, using the inverse of the equations employed to compute the default mood.

ALMA was implemented using AffectML, an XML-based affect modeling language. A character's personality profile consisted of the personality definition and subjective appraisal rules. At runtime, the affect computation periodically updated the affective profile of all characters, appraised relevant input for all characters, and gave as output a set of emotion eliciting conditions. These were used to update a character's emotions and mood.

Regarding visualization, facial expressions, or visual cues as "blush of shame" showed the experienced emotion. Idle behaviors represented the mood. Nevertheless, ALMA has been mainly used for dialog-generation in virtual characters [64]. Our work is based on this model because it provided the framework to interrelate personality, mood and emotions in a novel and practical way. Figure 3.5 shows the PAD space where affective traits are mapped and the resultant behavior in a character.

3.1.8 FATIMA

Inspired by the work of traditional character animators, Dias and Paiva [38] proposed an architectural model to build autonomous characters whose behavior was influenced by their emotional state and personality.

The architecture presented two layers: the reactive layer (hardwire reactions to emotions and events that must be rapidly triggered and performed after the appraisal process), and the deliberative layer for the agent's planful behavior. FATIMA generated character's behavior based on appraisal and coping processes. Appraisal focuses on the goals of the character, triggering the emotions to take into account to prepare a plan. Coping depended on the emotional state and personality of the character. They considered two types of coping: problem focused (set of actions to achieve and execute a result) and emo-

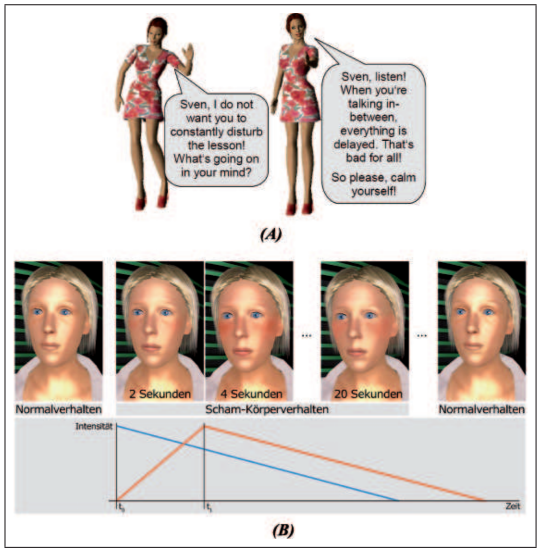


Figure 3.5: ***(A)*** Character Behavior ([63]). ***(B)*** Shame representation over time ([64])

tional focused (changes the agent's interpretation of circumstances (importance of goals, effect's probability), thus lowering strong negative emotions).

They used the OCC model for emotions, and also represented arousal (degree of excitement of the character) and mood. Mood, represented as *good* or *bad*, was an overall valence of the character's emotional state and influences the intensity of emotions. Personality was defined by: a set of goals, a set of emotional reaction rules, the character's action tendencies, emotional thresholds, and decay rates for each emotion type.

FATIMA provided synthetic characters that were believable and empathic. They had cognitive capabilities, interacted with external users and were domain independent. This model was mainly goal-based, letting motivations and standards to define the character's personality. Our model is a simplified version of a goal-based model, which takes it into account to generate emotions, but also considers preferences and admiration for other agents to elicit other OCC emotions.

FATIMA was implemented in the computer application FearNot! [37], which was developed to tackle and eventually help to reduce bullying problems in schools. Figure 3.6 shows a screenshot of FearNot!.

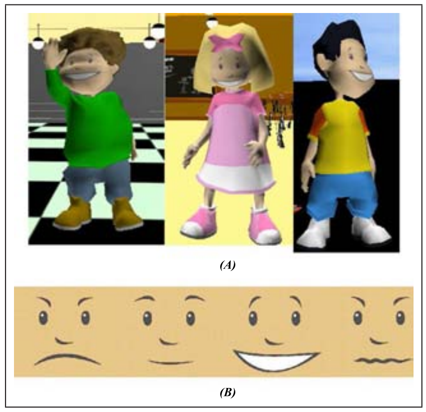


Figure 3.6: ***(A)*** Characters in FearNot! and ***(B)*** Facial Expressions (Fig. 3 and 4 [121])

3.1.9 WASABI

Becker-Asano [12] presented **W**ASABI **A**ffect **S**imulation for **A**gents with **B**elievable **I**nteractivity, a computational simulation of affect for embodied agents. The architecture of WASABI distinguished two layers: a physis layer and a cognition layer; and three affective states: mood, primary emotions, and secondary emotions.

In the physis layer, primary emotions were produced from the *non-conscious appraisal* of the stimuli. The set of primary emotions were anger, annoyance, boredom, concentration, depression, fear, happiness, sadness, and surprise.

In the cognition layer the agent used its BDI-based cognitive reasoning abilities to update his *memory* and generate *expectations*. From the conscious appraisal, secondary emotions were produced. They were first filtered in the PAD space influencing the embodiment of the agent and the expression of these emotions. Secondary emotions corresponded to the "prospect-based emotions" OCC-cluster: *hope, fears-confirmed*, and *relief*.

Mood was the background state that influenced the elicitation of emotions. In contrast to ALMA (Section 3.1.7), mood was not derived from PAD space, but modeled as an agent's overall feeling of well-being on a bipolar scale of positive vs. negative valence.

The ECA where WASABI was tested was Max. He was employed in a museum application, where he conducted multimodal smalltalk conversations with visitors. Furthermore, WASABI has also been applied to a gaming scenario, in which secondary emotions were simulated in addition to primary ones [13]. The main difference of WASABI with our model is the differentiation between primary and secondary emotions at the appraisal level. We make this distinction when visualizing facial expressions of our characters, and moreover, our secondary emotions are mixtures of primary emotions. Although we also use the PAD space, we consider mood traits as the octants of the space instead of limiting them to positive or negative. Figure 3.7 shows the virtual agent Max.

Figure 3.7: Virtual character Max (Fig. 4. from [13])

3.1.10 EMA

Marsella and Gratch [94] [95] proposed EMA (**EM**otion and **A**daptation), a computational framework that represented the dynamics in appraisal, which make the elicited situations change based on inferences and previous knowledge to cope with that situation.

The agent's interpretation of its agent-environment relationship was called *causal interpretation*. It provided a explicit representation of the agent's beliefs, desires, intentions, plans and probabilities used for the appraisal processes. This causal interpretation changed in time depending on the agent's future observations or inferences. Regarding events, they were defined in terms of appraisal variables which were: Perspective, Desirability, Likelihood, Causal Attribution, Temporal Status, Controllability and Changeability.

Coping refers to how the agent reacts to the appraised events. Coping strategies in EMA used the cognitive operators of the appraisal process, and decided for the most suitable actions to be performed. Strategies included: planning, seek instrumental support, procrastination, positive reinterpretation, acceptance, denial, mental disengagement, shift blame, seek/suppress information.

As AR (Section 3.1.2) and FATIMA (Section 3.1.8), EMA followed Frijda's theory, so then appraisal and mood elicited emotional states. Finally, coping response was biased by this overall mood state. Regarding knowledge, it was represented through propositions, and SOAR [114] was used to model cognitive operators (e.g. update belief, output speech, listen to speaker, initiate action, and so on) [95].

The relevance of this work is the single layered appraisal model, which resulted simply enough to be implemented in virtual characters, so they can make congruent inferences about their world and cope accordingly to them. We also followed Frijda's background, because through our appraisal mechanism (ontologies) we elicit emotional states. We also used variables as desirability, likelihood and temporal status as the variables to appraise the different situations.

3.1.11 Memory-based Emotion model

Kasap et al. [80], proposed a memory-based emotion model that intended to achieve a more natural interaction between the user and a virtual character. Through face recognition techniques, the character could "remember" a user's face and automatically adjust the current interaction on the basis of its existing relationship with the user.

To model emotions Kasap et al. used the reduced OCC model, which has 12 emotions (six positive: *joy, hope, relief, pride, gratitude,* and *love*; and six negative: *distress, fear, disappointment, remorse, anger,* and *hate*). In addition, they used another 4 user-related emotions: *happy-for, gloating, sorry-for,* and *resentment*. Personality was modeled using FFM and moods were represented in the PAD space, defined by equations proposed by Mehrabian [105].

This architecture was similar to ALMA (Section 3.1.7), but Kasap et al. integrated the interpersonal-relationship concept in which emotion, mood, personality, and social relationships affect to each other. Long-term memory allowed the virtual character to store specific interaction sessions, and then retrieving this information as needed.

At the beginning, during, and at the end of each interaction, emotions and moods were updated using the values provided in a matrix that related emotions (rows) with moods (columns). Relationships were framed on the dimensions of Dominance and Friendliness, following Argyle's model [5]. Long-term memory was represented through structures named *episodic memory*, which kept track of people that had interacted and calculated relationship levels with them [91].

Their example application was Eva, a geography teacher who had a "good" and a "bad" interaction with two different students, showing the differences in the interaction's outputs. Figure 3.8 shows the facial expression of Eva during interaction.

This model is very similar to our model, regarding mapping of affective traits in the PAD space. While they consider relationship during the calculation of the affective state, we take it into consideration while appraisal of the event (in the ontology). Also, Kasap et al. only modeled facial expressions of emotions, while we map mood's pleasure, arousal and dominance values in the face.

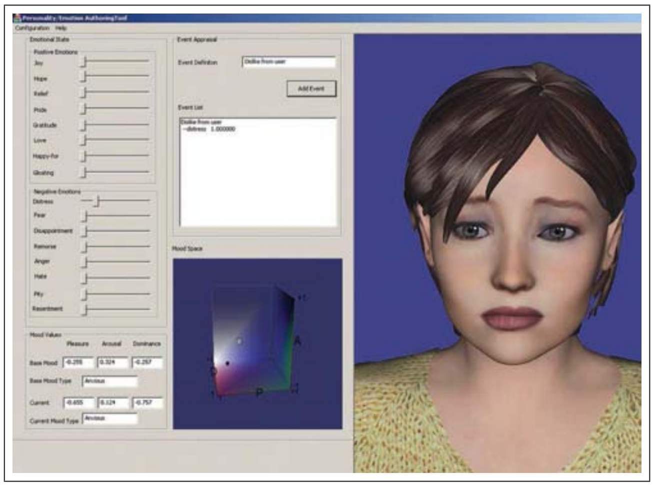


Figure 3.8: Eva's response to events (Fig. 3. from [80])

3.1.12 OSSE

Ochs et al. [118] proposed a model of the dynamics of social relations, based on emotions, for Non-Player Character's (NPC). NPCs are defined according to their *personality traits* and *social roles* (relation with other NPCs).

To represent the world surrounding the NPCs and its events, they used a formal representation that included: a vocabulary (entities with no reasoning capacity and actions), NPC's attitudes functions (towards objects and other characters), praise functions (towards actions), events as the 4-uplet <*agent, action, patient, degree_certainty*>, emotion representation, emotions' intensity (degree of desirability, of praiseworthy/blameworthy), personality traits, dynamics of social relations as the 4-uplet <*liking, dominance, familiarity, solidarity* >, and social roles (e.g. employee/manager, child/father).

In the architecture, events were triggered by the scenario and appraised using OCC-based algorithms. It elicited emotions that were influenced by personality. In turn, emotions affected the NPC's emotional state and altered the social relations with other NPCs.

In the implementation of the architecture, emotion representation was done through the 10-emotions reduced OCC model [119], and they just considered the personality traits Neuroticism and Extraversion. For instance, a more extroverted NPC experiences higher *joy, hope, pride* and *relief* emotion values. Emotional decay functions and emotion thresholds depended on the personality. To test the model, they used interactive dialogs that simulated scenarios with different contexts (e.g. police interrogation and job interview).

This model is important because it focused on the dynamics of emotions, and not just in their representation. They considered most of the aspects that participate in the emotion elicitation from a cognitive perspective, achieving a simple representation. Ochs et al.'s model conceptually resembles our model because actions, objects, agent, preferences, and events are related in a similar fashion. Nevertheless, we make use of ontologies to represent the knowledge that they implemented through functions. In this way, we reuse existent knowledge and perform inferences about the context defined. Moreover, they did not consider emotions as *happy-for* (*sorry-for*), which occurs when someone we appreciate undergoes desirable (undesirable) events; nor *gloating* (*resentment*). In our model we can elicit these emotions because we have a "liking" level for another agent which is represented in the ontologies.

3.1.13 MARC system

Courgeon et al. [31] proposed a model based on Scherer's Componential Process Model (CPM) (Section 2.1.3). Their motivation was the appraisal of affective events in real-time. For this reason, they used Scherer's model, which defines appraisal based on the evaluations an organism make in order to survive.

MARC's architecture had an appraisal module that evaluated the elicited events and generated the parameters for facial animation. They just used 7 out of the 10 appraisal sub-checks of the CPM: expectedness, unpleasantness, goal hindrance, external causation, copying potential, immorality, and self consistency. For each sub-check they defined Gaussian curves, based on the proposed discrete prediction values (open, very low, low, medium, high, and very high), because they provided a linear quantification of discrete values. Therefore, they could evaluate the sub-checks in a continuous scale.

The process can be summarized as, when an event occurs the relevant emotions for that event are evaluated. They used a set of four emotions: joy, sadness, anger, and guilt. For each emotion, they multiply its relevance by the emotion's Gaussian value of all its sub-checks. Then, the final emotion is set with a value and animation parameters are generated. Visualization was done using MARC, a virtual character that displayed sequential facial expressions. Figure 3.9 shows the system's architecture.

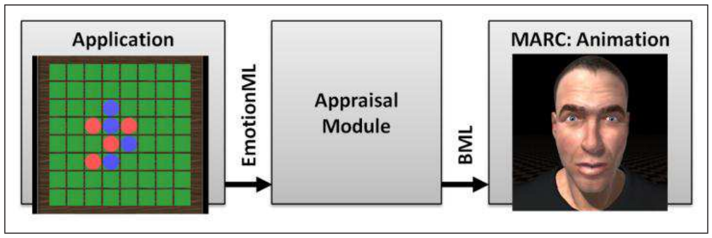


Figure 3.9: MARC's architecture (Fig. 1. from [31])

We decided to review this work because it is a novel appraisal model that uses the CPM in a simple manner. In essence, Courgeon et al.'s model follows our own framework organization: we have an event elicitor module that performs appraisal, then a module where the affective parameters are fine-tuned and values for facial animation are generated, and finally a facial animation module.

3.1.14 Comparison between models

Table 3.1 presents the most important aspects we have taken into consideration when studying previous works. We have focused in the affective elements they use (number of emotions, mood and personality; and which theory they based on), the psychological theory background (CPM, *Belief-Desire-Intention* (BDI) theory, Cognitive Appraisal, Reactive or deliberative planning), the implementation techniques (Bayesian Belief Networks, OCC rules, Quantitative functions), and the visualization method. Regarding this last aspect, we have biased our research of previous works to those that use virtual characters and generate facial expressions.

Model	Affective Elements	Psychological Background	Implementation	Visualization	ECA
Cathexis (1997)	- 6 basic emotions (Ekman) - Mixed Emotions - Mood - Temperament (emotions thresholds)	Appraisal + Physical motivations (Roseman model)	Emotions: Sensor agents (neural, sensorimotor, motivational, cognitive). Behavior: motivations, external stimuli.	- Basic facial expressions - Body postures - Vocal expressions	Simón
Affective Reasoner (1998)	- 24 emotions (OCC model) - Mood	BDI	Databases for expectations, concerns-of-other, goals, standards and preferences (GPS). OCC rules, actions, conflicts sets.	- Facial expressions	Talking heads (either computer or human)
PUPPET (1999)	- 4 Emotions (anger, fear, sadness, happiness) - Personality (extraverted and agreeableness)	Deliberative and reactive planning + BDI	OCC rules	- Facial expressions - Sounds (e.g. cat purrs and hisses)	Farm characters (farmer, pigs, etc.)
Multilayer Personality Model (2002)	- 24 emotions (OCC model + Surprise + Disgust) - Personality (FFM) - Mood (good/bad/neutral)	Emotional reactive	Bayesian Belief Networks (BBF) for personality. Probability transitions matrices for mood.	- Basic facial expressions - Vocal expressions	Virtual character
Greta (2003)	- 24 emotions (OCC model)	BDI	Dynamic Belief Networks for emotion representation.	- Facial expressions - Body postures - Head movements and gaze - Vocal expressions	Greta
Generic Personality and Emotion Model (2004)	- N emotions - P Personalities - M Moods	Appraisal (OCC model + personality)	Matrices of influence. Functions to compute affective traits changes.	- Basic facial expressions - Vocal expressions	not found
FATIMA (2005)	- 24 emotions (OCC model) - Personality (goals, emotional reaction rules, action tendencies, emotional thresholds and decay rates) - Mood (good/bad)	Appraisal and Coping	Reactive and deliberative appraisal. Problem focused and emotional focused coping.	- Facial expressions - Body postures	FearNot! (John the victim, Martinha the neutral and Luke the bully)

ALMA (2005)	- 24 emotions (OCC model) - Personality (FFM) - Mood (PAD space)	Cognitive Appraisal	Appraisal rules: basic, act, emotion and mood display (AffectML)	- Facial expressions - Body postures - Written dialog	Cyberella, Cross Talk, VirtualHuman, Eric, Virtual Poker-Character
WASABI (2008)	- Primary emotions (prototypical emotions) - Secondary emotions ("prospect-based emotions" in OCC-cluster) - Mood (positive/negative)	BDI + "bodily" dynamics	Physis and cognitive layers in PAD Space.	- Facial expressions - Vocal expressions	Max
EMA (2009)	- Emotions (surprise, hope joy, fear, sadness, anger and guilt) - Mood (aggregated emotional states)	Dynamic Appraisal and coping	Cognitive architecture (SOAR)	not found	not found
Memory-based Emotion Model (2009)	- 12 Emotions (reduced OCC) - Personality (FFM) - Mood (PAD space)	Cognitive appraisal + Interpersonal relationship (dominance-friendliness) + Long-term memory	Matrices relating emotions and moods. Probabilities of affective state change. Episodic memory structure.	- Facial expressions - Body postures - Written dialog	Eva
OSSE (2009)	- 10 Emotions (reduced OCC) - Personality (extraverted and neurotic)	Dynamics of social relations	Semiquatitative. Numerical functions.	- Written dialog	not found
MARC (2009)	- 4 Emotions (joy, anger, sadness, guilt)	CPM (7 sub-checks)	Gaussian functions	- Facial expressions	Marc
Our system	- 24 Emotions (OCC model) - Personality (FFM) - Mood (PAD space)	Deliberative Appraisal + Knowledge Inference	Ontologies.	- Facial expressions	Alice, Alfred

Table 3.1: Comparison between Computational Affective Models

3.2 Visual Perception of Affective Phenomena

When it comes to Personality, little has been done regarding its visual representation in a virtual character. Nevertheless, some previous works have dealt with this topic, obtaining the results that are presented in the following.

3.2.1 Visual Cues for Personality

Personality is something that everyday people recognize and discuss about others, and personality is a valuable piece of information about a person [77]. The following previous works have focused on personality as a component in affective models that modifies the resultant emotional state of the virtual character.

According to Mehrabian [102], facial pleasantness was associated with less dominant, more neurotic, and more anxious tendencies of an individual. Thus, when greater facial pleasantness or higher rates of smiling occur in what could be considered awkward situations, they indicate greater efforts by the speaker to relieve tension and discomfort by "placating" the listener.

According to Keltner [81], Neuroticism is correlated with increased facial expressions of anger, contempt, and fear. In a study, neurotic individuals showed increased facial expressions of distress while watching a person making an embarrassing face. Following an overpraise induction, Neuroticism was negatively correlated with participants' Duchenne smiles, which was the dominant response in the situation mentioned before. Extraversion consistently predicted facial expressions associated with social approach. It was positively correlated with increased Duchenne smiles of enjoyment and amusement, as well as with increased facial expressions of sadness, which they viewed as a signal of increased social approach.

Isbister and Nass [77] examined whether people would interpret and respond to verbal and non-verbal cues of personality in virtual characters as they do from other persons. Their experiment used subjects who had previously taken personality tests, so they could determine if people prefer to work with others that are similar to themselves. As a result, participants accurately identified the extroverted language and non-verbal cues as significantly more extroverted than the introverted language and postures. Similarly, they preferred characters with consistent cues, regardless of participant personality, showing that they rather to work with a character that was complementary to them, vs. one that was similar.

Krahmer et al.[83] investigated three potential personality cues: gaze, speech and eyebrow movements, which were assigned variants of Extraversion and Introversion. The novelty was the study of the perception of these cues combined in different personality profiles (e.g. introverted gaze, introverted speech and extraverted brow). They used a virtual talking-head with the three variants of personality cues, which had to be rated by subjects while reading a poem in Dutch. The results showed that extravert brows were perceived more extraverted when combined with extraverted gaze, and introvert brows were perceived as more introvert with introvert gaze. Concerning combinations of cues they found that including an extravert feature in an introvert agent does not imply that subjects perceive that agent as more extraverted. They also observed that the personality profile of the character had no influence in the quality assessment. They also confirmed that speech influences perception of personality.

Arya et al. [7] experimentally associated facial actions (head tilting, turning, and nodding, eyebrow raising, blinking, and expression of emotions) and their frequency and duration to the dimensions of Dominance and Affiliation, proposed by Wiggins [155]. Their objective was to have an agent with certain facial actions that can be perceived by the user as certain personality types, instead of establishing the relation between personality types and facial actions. The results showed that joy was highly related to the Affiliation dimension and was seen more dominant. Contempt was also seen as very dominant but correlated negatively with Affiliation. Slowly and fast raising of both brows was seen as an Affiliation signal. Slowly turning the head was seen as very dominant, while slowly moving the head to the side was seen as very submissive. On the other hand, raising fast one brow was seen as very dominant, while a fast avert gaze was seen as more submissive.

Zammitto et al. [156] tried to expand the personality model proposed in Arya et al. [7] by using the AB5C model (Section 2.2.3), which provided the framework for going from mapped circumplexes to meticulous use of labels. As a result they obtained adjectives for identifying the Big Five personality factors, plus specific visual cues for two of them. Their idea was to incorporate visual cues for the rest of the Big Five traits.

Bee et al. [15] analized how facial displays, eye gaze, and head tilts express social dominance. Using one-way ANOVAs and two-tailed t-test, depending on what they wanted to obtain, they obtained results as the emotional displays of joy, anger and disgust were perceived as high dominant, while fear was less dominant. Regarding gaze, joy, disgust and the neutral display with direct gaze (looking straight to the user) were the most dominant, while fear was again the less dominant. Nevertheless, anger with averted gaze was perceived as high dominant. Concerning influence of head orientation, significant effects were only obtained for anger, sadness and the neutral display.

McRorie et al. [101] proposed a model to construct Sensitive Artificial Listeners (SAL) using Eysenck's model of personality to generate behavioral characteristics (e.g. visual cues) from it. The idea was to link verbal/non-verbal behavior with impressions of personality. In order to do that, first they defined the agents specifying its characteristics and mental state: agree, disagree, accept, refuse, believe, disbelieve, interest, not interest, like, dislike, understand, and not understand. Then, they computed the agent's behavior when it was listening to the user, selecting the most appropriate signal. Finally, they determined the corresponding non verbal behaviors taking into account the character's modality preference and expressiveness parameters. For example, extraverts tend to demonstrate more body movements, and display greater levels of facial activity and gesturing, more frequent head nods, general speed of movement, and direct facial posture and eye contact is more likely to be maintained. For instance, their character Spike, who is angry and argumentative, conveys negative communicative functions, in particular dislike, disagreement and lack of interest.

Cloud-Buckner et al. [28] conducted an experiment to investigate how people perceived personality on avatars based on actions, language, and behavior; and if race and gender of the avatar influenced this perception. The independent variables taken into consideration were race (dark or white), gender (male or female), and personality (P1: friendly, outgoing, self-sufficient, with high-activity level and some anger; P2: introverted, self-conscious, cooperative, orderly, modest, disciplined and sympathetic to others). Results showed that race and gender of the avatar did play a role in the perception of personality. For example, for P1 and P2, when there was a difference on Race, the dark skin had a higher rating for every item except anger. When there was a difference on Gender, in P1, the male had a higher score, but in P2, the women had a higher score.

Neff et al. [113] studied the impact of verbal and non-verbal factors in the perception of the Big Five trait of Extraversion. The non-verbal expression of Extraversion was given by the head and body attitude: gesture amplitude, direction, speed, and movement of body parts. Neff et al. performed evaluation on videos of a female avatar making a restaurant recommendation and asking subjects to judge her extraversion level and naturalness. Results showed that linguistic extraversion has more influence on the perception of extraversion than gesture rate or gesture performance; that indeed higher gesture rates are perceived as more extraverted; changes in gesture performance correlate with changes in extraversion perception; and the combination of higher gesture rates with a more extraverted gesture performance increase the perception of extraversion.

Bee et al. [16] examined the interaction of verbal and non-verbal behavior to create the impression of *dominance* in intelligent virtual agents. Non-verbal communication is achieved by gaze and head movement, which is associated with social dominance; and gestures that acquaint friendliness and enthusiasm. Verbal communication is achieved through linguistic behavior, which is associated with the personality traits of extraversion and agreeableness. Their novel result demonstrated that linguistic personality traits (extraversion and agreeableness) influence the perception of dominance. Also, gaze-based dominance influences the perception of personality traits.

3.3 Summary

This chapter can be summarized as the overview of models to make character "feel" and to make character "look like feeling". In the first group we found the models of Velásquez, André et al., Kshirsagar et al., Egges et al., or Gebhard et al., which have become State of Art when studying computational models of affect. Other works as Kasap et al., Ochs et al., and Courgeon et al., propose new models that intend to improve the creation of affective characters. Table 3.1 shows the highlights of the reviewed models as well as of our model.

In the second group we have briefly described studies related with the perception of personality and their relation with different visual cues. This studies have been mostly performed by psychologists, but recently researchers in Computer Science like Arya and colleagues, Zammitto and colleages, or Bee and colleagues are experimenting with the implementation of these cues in virtual characters and explore how they enhance the perception of emotions, mood and personality.

Chapter 4

Framework Overview

Da Vinci combined art and science and aesthetics and engineering, that kind of unity is needed once again.

Ben Shneiderman

The combination of different fields and theories to achieve believable virtual characters is not an easy task. It could be seen in the previous chapters the amount of previous work to give characters affective traits. It also could be seen that context is a key element in the generation and recognition of emotions. On the other hand, little has been seen about expression of mood or personality that could enhance the believability in the characters.

Therefore, we propose a framework that deals with the representation of context and the visualization of emotions, mood and personality, combining ontologies, psychological theories and previous computational models. Nevertheless, due to the novelty of this work, every piece of the framework needs to be evaluated to prove our research hypothesis established in the introductory chapter. Therefore, the main purpose of this framework is to establish the basis for a model that could help in the development of applications with storytelling, interaction with virtual characters or fast visualization of affect.

This chapter gives an overview of how we implement the necessary elements to create believable affective virtual characters immersed in contextualized virtual worlds.

4.1 System Framework

To represent daily events it is necessary to have a model that defines them, describes the concepts related with those events, and implements the rules of appraisal that will elicit affective responses.

Therefore, we propose a three-layered Computational Affective Model that consists of a ***semantic layer*** (Context Representation Module), an ***affective layer*** (Affective Module) and a ***visualization layer*** (Facial Expressions Visualization Module). Figure 4.1 presents the diagram of our model, where the relationships between the main modules are shown.

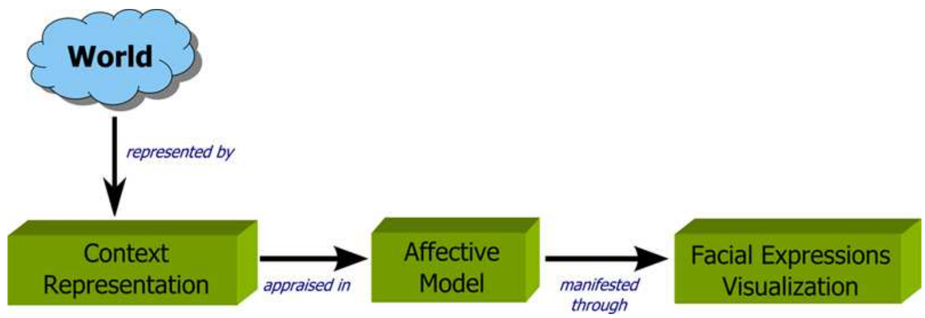


Figure 4.1: General Conceptual Model

As can be seen, the world provides the elements to represent the context, which are appraised and elicits emotions that are interpreted by the affective model. Then, the affective model combines these emotional responses with the mood and personality of the character, to produce a final affective state, or mood. Finally, this mood is manifested by the agent through its facial expressions. Figure 4.2 presents a more detailed schema of the modules to be developed, and the psychological theories (or models) that will be used.

Starting from the top leftmost side of Figure 4.2, it is seen that the *World* is defined in terms of the *events* that occur in it, and also in terms of the characters, or *agents* who inhabit it. This categorization responds to idea of differentiating context regarding things that happen outside the character (events) and inside the character (the character itself through its psychological-affective characteristics).

An event is composed of an action that is performed, or affects a character (agent) or an object; a time unit when it occurs; and a place where the event occurs. As for the agent, it is defined in terms of its goals, preferences, social admiration for other agents (although

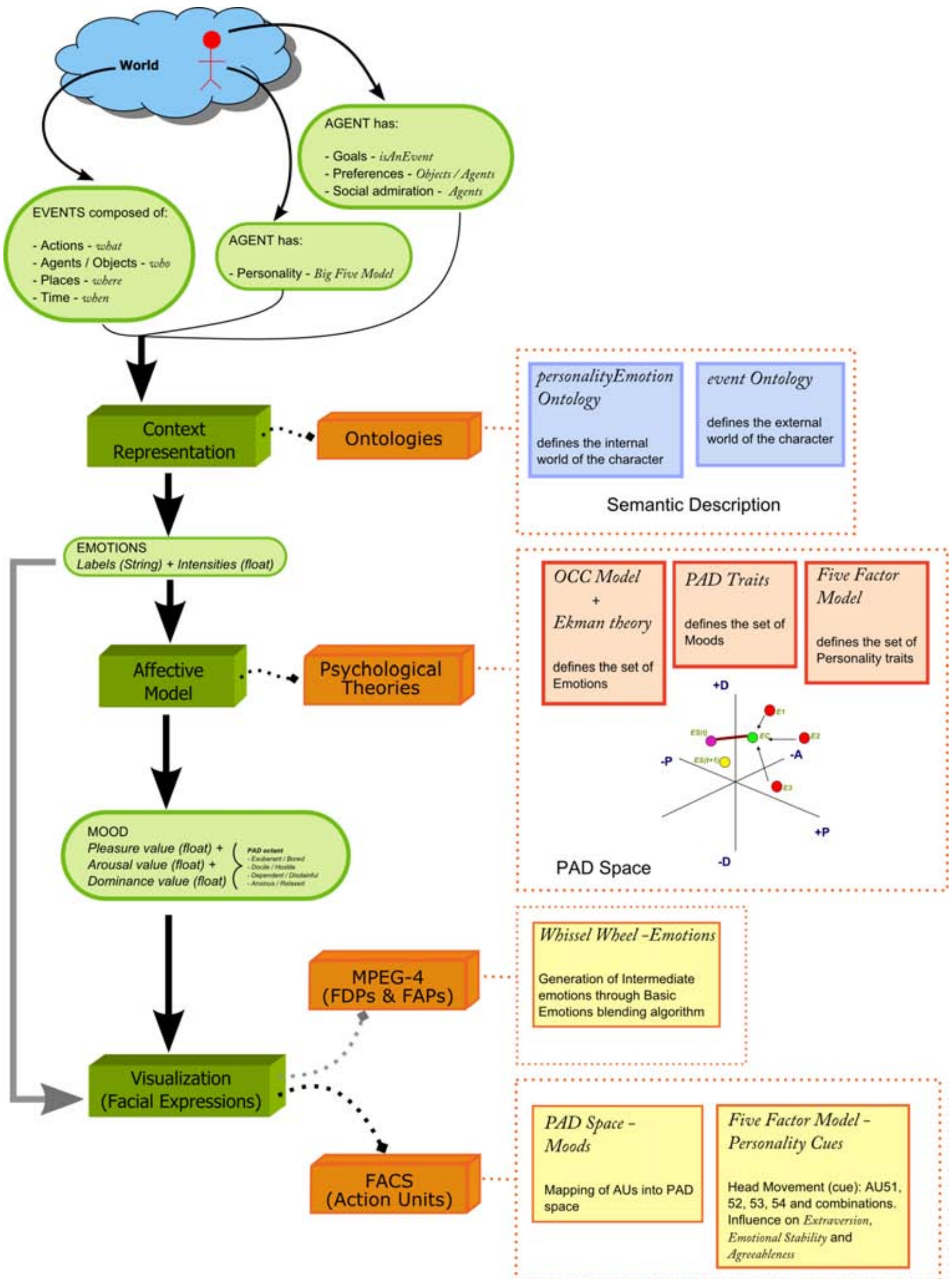


Figure 4.2: Conceptual Model of the Framework

this term uses the emotional word "admiration", which has a positive connotation, it can be negative), and personality.

The *World* elements are inputted to the *Context Representation* module that is implemented using two ontologies: *Event Ontology*, which describes all the concepts that form part of an event; and *PersonalityEmotion Ontology*, which considers all the concepts that define a character from a psychological point of view (goals, preferences, social admiration with other agents, and personality). The output of this module is a set of emotions with their respective intensities.

These emotions are the input of the *Affective Model*, which computes the interrelations between emotions, moods and personality, giving more accurate affective responses. The output of this module is a set of moods expressed in terms of pleasure, arousal and dominance values.

The *Visualization* module is responsible for the generation of facial expressions, providing a visual representation for the emotions elicited in the Context Representation module and the moods elicited by the Affective Model. Regarding personality, it does not only influence at the computation level, but also at the visual level. That is why we explore how some visual cues influence the perception of personality traits.

In the following sections we offer a brief description of the parameters used in each layer of our computational affective model.

4.2 Semantic Layer: Context Representation

To represent the context in which the characters will be immersed we propose a Semantic Model that will be briefly described in this section, and then explained in Chapter 5.

4.2.1 Context - Inner world of the character

The internal state of a character is the result of the context appraisal, which is performed using information as the goals, preferences, admiration for other characters, and personality traits. Many other aspects could be taken into consideration as social role, culture, religion, social dynamics between characters, etc. Nevertheless, we consider the former elements the basic ones to represent the interaction of the character with his environment. In the following subsection we will make explicit our intended meanings for them.

Goals

In its simple sense goals define a group of affairs that an agent desires to happen. In this dissertation, they are related to the occurrence of an event that the agent wishes to happen and produces benefits to it. A benefit is represented as the elicitation of one, or a set of positive emotions. Goals are considered equivalent in their structure, which means that no difference will be made among preservation goals, partially achieved goals, and so forth.

Preferences

We have defined them as the degree of liking, or disliking, that an agent feels for "surrounding" entities. They can be things around the character as a specific park, certain street, flowers, chocolates, or other agents; or "things" that are perceived by the character as thoughts, ideas, standards, etc. For example, the agent may be a pacifist and love the idea of "freedom", or dislike "racism".

Interaction / Relation with other agents

In real life people like or dislike other people to a certain degree. This "feeling" influences the affective output when two characters are participating in the event, or when the event is evaluated from the perspective of an external agent (an agent that is not participating in the event, but has "witnessed it" and might feel emotions because of it).

Social role

According to Edelstein [40], roles are blend of personality traits and the work a person does (company president, hit man, or new mother). A role emphasizes different aspects of an individual. Although we have not set explicitly the roles as explained, we do have established four roles which deal with the character as a protagonist or as spectator of the event.

4.2.2 Context - Outer world of the character

An **Event** is defined based on four questions that provide the main information about it: *what*, *where*, *who* and *when*.

- **what:** references the action that happens in the event. An action is represented with a verb, which indicates what occurs in the event. The action has complements that complete it, giving sense to the event. Complements can be *direct* or *indirect* objects, which are represented by **Abstract Entities** and **Physical Entities**, which were overviewed in subsection 4.2.1.

- **who:** indicates the **role** of the character with respect to the action in the event.
- **when:** specifies the time of occurrence of the event.
- **where:** provides a description of the place where the event occurs.

4.3 Affective Layer: Affective Model

The following theories are the ones used to represent emotions, mood and personality. The implementation of the model is explained in a further chapter.

4.3.1 Emotions

To represent emotions in our system we chose the ones proposed in the OCC model, plus the emotions of "disgust" and "surprise", explained in Chapter 2. The reason to choose it, as done previously by other researchers, is because is comprehensible and precise enough to allow a computational implementation of emotions. These are obtained from contextual elements for world and agents context representation, managed by the semantic layer.

4.3.2 Mood

For mood we chose the PAD Model, also explained in Chapter 2, because it links emotions, mood and personality in the same 3D space. In PAD, each mood corresponds to an octant of that space resulting in: Exuberant, Bored, Dependent, Disdainful, Relaxed, Anxious, Docile and Hostile.

4.3.3 Personality

Finally, for personality, we use the traits of the Five Factor Model (FFM) [97] (also known as Big Five) because of its proven universality after years of research using self-report questionnaires [74], and because this model can be mapped in the PAD Space with equations provided to this end. FFM is explained in details in Chapter 2.

4.4 Visualization Layer

To generate the different expressions we use two standards: the MPEG-4 standard [58] and the *Facial Animation Coding System* (FACS) [48]. MPEG-4 is considered a derivative of FACS, and while the former has been mainly used for synthesis of facial expressions, the latter has been mainly used for recognition of facial expressions.

The MPEG-4 standard provides facial animation parameters, which result in fast and computationally inexpensive animations. We decided to use this standard because of its simplicity and efficiency to define facial points that can be mapped to all areas of the face (eyes, nose, mouth, head), to manipulate them through animation parameters, and because of the satisfactory visual output that it produces. We use MPEG-4 for visualization of intermediate emotions, obtained as the linear combination of basic ones.

On the other hand, FACS is a coding system that describes facial movements, based on muscular activity. This movement description is done through *action units* (AUs), e.g. AU1: inner brow raiser. We use FACS to map the values of Pleasure, Arousal and Dominance into facial expressions, based on a database of facial movements described and defined for a set of expressions associated with these dimensions.

4.5 Summary

In this chapter we provided a global view of our Computational Affective Model. It is formed by three layers that allows the simulation of believable virtual characters.

The first layer is related with the semantics that define the context of the character (inner context, based on a BDI theory plus personality traits; and outer context, which is the world and its entities).

The second layer deals with the affective output produced as a result of the events elicited by the semantic layer. In this layer emotions, mood, and personality are combined to leave the character in an affective state defined by the values of Pleasure, Arousal and Dominance.

The third layer is in charged of the visualization of the facial expressions that show the affective state of the character. We have used MPEG-4 and FACS to prove that our model is domain independent, regarding the visualization methods.

Chapter 5

Context Representation

There are no facts, only interpretations.
Friedrich Nietzsche

Appraisal can be defined as the process of understanding and evaluating what is happening around us, allowing the elicitation of emotions. Therefore, to create emotional characters we need to simulate a context where a variety of situations occurred and can be appraised.

This chapter is organized as follows. First, a review of previous works related with generation of context and its representation is presented, followed by the explanation of the implementation of our own conceptual model to represent context. Then, a practical summary of the whole conceptual model is given, as well as a discussion about the implementation details. Afterwards, a practical example is provided to demonstrate the use of the model. Finally, a summary concludes the chapter.

5.1 Context - An Overview

Dey et al. defined context as *any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between an user and the application, including the user, the device and application themselves.* [36]

Similarly, Doyle offered another definition of context as *a representation of certain aspects of the state of the world... There may be several contexts active at one time, and contexts may be nested within one another.* [39].

Hence, how a character expresses its affective state significantly depends on the context. Without it, it might become difficult to discern between the meaning of a facial expression, to decide how to react in certain situation, or how the course of a story/situation should be unfolded. In this way, Kaiser and Wehrle [78] stated that facial expressions can only be interpreted when they are inside a context (temporal or situational) that allows us to generate them in an accurate way.

One of the problems when representing context is that aspects like culture, religion, and other social rules and roles should also be taken into account, making the context's representation and evaluation an unmanageable task.

A solution for this is to represent context from a "child's point of view". When we think of children, we realize that their context has the same set of events as the one from adults, but their appraisal lacks of social rules. Therefore, they react to those events in a "purer" emotional way.

With this in mind, we decided to represent context as a child would do it, providing a generic description of what is happening outside and inside the virtual characters, or virtual agents - both terms will be used indistinctly. This is one of our main contributions, because as it will be seen in the next subsection, no previous work has managed to represent and elicit **affect** through ontologies.

5.1.1 Previous works on Context Representation

In the field of Computer Science some areas that have work on context representation are Affective Computing, Ubiquitous Computing, and Artificial Intelligence.

Strang et al. [141] evaluated six of the most relevant existing approaches to model context for ubiquitous computing: key-value models, markup scheme models, graphical models, object-oriented models, logic based models, and ontology-based models. These approaches are also useful for any field where context representation should be taken into account. Indeed, Strang et al. concluded that the most promising assets for context modeling can be found in ontologies.

Ontology has been a field of philosophy since Aristotle characterized by the study of existence, a compendium of all there is in the world. Nowadays, it has evolved in great measure in the computer science and artificial intelligence fields [89]. An ontology is defined as an explicit specification of an abstract, simplified view of a world to represent. It specifies both the concepts related to this view and their interrelations [117].

Krummenacher et al. [84] also stated that ontologies provide better modeling facilities (intuitive notions of classes and properties), while being semi-structured and incorporating a clear semantic model. They mentioned a number of *upper ontologies* for context definition, which are defined as the most general category of ontologies applicable across large sets of domains. General upper ontologies are DOLCE (*Descriptive Ontology for Linguistic and Cognitive Engineering*) [61], SUMO [115], Cyc [87], and SOUPA [26]. Nonetheless, ontologies still have their drawbacks, especially in issues related to scalability and domain specific reasoning.

Due to scalability and domain-related issues other researchers have proposed their own ontologies like López et al. [89], who proposed a generic ontology *Emotions Ontology*. The ontology differentiates the concepts of the "physical world" and the "mental world". By relating these two worlds they achieved a model for describing emotions and their detection and expression in systems that work with contextual and multimodal elements. To complete their specification they used DOLCE because it defined concepts as *event*, *process*, or *action*, used to contextualize other concepts in the *Emotions Ontology*; and FrameNet [139] because it is better suited for modeling context as situations. Although this work resembles our research, they did not deal with concepts as goals, likings of the character or relation with other agents.

Nakasone et al. [112] presented a generic storytelling ontology model, the *Concept Ontology*. Their idea was to define a set of topics in which the story, or part of the story, is based, and to link them through a pseudo-temporal relation that ensures a smooth transition between them. As this ontology was for storytelling, the classes defined were related to scenes, acts, relations, agents participating in the story and their roles. Its main advantage is that it provided the elements for creating a story according to narrative principles.

Figa et al. [56] used ontologies and other components to develop an architecture for Virtual Interactive Storytelling Agents (VISTAs) capable of interacting with the user through natural language. First, they generated AIML scripts from live audio, video recordings of storytellers, or from online chats, which were analyzed using the WordNet lexical database [55] enhanced with Prolog inference rules. Then, they used ontologies to select a story's subset expressing the focus of interest of the user. These agents were oriented to online teaching and shared virtual environments to support learning.

Swartjes et al. [142] implemented a multi-agent framework that generated stories based on emergent narrative. Story generation was performed in two phases: simulation and presentation. During simulation, the one that concern us the most, they used an ontology to define the *settings* of the story world. They used the example of a pirates world, where the ontology defined concepts as Sword or Pirate, and relations as “hate” or “owns”.

Ontologies can also be used for the representation of the emotional output generated by context. For instance, Obrenovic et al. [116] provided flexible definitions of emotional cues at different levels of abstraction. Their *Emotional Cues Ontology* provided a language to share and reuse information about emotions. The concepts handled by this ontology were emotions, emotional cues (i.e. facial expressions, gestures, speech and voice), and media (where the emotional cues are represented). Their main objective was to generate or recognize emotional cues according to the media and the emotion felt. They did not focus on the process of simulation of the environment that elicits the affective information.

Heckmann et al. [71] introduced the general user model ontology GUMO as part of a framework for *ubiquitous user modeling*. What is interesting about this work is the modeling of Basic User Dimensions as: personality, characteristics, emotional state, physiological state, mental State and facial Expression. The principal use of this data is in assessing the actual state of the user. Regarding facial expressions, if a user shows some expression, they represented this information in their *UserJournal* without interpreting the current emotional state of the user. This work is very similar to our work but from the Ubiquitous Computing field. Nevertheless, their inference process is related to what will occur in the environment (ambient intelligence) and not to what will be the affective state of the user.

Chang et al. [25] presented a three-layered framework for scenario construction, formed by: a mind model, a concept model and a reality model. The concept model provided characters with ontology-based environmental information, so they can use ontological inference to associate objects in the world with their goals and build plans according to the world where they are. Nonetheless, the concept layer did not take into consideration affective elements, which were in the mind layer.

Benta et al. [18] proposed an application that combined affect, context, ontologies and ubiquitous computing. They presented an ontology-based representation of affective states for context aware applications. Using the Activation-Evaluation space proposed by Cowie et al. [32], they extended the ontology SOCAM (CONON) [149] so it can define different *States*: Affective, Mental and Physiological. CONON is an ontology for modeling context in pervasive computing environments.

Gutiérrez et al. [70] developed an ontology to provide a semantic layer for concepts related to: human body modeling and analysis, animation of virtual humans, and interaction of virtual humans with virtual objects. This ontology was more focused on defining a character from a physical and behavioral point of view, which can be of great help when deciding which actions to take depending on the context that surrounds the character.

Our intention with this overview of previous works was to show how context has been represented before, and how ontologies have also been used to represent behavior in virtual characters. Nevertheless, we found that former research lacks of a structured definition of the psychological characteristics that build a virtual character from an internal point of view. Moreover, we think it is necessary to describe the process between situations produced in certain context and the elicitation of emotions based on a belief-desire-intention perspective. This process of event appraisal carried on by the character is what we have intended to define using ontologies.

5.2 Semantic Model

In order to describe an agent's environment we propose a semantic framework based on ontologies, as seen in Figure 5.1. The motivation behind it is the potential that ontologies offer to represent knowledge in certain domain, and infer new knowledge from the already existing one.

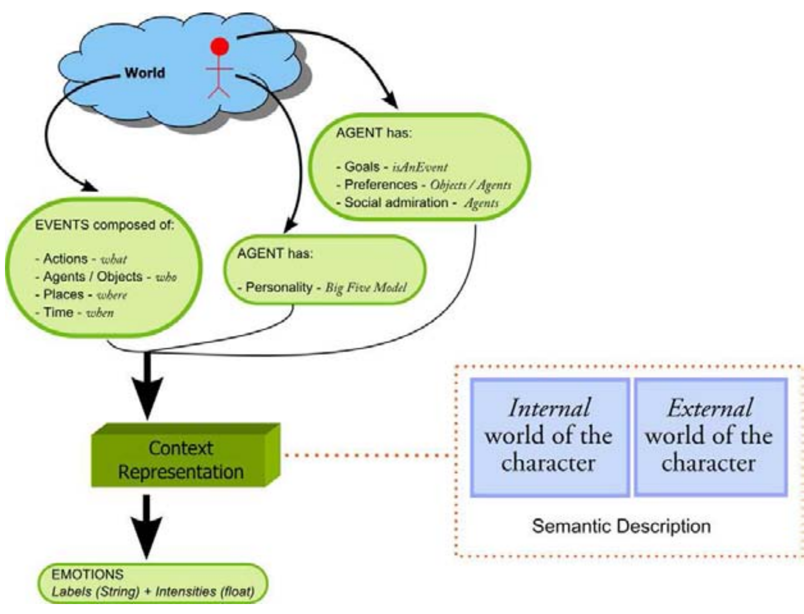


Figure 5.1: Context Representation Schema

The development of ontologies usually starts by defining its domain and scope. It means that given a motivating scenario, we should be able to answer certain questions related to it. These questions are known as competency questions (CQs). Informal CQs are queries which require the objects or constraints defined with the object. Fomal CQs are defined as an entailment or consistency problem with respect to the axioms in the ontology [69]. We have focused only on informal CQs to evaluate the expressiveness of our ontologies: Outer World CQs and Inner World CQs.

The Outer World Competency Questions are:

1. In a certain situation (e.g. a fragment of a story, an episode of daily life), which are the occurring events?
2. How is an event described? Which properties does it have? Which is the main action that gives meaning to that event?
3. What is affected by the action?
4. Where is the event happening? Can it happen in more than one location?
5. When is the event happening? How can we describe the duration of events? How can we simulate the duration of an event?
6. Can events be organized temporarily (event 1 occurs first, then event 2, and so on)? Can they be organized automatically, so they produce some temporal lineal story?
7. Who is performing the event? Or who is affected by the event? Are there other agents involved? How are they related?

The Inner World Competency Questions are:

1. Which are the goals of an agent? What are the consequences of achieving a goal?
2. What does the agent like and dislike? Can they be physical objects or intangible things?
3. How does the agent feel about other agents?
4. Which emotions can the agent feel? How are they elicited?
5. What is the personality of the agent? How does it influence its emotional state?

From the former analysis we decided to design and implement two different ontologies, represented in Figure 5.2. The ***personalityEmotion Ontology*** considers all the concepts that define a character (or agent) from a psychological-affective point of view - goals, preferences, social admiration with other agents, and personality (inner world). The ***event Ontology*** describes the environment that surrounds the character (outer world) based on the events occurring in it. The following sections describe both ontologies in detail

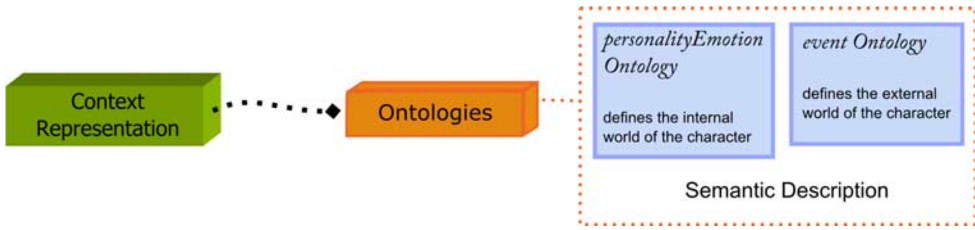


Figure 5.2: Semantic Model for Context Representation with Ontologies

5.3 *Event* ontology

According to Ortony et al. [120], events are the constructions people make about things that happen, independently of any beliefs about their causes. As mentioned in Section 4, an Event is defined based on four questions (*what*, *where*, *who*, and *when*), which are represented by the classes Action, SpatialLocation, AgentRole and TemporalEntity (Fig. 5.3). Then, each class has its corresponding subclasses, as will be seen in the following.

5.3.1 Action - (Fig. 5.3: A)

An *Action* is represented with a verb. So, as in grammar a verb has complements (direct or indirect objects) that give a meaning or complete the sentence, an Action has complements represented by the classes *AbstractEntity* and *PhysicalEntity*.

AbstractEntity includes all intangible concepts as ideas, thoughts, dreams, or standards (the notion of how to be socially correct).

PhysicalEntity defines all things that we can see and touch through the subclasses *SpatialLocation*, *MaterialThing* and *Agent*. A PhysicalEntity has a *Dimension* formed by the subclasses: *Width*, *Height*, and/or *Depth*. For instance, a building can be very wide and tall, a pool can be 3 meters deep, or a floor-lamp can have a height of 1.2 meters.

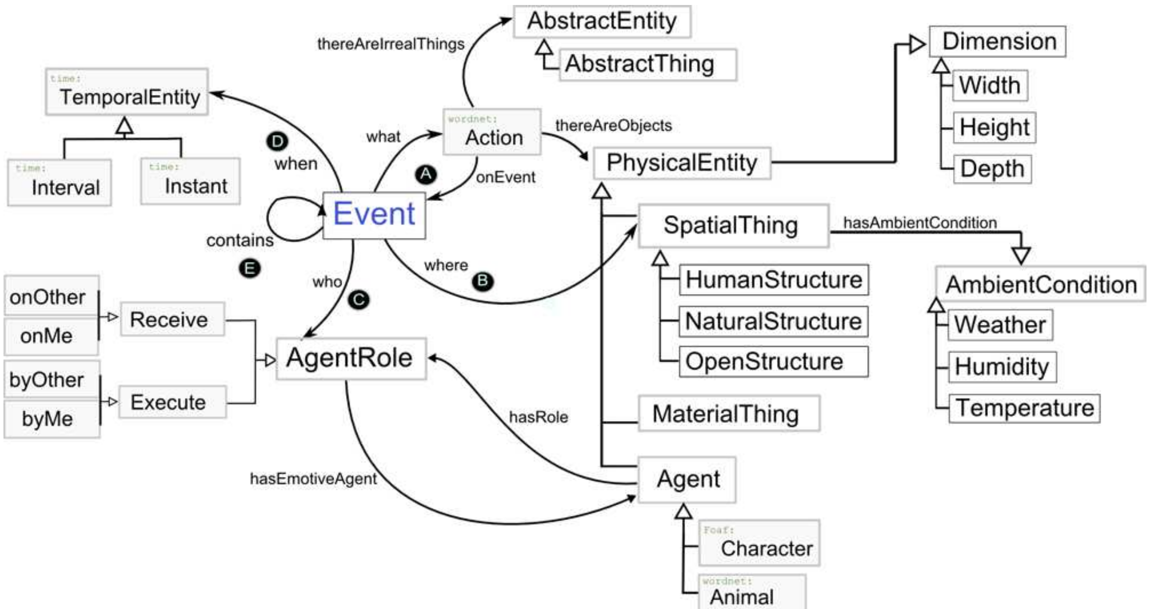


Figure 5.3: Event Ontology Diagram

The relation that links the concepts *Event* and *Action* are ***what*** and ***onEvent***. The latter specifies that an action occurs in certain event, making the relation between these concepts cyclic. For instance, the action “Eat” can be linked to physical entity “Bread”, and it is part of certain event. Therefore, the description logic (DL) representation is

$$\begin{aligned} Eat := \; & Action \\ & \wedge(\exists thereAreIrrealThings(Eat, -) \vee \exists thereAreObjects(Eat, Bread)) \\ & \wedge \exists what(Event1, Eat) \end{aligned}$$

5.3.2 SpatialThing - (Fig. 5.3:B)

SpatialThing defines where the event occurs. Its subclasses are: *HumanStructure* (e.g., buildings), *NaturalStructure* (e.g., beach) and *OpenStructure* (e.g., street).

This concept has a characteristic represented by the class *AmbientCondition*. Its subclasses *Temperature* and *Humidity* describe how cold or hot, and how wet or dry, a place is. From these two elements *Weather* can be inferred, thus defined as the state of the atmosphere with respect to temperature, and wetness or dryness.

The relation that relates the event with its location is named ***where***. For example, an event that occurs in a "Farm" in "sunny day" can be described as

$$\begin{aligned} Farm := \; & HumanStructure \\ & \wedge \exists hasSuperClass(Farm, SpatialThing) \\ & \wedge \exists hasTemperature(Farm, 25) \\ & \wedge \exists hasWeather(Farm, Sunny) \end{aligned}$$

5.3.3 AgentRole - (Fig. 5.3:C)

An agent, represented by the class *Agent*, is the person or animal around which the event happens. Therefore, it extends the subclasses *Character* and *Animal* to differentiate between human-like agents and animal-like agents.

To know exactly the role of the agent in an event, we have created the class *AgentRole* with its subclasses: *Execute* and *Receive*. The subclass *Execute* instances those agents that perform the action of the event (executers), while *Receive* instances the agents affected by that action (receivers).

However, to specify even more the **role** we extended these two classes to represent the participation of the different agents in the event. Thus, *Execute* presents the subclasses *ByMe* and *ByOther*, and *Receive* extends the subclasses *OnMe* and *OnOther*.

- The role *ByMe* is taken by the agent who analyses the event and at the same time executes the action.
- The role *ByOther* is taken by that agent who executes the action, but is not the one who analyses the event.
- The role *OnMe* is taken by the agent who analyses the event and at the same time receives the effects of the action.
- The role *OnOther* is taken by the agent that receives the action of the event, but this agent is not the one who analyses the event.

Let us take the situation *"**Rose** buys flowers for **Charlie**"*. If **Charlie** is the one who evaluates the event, the **Rose** has the role "ByOther" because she is executing the action "buy". But if Rose evaluates the event, her role would be "ByMe" and **Charlie**'s role would be "OnOther" because he is the passive subject.

The relation that relates the event with the agent, and specifically, with its role is ***who***. For example, using the previous event we can describe it as

$$\begin{aligned} Charlie := \; & Character \\ & \wedge \exists hasSuperClass(Charlie, Agent) \\ & \wedge \exists hasRole(Charlie, Charlie\_OnMe) \\ & \wedge \exists hasSuperClass(Charlie\_OnMe, Receive) \end{aligned}$$

5.3.4 Temporal Entity - (Fig. 5.3:D)

The *TemporalEntity* class specifies the time of occurrence of the event through the relationship ***when***. It has two subclasses: *Instant* and *Interval*. The first one defines the specific point in time when the event occurs; the second one defines the period of time when the event occurs. For instance, if *"Rose buys flowers for Charlie in the morning"*, we can specify morning as a period of time from 06:00 until 12:00, then

$$\begin{aligned} morning := \; & Interval \\ & \wedge \exists hasSuperClass(morning, TemporalEntity) \\ & \wedge \exists hasBeginning(morning, time0600) \\ & \wedge \exists hasEnd(morning, time1200) \end{aligned}$$

5.3.5 Contained Events - (Fig. 5.3:E)

Another important aspect that needs to be considered is when an event describes the occurrence of another event. These are called "Contained Events" and are represented by the recursive relation ***contains***. An example of this kind of relation can be seen in the event: *"Rose sees Charlie stealing an expensive car"*. In this case, the main event would be "Rose sees *something*". But that *something* is another event: "Charlie steals an expensive car". Therefore, two events should be evaluated: from Rose's perspective and from Charlie's perspective.

The level of recursion for contained events can be extensive. Nevertheless, we are working with only two levels of recursion.

5.4 *PersonalityEmotion* ontology

How someone feels is the result of a process of context appraisal, which is performed using information like one's goals, preferences, degree of admiration for others, and personality traits.

To implement these concepts, explained in Section 4, we designed the *PersonalityEmotion Ontology*, presented in Figure 5.4. It is worth noting that from now on we use the term **Character** instead of **Agent** because we are considering the domain from a human perspective. But as a **Character** is an **Agent**, then both terms can also be used indistinguishable. The following subsections explain the diagram according to the main classes pointed out by letters.

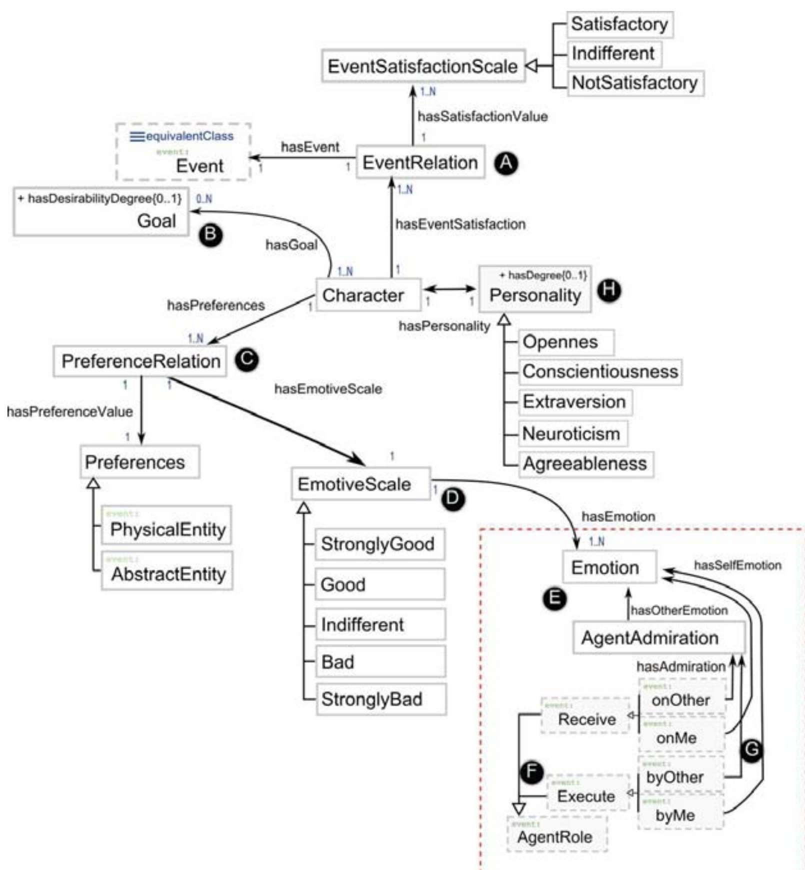


Figure 5.4: Personality-Emotion Ontology Diagram

5.4.1 EventRelation - (Fig. 5.4:A)

The class *EventRelation* defines the relation established between an *Event*, a *Character* and the level of "satisfaction" produced in that character specified by the class *EventSatisfactionScale*. The subclasses of *EventSatisfactionScale* are: SATISFACTORY (S), INDIFFERENT (IA), and NOT SATISFACTORY (NS), and each one has instances which values range in a *degree* $\in (0, 1)$.

For instance, in the event: *event*001:"Rose goes to the movies every Saturday", we can deduce that the character Rose enjoys going to watch films every week, and we can describe it as

$$
\begin{aligned}
event001\_rel := \; & \mathit{EventRelation} \\
& \wedge \exists hasEvent(event001\_rel, event001) \\
& \wedge \exists hasEventSatisfaction(Rose, event001\_rel) \\
& \wedge \exists hasSatisfactionValue(event001\_rel, event001\_s)
\end{aligned}
$$

5.4.2 Goals - (Fig. 5.4:B)

The *Goals* of a character are events with certain *desirability degree*. This degree indicates how much a character wants that event to happen. If $desirabilitydegree \geq 0.7$, then we consider the event as a goal. The intensity of the emotions elicited due to the occurrence, or achievement of a goal are determined by the *desirability degree*.

5.4.3 PreferenceRelation - (Fig. 5.4:C,D)

Preferences are set for physical or abstract entities. The class *PreferenceRelation* defines the relation established between a *Character*, its *Preferences* and the emotional attachment to them, expressed by the class *EmotiveScale* (Fig. 5.4:**D**).

The class *Preferences* groups all the instances independently of the character.

The class *EmotiveScale* has the subclasses: STRONGLYGOOD (SG), GOOD (G), INDIFFERENT (IP), BAD (B), and STRONGLYBAD (SB), and each one determines the emotion to be triggered: *Love, Liking, No emotions, Disliking, Hate/Fear*, respectively (Fig. 5.4:**E**). The intensity of each emotion is determined by the degree of each instance of these subclasses, where *degree* $\in (0, 1)$. These emotions are taken from the OCC model set based on attitudes or tastes [27].

PreferenceRelation allows us to model the idea of the OCC model, where **attitudes** of the character **towards aspects of objects** lead to Like them or Dislike them; and when there is **attraction** to those objects, to emotions of Love or Hate. A set of logic rules helps to discern between fear and hate.

For instance, the event $rcomedy001$: "Rose enjoys watching romantic comedies" can be formally described as

$$
\begin{aligned}
rcomedy001\_rel := \quad & PreferenceRelation \\
& \wedge \exists hasPreference(Rose, rcomedy001\_rel) \\
& \wedge \exists hasPreferenceValue(rcomedy001\_rel, romanticcomedy) \\
& \wedge \exists hasEmotiveScale(rcomedy001\_rel, rcomedy001\_sg) \\
& \wedge \exists hasSuperClass(rcomedy001\_sg, StronglyGood) \\
& \wedge \exists hasEmotion(rcomedy001\_sg, Love)
\end{aligned}
$$

5.4.4 AgentAdmiration - (Fig. 5.4:F,G)

The class *AgentAdmiration* (Fig. 5.4:**F,G**) defines the admiration of one agent for another, based on their roles (specified by the class *AgentRole*). It also decides the set of produced emotions. For example, receive good news from a best friend awakes more positive emotions than receiving them from someone one really dislikes.

AgentAdmiration has three subclasses that categorized the admiration: POSITIVE (P), INDIFFERENT (IAg) or NEGATIVE (N), again with $degree \in (0, 1)$.

The roles that are related to AgentAdmiration are "onOther" and "byOther" because they depend on the appreciation of the main agent to generate the emotions corresponding to the occurred event.

5.5 Emotion Elicitation

The OCC model provides a framework to elicit emotions according to three kinds of value structures underlying perceptions of goodness and badness: goals, standards and attitudes.

Goals represent desirable events that can be achieved, or not, by the character.

Attitudes provides the basis for evaluating objects, which give rise to emotions of *Love, Liking, No emotions, Disliking, Hate/Fear*, according to the Preference values.

Standards are considered in terms of how praiseworthy (or blameworthy) an agent is in relation to the main agent evaluating certain event.

Therefore, to generate emotions according to standards, three main aspects should be taken into account: (a) what is the role of the agent to be evaluated (*AgentRole*), (b) which is the level of satisfaction of the event (*EventSatisfactionScale*), and (c) which is the admiration degree of the main agent of the event for the other agents (*AgentAdmiration*).

Emotions are represented as instances (individuals) of the class *Emotion*, and its attributes are used to determine which ones will be elicited. These attributes are:

- Type of emotion: Positive (**P**) and Negative (**N**)

- Type of admiration: Positive (+) and Negative (**-**)

Figure 5.5 is an expansion of the red-dotted segment of Figure 5.4:**F,G**. It shows the implementation of the different roles as individuals and how they are related with *Emotion*'s and *AgentAdmiration*'s individuals. An "individual" is an instance of an ontology class.

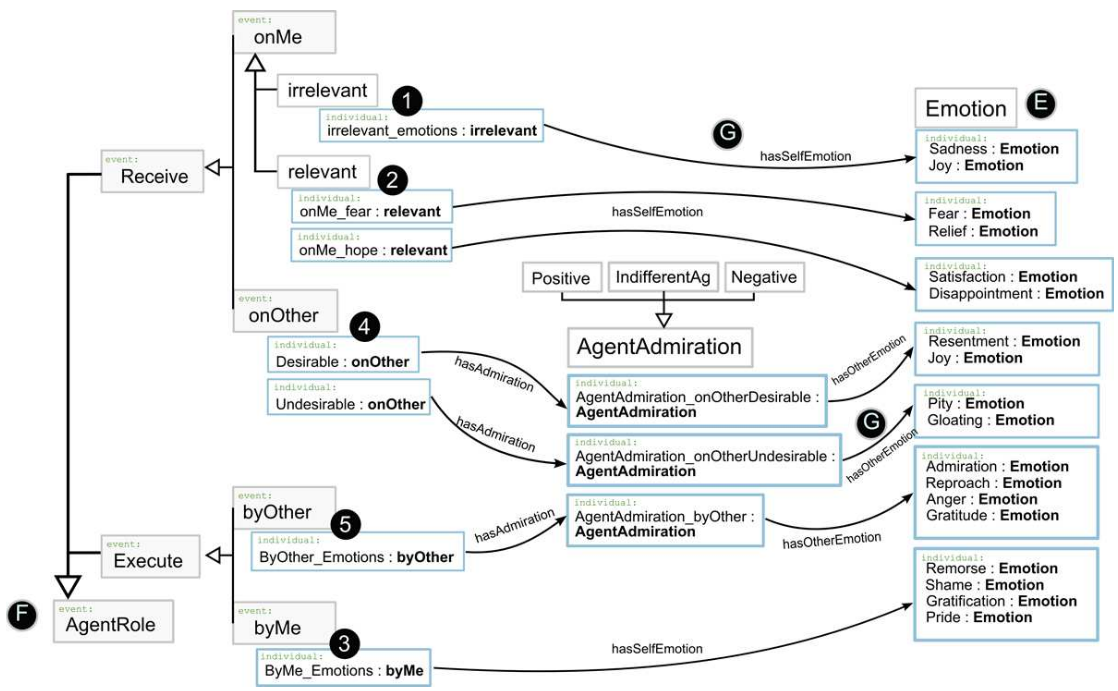


Figure 5.5: Agent Admiration at AgentRole level

onMe - (Fig. 5.5: ❶, ❷)

The subclass *onMe* indicates that the agent receives the effects of the event. According to the OCC theory, the effects or consequences for the self can be relevant or irrelevant. If irrelevant, elicited emotions are *Joy* or *Sadness*.

If consequences are relevant, then there are two individuals related to *Hope* or *Fear*. So, to know which emotions to elicit, we need to follow these rules:

- If the event is "hoped" and it occurs (meaning it is confirmed), the emotion *Satisfaction* arises; but if it is disconfirmed, the emotion *Disappointment* arises.

- If the event is "feared" and confirmed, the emotion *Fear-Confirmed* is elicited; but if it is disconfirmed, the emotion *Relief* is elicited.

We have represented these consequences as the subclasses *irrelevant* and *relevant*. *irrelevant* has the individual irrelevant_emotions (Fig. 5.5: ❶), which is linked to the individuals Sadness and Joy through the relation *hasSelfEmotion* (Fig. 5.5: **G,E**). **relevant** has two instances or individuals: onMe_fear and onMe_hope. The first one relates the agent with role onMe with the emotions Fear and Relief through the relation *hasSelfEmotion* (Fig. 5.5: ❷,**G,E**). The second one relates the agent affected by the hoped event to Satisfaction and Disappointment through the same relation *hasSelfEmotion*.

For example, in the case Rose has the role Rose_OnMe, first we need to see if the event in which she participates is relevant or irrelevant for her. If the event is a *Goal*, then it is relevant, otherwise, it is irrelevant.

1. If relevant, then Rose_OnMe should be equivalent to one of the individuals of the class *relevant* according to the following cases:

    - If the goal is "hoped", then Rose_OnMe is associated with the individual onMe_hope, and thus associated with Satisfaction and Disappointment.
    - If the goal is goal is "feared", which means that the sentence describing the goal has an opposite semantic meaning to the goal (e.g. a goal would be "winning the lottery", but the event is "Not winning the lottery"), then Rose_OnMe is associated with the individual onMe_fear, and thus associated with Fear and Relief.

    The next step is to discern which emotion will be elicited. Then, we take a look at the satisfaction level of the goal-event.

- If Rose_OnMe is associated with onMe_hope and the event is *Satisfactory*, the elicited emotion is Satisfaction; if the event is *NotSatisfactory*, the elicited emotion is Disappointment.
- If Rose_OnMe is associated with onMe_fear and the event is *Satisfactory*, the elicited emotion is Relief; if the event is *NotSatisfactory*, then Fear is elicited.

2. If irrelevant, then Rose_OnMe is equivalent to the individual irrelevant_emotions. Thus, we look at the level of satisfaction of the event. If the event is *Satisfactory*, Joy is elicited. If the event is *NotSatisfactory*, the elicited emotion is Sadness.

byMe - (Fig. 5.5: ❸)

According to the OCC theory, the action of the agent focused on the self can produce *Pride* or *Shame*; and depending on the consequences of the event, produces *Gratification* or *Remorse*. In our model, this is translated as:

- If the event is *Satisfactory*, elicited emotions are positive: *Pride* and *Gratification*
- If the event is *NotSatisfactory*, elicited emotions are negative: *Shame* and *Remorse*.

The subclass *byMe* represents the agents that perform the action of the event, and the individuals are also related to *Emotion* through the relation *hasSelfEmotion* (Fig. 5.5: ❸). Therefore, the individual ByMe_Emotions is linked with the individuals Remorse, Shame, Gratification and Pride.

For instance, if the individual Rose is the one performing an event, her role Rose_ByMe will be equivalent to the individual ByMe_Emotions. Then, we need to see if the event in which she participates is *Satisfactory* or *NotSatisfactory*, and the elicited emotions will be the ones corresponding to the individuals previously enumerated.

onOther - (Fig. 5.5: ❹, ❺)

The OCC theory proposes the set of emotions that should be elicited regarding the consequences or effects that an event has on other agents. If the event is **desirable** for others, elicited emotions are *Happy-for* or *Resentment*, and if the event is **undesirable** for others, elicited emotions are *Gloating* or *Pity*.

As mentioned in Subsection 5.4.4, emotions elicited due to individuals belonging to the class *onOther* depend on the degree of *AgentAdmiration* for those individuals. The individuals of the class *onOther* are: Desirable and Undesirable.

Desirable is linked with the individual AgentAdmiration_onOtherDesirable of the class **AgentAdmiration** through the relation *hasAdmiration*. In turn, AgentAdmiration_onOtherDesirable is linked with the individuals Resentment and Joy through the relation *hasOtherEmotion*. (Fig. 5.5: ❹, **G**).

Undesirable is linked with the individual AgentAdmiration_onOtherUndesirable through the relation *hasAdmiration*. In turn, AgentAdmiration_onOtherUndesirable is linked with the individuals Pity and Gloating through the relation *hasOtherEmotion* (Fig. 5.5: ❹, **G**).

Let us take as example Rose's role Rose_onOther:

- Rose_onOther is equivalent to Desirable if the consequence of the event is desirable for her, which means that the event is *Satisfactory*. To discern between elicited emotions, we consider the AgentAdmiration degree:

  1. If the main agent has a **Positive** admiration for Rose, the elicited emotion in the main agent is positive, Joy
  2. If the main agent has a **Negative** admiration for Rose, the elicited emotion in the main agent is negative, Resentment

- Rose_onOther is equivalent to Undesirable if the consequence of the event is undesirable for her, which means that the event is *NotSatisfactory*. To discern between elicited emotions, we consider the AgentAdmiration degree

  1. If the main agent has a **Positive** admiration for Rose, the elicited emotion in the main agent is negative: Pity (the main agent feels sorry for the non-satisfactory event on Rose)
  2. If the main agent has a **Negative** admiration for Rose, the elicited emotion in the main agent is positive: Gloating

byOther - (Fig. 5.5: ❺)

The OCC theory that states that the action of other agent can produce *Admiration* or *Reproach*, and depending on the consequences of the event, it can produce *Gratitude* or *Anger* towards that other agent.

In our model, the individual ByOther_Emotions of the class *byOther* is linked to the individual AgentAdmiration_byOther of the class *AgentAdmiration* through the relation *hasAdmiration*. In turn AgentAdmiration_byOther is linked with the individuals Admiration, Reproach, Anger and Gratitude (Fig. 5.5: ❺, **G**).

Taking as example Rose's role Rose_byOther, which is equivalent to AgentAdmiration_byOther:

- If the event is *Satisfactory* and the main agent has a **Positive** admiration for Rose, the elicited emotion is Admiration
- If the event is *Satisfactory* and the main agent has a **Negative** admiration for Rose, the elicited emotion is Gratitude
- If the event is *NotSatisfactory* and the main agent has a **Positive** admiration for Rose, the elicited emotion is Reproach
- If the event is *NotSatisfactory* and the main agent has a **Negative** admiration for Rose, the elicited emotion is Anger

Figure 5.6 shows a diagram with all the elicited emotions according to the type of event (Positive (P) or Negative (N)) and the type of agent admiration (Positive (+) or Negative (-)), which summarizes what was explained above.

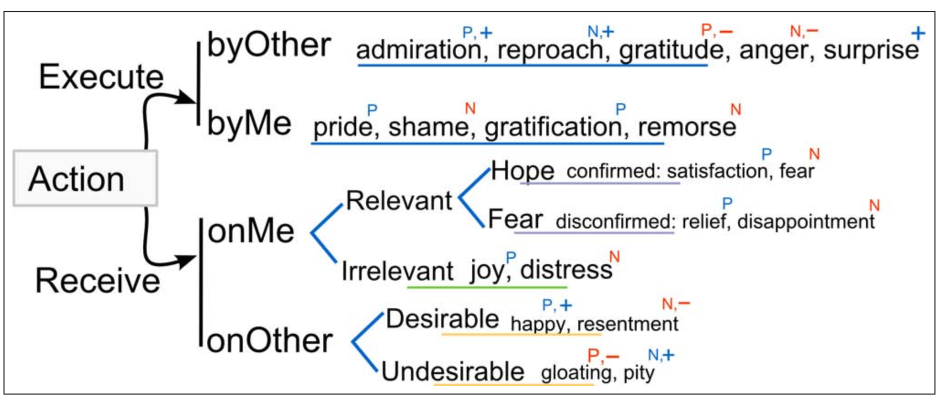


Figure 5.6: Categorization of Emotions.

5.6 Guideline to use the ontologies

As seen in the previous sections, the *Event* ontology provides all the elements to represent an event, while the *PersonalityEmotion* ontology provides the relations between the event and the character, as well as all elements related to the character's internal aspects (goals, preferences, admiration for other agents, personality) used in event appraisal.

The following is a guideline for representing a situation in certain scenario:

1. **Situation Identification.** First of all we need to describe what the characters will go through as if it were a story. In this way we can start identifying all the elements of the ontologies. For example,

   "*Rose started her day at 6 a.m. this morning. While she was having breakfast, she heard about train strike in the radio. This was very inconvenient, because she had an early appointment with Charlie at the office and with the strike she won't get there*".

2. **Event Identification.** From the whole situation to be represented, we extract each relevant event that provokes a change in the character or in the environment, so we can define the elements of the *Event* Ontology (Fig. 5.3).

   Each event is seen as a predicate that includes a subject (agent), verb (action) and predicate (ambient conditions, physical and abstract things - objects, other agents, location). Therefore, once we define the instances of each class in the ontology, we assign a level of *Satisfaction* to each event regarding the agent that appraises it.

   For instance, from the situation "*Rose started her day at 6 a.m. this morning*", we can get the *Event* instance:

   $event001 :=$ Rose wakes up at 6 a.m.

   If it is difficult for Rose to wake up early, then the instance of *EventSatisfactionScale* is

   $$\begin{aligned} event001\_satScale := \;& \text{NotSatisfactory} \\ & \wedge \exists satisfactionDegree(event001\_satScale, 0.4) \end{aligned}$$

3. **Character Preferences and Goals definition.** Once all elements that form the event are identified, we assign values to them using the *PersonalityEvent* Ontology (Fig. 5.4:**B,C**). The steps to follow are:

(a) Define the instances of *PreferenceRelation* using the PhysicalEntities and AbstractEntities identified in step 2, and assigning the corresponding *EmotiveScale*s. For example:

$$
\begin{array}{ll}
breakfast := & \text{Preferences} \\
breakfast001\_sg := & \text{StronglyGood} \\
breakfast001\_rel := & PreferenceRelation \\
 & \wedge \exists hasPreferences(Rose, breakfast001\_rel) \\
 & \wedge \exists hasPreferenceValue(breakfast001\_rel, breakfast) \\
 & \wedge \exists hasEmotiveScale(breakfast001\_rel, breakfast001\_sg)
\end{array}
$$

(b) Define the instances of *Goal* by assigning a *Desirability degree* to each potential event-goal. For example, Rose has the goal:

$event002 :=$ Rose get early to work

but according to the defined situation, we find the following event:

$event003 :=$ Rose is not going to get early to work

As can be seen, the $event003$ has an opposite semantic meaning to her goal ($event002$). Therefore, $desirabilityDegree(event003) = 0.2$.

4. **Agent Admiration for other agents.** To define the admiration that the main character (the one from whose point of view the event is evaluated) feels for other agents, we need to define the instances of *AgentAdmiration* in the story. In the former example the other agent is Charlie, so the event can be defined as:

$event004 :=$ Rose attends to an appointment with Charlie

First of all, we need to define the roles of Rose and Charlie to proceed with the identification of the corresponding instances. As this event might be ambiguous, we have two options:

(1) Rose's role is Rose_byMe and Charlies's role is Charlie_onOther

(2) Rose's role is Rose_onMe and Charlies's role is Charlie_byOther

In case **(1)**, we would need to define the event as desirable or undesirable for Charlie. As this event is neither one nor the other for Charlie, then we try with case **(2)**. Thus, following Fig. 5.5: ❺:

(a) Associate Charlie_byOther with the instance ByOther_Emotions.

(b) Link ByOther_Emotions with the instance AgentAdmiration_byOther

(c) Define an instance of *AgentAdmiration* that can be used to discriminate among the set of emotions associated to AgentAdmiration_byOther. In this case, Rose has Negative admiration for Charlie; therefore we define

$$\begin{aligned} negative001\_aa := \; & \text{Negative} \\ & \wedge \exists hasSuperClass(negative001\_aa, AgentAdmiration) \\ & \wedge \exists hasAdmiration(Charlie\_byOther, negative001\_aa) \\ & \wedge \exists admirationDegree(negative001\_aa, 0.9) \end{aligned}$$

5. **Personality definition.** Using the FFM the personality traits for each character are set. For instance, we can define Rose's personality as:

$$\begin{aligned} extraversion\_rose := \; & \text{Personality} \\ & \wedge \exists personalityDegree(extraversion\_rose, 0.2) \\ agreeableness\_rose := \; & \text{Personality} \\ & \wedge \exists personalityDegree(agreeableness\_rose, 0.3) \\ conscientiousness\_rose := \; & \text{Personality} \\ & \wedge \exists personalityDegree(conscientiousness\_rose, 0.9) \\ openness\_rose := \; & \text{Personality} \\ & \wedge \exists personalityDegree(openness\_rose, 0.1) \\ neuroticism\_rose := \; & \text{Personality} \\ & \wedge \exists personalityDegree(neuroticism\_rose, 0.95) \end{aligned}$$

6. **Direct Emotion elicitation.** As a result of these two ontologies, a set of positive and negative emotions is produced. The intensities of these emotions depend on the preferences and admiration level for other agents (Figure 5.6).

   For instance, the preference $breakfast001\_sg := StronglyGood$ elicits the emotion Love.

   On the other hand, the instance AgentAdmiration_byOther is linked to the emotions Admiration, Reproach, Anger and Gratitude. Also, the instance of AgentAdmiration that relates both agents, Rose and Charlie, is $negative001\_aa$, and the event is Not-Satisfactory, then following the previous rules, the elicited emotion is Anger.

7. **Rules definition.** By defining a set of rules it is possible to handle specific events and personalities to elicit different emotions in similar situations. Rules are of the form *IF THEN ELSE*. For example, a rule for the event "*Rose wakes up very early*" might be:

$IF Action =$ wake up $\wedge Temporal Entity =$ very-early
$THEN Emotion =$ Hate

Appendix A shows a list of the rules implemented in this thesis.

8. **Contained Events (Optional)**. In case there are contained events (given by the relationship ***contains***), the appraisal is done in the main event following the steps described above, but taking into consideration the next issues:

   (a) The *EventSatisfactionScale* is defined in relation to the **contained** event, and from the main character's point of view (the leading agent in the main event).

   (b) The *AgentAdmiration* is defined in relation to the agents in the **contained** event. It means, how the main character feels about the agents in the contained event.

   (c) Preferences are not evaluated in the **contained** event.

   (d) Personality is defined for all agents.

   (e) Emotions are elicited according to Step 6

   (f) Rules are created for refinement of emotions according to Step 7

5.7 Implementation

To implement the proposed Semantic Model, we divided the tasks in two main parts:

1. Implementation of the ontologies: using Protégé version 4.0

2. Implementation of the interface: using JDK 1.6.0_12 and JENA libraries for ontology support.

5.7.1 Ontology implementation

In order to implement our ontologies, we needed to consider various aspects like the language to use, how to create inference rules, or which other ontologies could be useful to complete the knowledge we wanted to represent.

The answers to these issues are explained in detail in the following subsections.

OWL (Ontology Web Language)

The W3C's Web Ontology Language (OWL) [68] is considered by many as the prospective standard for creating ontologies on the Semantic Web.

OWL features two core elements: classes and properties. A **class** represents a set of individuals, all of which also belongs to any superclass of the class. A **property** specifies the relation between an instance of the domain class to an instance of the target class [25]. Besides that, OWL provides individuals and data values that are stored as Semantic Web documents.

OWL was designed to be used by applications that need to process the content of information instead of just showing it to the user. OWL provides a better machine interpretability of Web content than that offered by XML, RDF, and RDF Schema (RDF-S) because it provides the formal semantics plus additional vocabulary [100].

To model the ontologies, we use OWL because it is the standard language and because of its rich expressiveness and solid foundation for concept modeling and knowledge-based inference. The ontologies editor we have worked with is Protégé version 4.0, a free and open source ontology editor and knowledge-base framework [57]. Figures 5.7, 5.8, 5.9, 5.10, 5.11 and 5.12 show the ontology diagrams for the different concepts of the ontologies defined using OWL and Protégé.

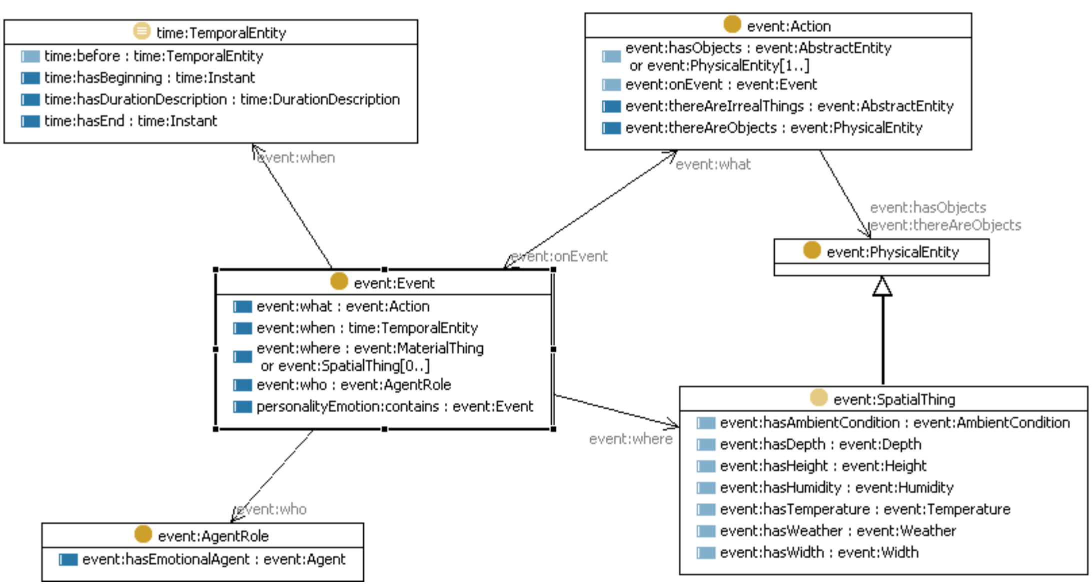


Figure 5.7: Event defined in OWL

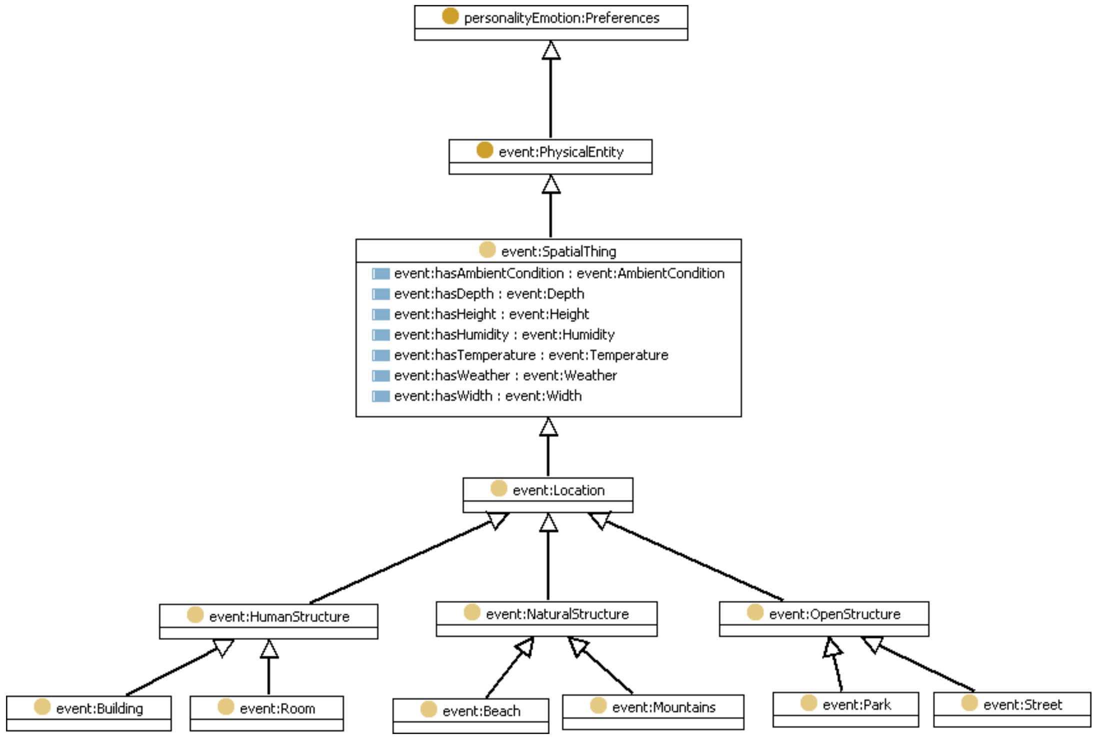


Figure 5.8: Spatial Thing concept defined in OWL

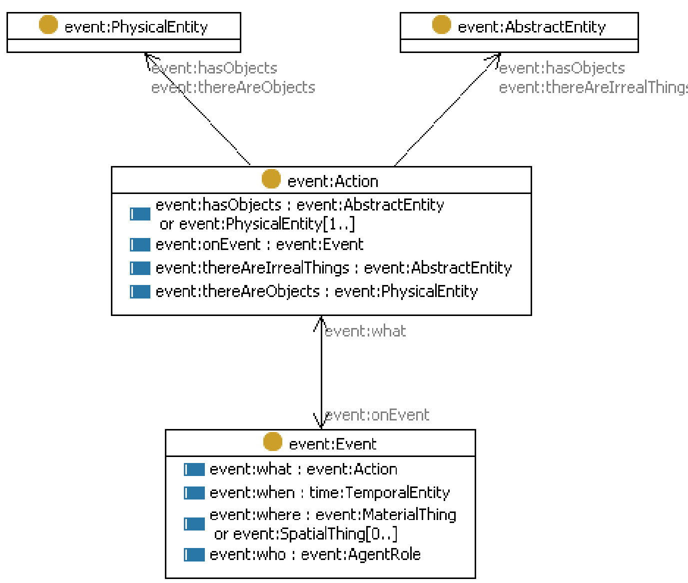


Figure 5.9: Action defined in OWL

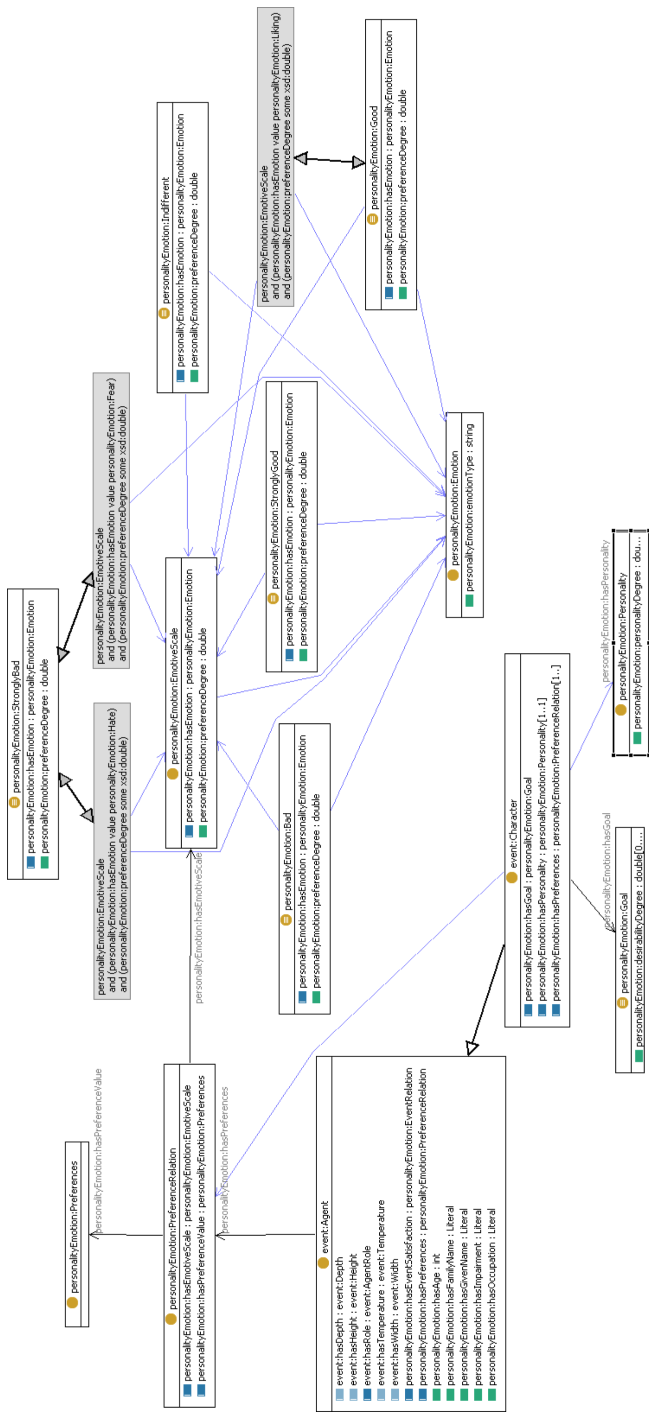


Figure 5.10: Agent Preferences and Goals defined in OWL

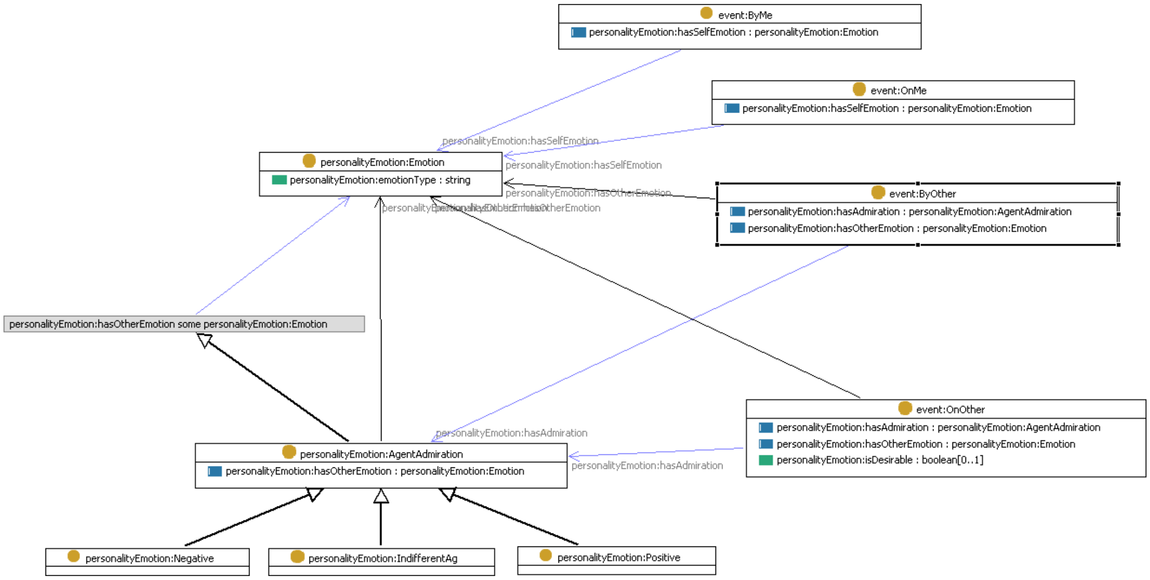


Figure 5.11: Agent Admiration defined in OWL

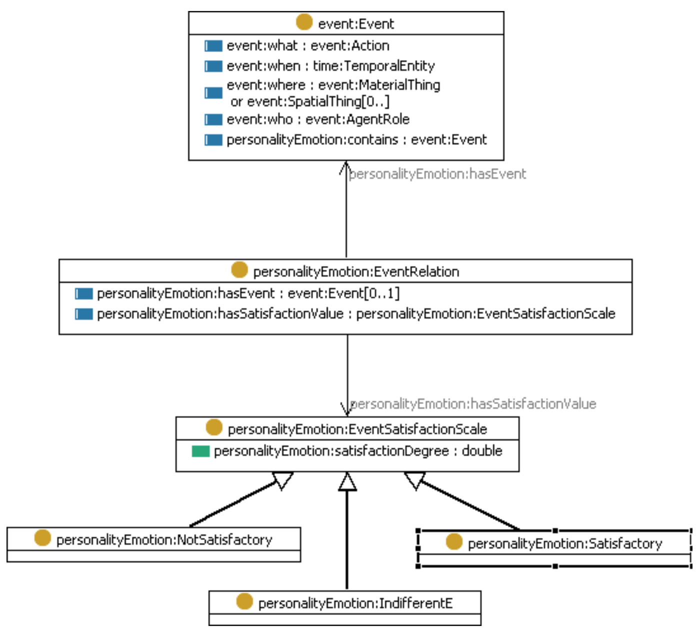


Figure 5.12: Event Relation defined in OWL

External Ontologies

Many times the ontologies proposed for certain domain are not enough, and one can found other ontologies already defined by other researchers that help to describe all the required knowledge.

In our case, we have used the WordNet [107] library for ontology Java processing, named **RiTa.WordNet** [75]. It defines the **verbs** as instances of the class *Action*, **nouns** as instances of the class *Preferences*, and **adverbs** to give semantic meaning to the instances of *Event*.

RiTa.WordNet is the API that provides simple access to the WordNet ontology. It is an easy-to-use natural language library that provides simple tools for experimenting with generative literature.

The other external ontology we have used is the **OWL-Time** ontology, which is an ontology of temporal concepts. It provides a vocabulary for expressing facts about topological relations among instants and intervals, together with information about durations, and about *datetime* information [73].

We have used the OWL-Time ontology to specify the instances of *TemporalEntity*, defined in our *Event* Ontology. Thus, we could represent the temporal characteristics of an event: when it started, how long it lasted (minutes, hours), and so on.

Inference Rules

Inference rules are useful to define particular scenarios, which can be obtained from data previously defined. The following are the scenarios where rules are used:

- In our model, most of the rules allow the elicitation of the emotion, or set of emotions, depending on the level of satisfaction of the event (*EventSatisfactionScale*) and role of the character (*AgentRole*). For instance, if we have an agent with the role *byMe* (e.g. Rose_ByMe), it can be associated to the already defined individual ByMe_emotions, and with the rule, emotions linked to this individual will be triggered.

- Rules are also used when the level of admiration (*AgentAdmiration*) of one agent for another needs to be taken into account. In the same way as with the agent role, an individual of a subclass of *AgentAdmiration* (e.g. negative_aa, which indicates a *Negative* admiration) can be associated through inference rules with a certain agent role (e.g. Rose_ByMe), and therefore, only the corresponding negative emotions will be elicited.

- Finally, rules can be used to enhance the personality traits levels of the character, according to the rules defined by Poznanski and Thagard [126]. They imposed limits on how much personality can change due to the environment. Once this limit is reached, the environment does not change the personality anymore. They considered five types of situations: friendly, hostile, explore, persist and stressful. However, as we have just two relevant types of events, or situations, we will consider the rules just for friendly (SATISFACTORY) and hostile/stressful (NOTSATISFACTORY). Table 5.1 presents the rules proposed by them, and adapted to our work.

Situation	***Effects on personality***
Satisfactory	*more* Extroverted AND *more* Agreeable
(Friendly)	*less* Introverted AND *less* Disagreeable
Not Satisfactory (Hostile/ Stressful)	IF Disagreeable THEN *more* Disagreeable IF Introverted THEN *more* Introverted ELSE randomly *more* Disagreeable OR *more* Introverted ALSO *less* Extroverted AND *less* Agreeable IF Neurotic THEN *more* Neurotic

Table 5.1: Personality change rules

Appendix A shows all the rules defined in Java using Jena libraries, which are triggered at the beginning of the application execution.

5.7.2 Interface implementation

The application prototype we developed allowed us to simulate different situations which were automatically appraised. To achieve this, first we generated Java classes from the ontologies using Jastor, and then we manipulated them through JENA and a Java application interface.

Jastor

Jastor is a open source Java code generator that emits Java Beans from Web Ontologies (OWL), and generates Java interfaces, implementations, factories, and listeners based on the properties and class hierarchies in the Web Ontologies [143].

The advantage of using Jastor is that it converts all the classes defined in the ontologies to their equivalent Java classes, including individuals already defined in Protégé. If one needs to add more individuals, it just requires to modify the .java files. Nevertheless, to rewrite the .owl files, it is necessary to do it through the data stored in a database, which is done using JENA. Figure 5.13 shows an extract of the implementation of the class *ByOther*, which was automatically generated by Jastor.

```java
public java.util.Iterator getHasOtherEmotion() throws JastorException {
    if (hasOtherEmotion == null)
        initHasOtherEmotion();
    return new com.ibm.adtech.jastor.util.CachedPropertyIterator(hasOtherEmotion,_resource,hasOtherEmotionProperty,true);
}

public void addHasOtherEmotion(com.ibm.adtech.jastor.test.personalityEmotion.Emotion hasOtherEmotion) throws JastorException {
    if (this.hasOtherEmotion == null)
        initHasOtherEmotion();
    if (this.hasOtherEmotion.contains(hasOtherEmotion)) {
        this.hasOtherEmotion.remove(hasOtherEmotion);
        this.hasOtherEmotion.add(hasOtherEmotion);
        return;
    }
    this.hasOtherEmotion.add(hasOtherEmotion);
    _model.add(_model.createStatement(_resource,hasOtherEmotionProperty,hasOtherEmotion.resource()));
}
```

Figure 5.13: Implementation of the property *hasOtherEmotion* using Jastor

Once all the classes corresponding to the ontology entities were generated, these were used and modified by the application through functions of the JENA library.

JENA (JAVA libraries)

With Java JDK 1.6.0_12 and JENA library [72] we were able to perform operations on the ontologies, as well as inference that was done using JENA rules. JENA is a Java framework for building Semantic Web applications. It provides a programmatic environment for RDF, RDFS and OWL, SPARQL and includes a rule-based inference engine (JENA rules).

One of the advantages of JENA is that being developed in Java, it is applicable to various environments. In addition, it is open source and strongly backed up by solid documentation. Also, regardless to the schema and the used data models, JENA can simultaneously work with multiple ontologies from different sources, and it can be bound to SQL databases from different vendors.

Another powerful feature of the JENA framework is the inference API. It contains several reasoner types, which efficiently conclude new relations in the knowledge graph. Among the reasoners there are: RDF(S), OWL, Transitive and Generic reasoners. JENA also works with third party reasoners as Pellet.

Interface

To create the GUI that allowed us to manipulate the ontology classes, we used JFC/Swing.

The idea for creating an interface like this is that any user can create characters and define for each of them the events, goals, preferences and admiration for other agents, which will define their context. Then, all these data would be stored in a database (using JENA API), so it can be manipulated and reused to create new scenarios, or similar ones with different emotional outputs.

In this way, just by assigning values for the concepts of the ontologies, the application is capable of inferring and creating the relations between those concepts, giving as a result a set of emotions which are felt by the character. As a final goal, a database of contextual situations could be constructed, containing any kind of related data to be reused by the defined ontologies. Figure 5.14 shows two windows of the GUI which correspond to the **main** window and the **physical entity** window.

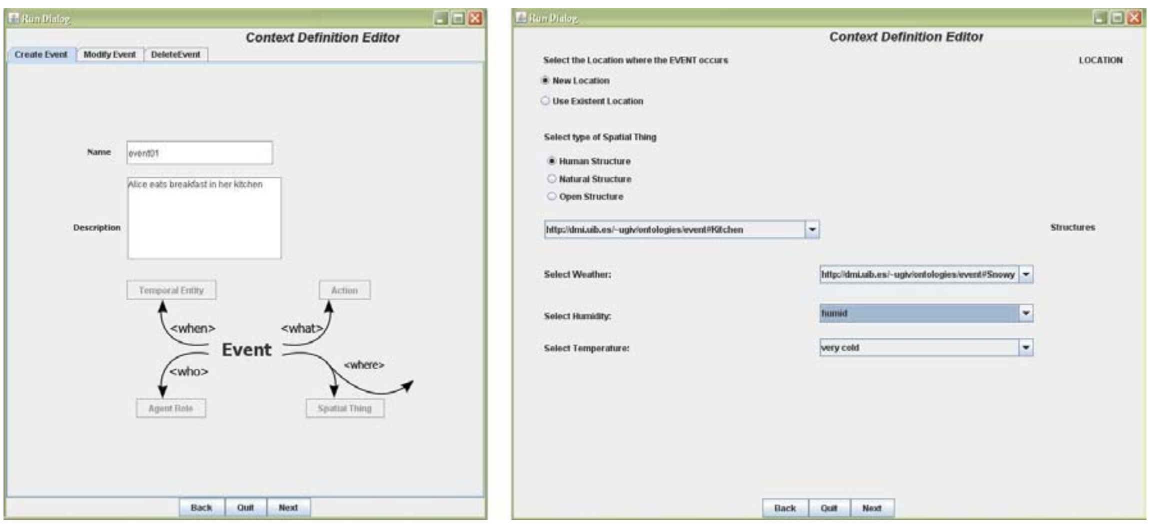


Figure 5.14: Interface of the Context Representation Application

5.8 Use Case

The semantic model we have proposed can be applied in different applications where having a story or allowing interaction between the character and its environment is required. To test it, we have used movie scenes, so we can have background information to validate with.

5.8.1 Movie Scenario

To test our model, following the guidelines of previous section, we have decided for a scene extracted from the Robert Aldrich's film *"What Ever Happened to Baby Jane?"* [2]. Using this scenario, we intended to show that with our computational model the evaluation of the context is done automatically and the elicited emotions are the same as the ones expressed by the characters in the selected scene. In this way we can guarantee coherence between the context, the events and the emotional output.

"What Ever Happened to Baby Jane?" is a psychological thriller with some black comedy. The specific scene we are taking as example of how to produce dynamic affective states is the following (1):

Jane enters Blanche's bedroom with a closed food tray, and informs Blanche that the maid has the day off. Blanche realizes that she is alone with Jane and she also knows that there are rats in the cellar. At this moment of the scene, Blanche is very hungry, and when she sees the tray she thinks of the rats in the basement. But then, she wants to believe that Jane is not capable of putting a rat in the tray. Jane gives the tray to Blanche and leaves the bedroom. When Blanche opens the tray, to her horror, finds a rat lying there.

From this scene, five events can be elicited (2):

(1) Blanche is hungry.
(2) Jane enters Blanche's bedroom with a closed tray.
(3) Blanche is alone with Jane in the house.
(4) Blanche does not believe that Jane is capable of putting a rat in the food.
(5) Blanche opens the tray and sees the rat.
(6) Jane hears Blanche opening the tray.

These events are a simplified version of the story, but they can help us to explain how we added emotional content to them. Through the wizard of the computational model (previously explained) the user can define the context for Jane and Blanche.

We will carefully examine the event (4) *"Blanche does not believe that Jane is capable of putting a rat in the food"*.

In this case the main event is: *Blanche does not believe* "something". That ""something" is considered as a CONTAINED event, which is: "Jane is capable of putting a rat in the food". The action is *put* (putting a rat in the food). Then we need to apply guideline 8.

- Event Satisfaction: The contained event is evaluated from the perspective of the character that performs the main event: Blanche. She considers this event as NOT-

SATISFACTORY = 0.8, and it is not a goal.

- Admiration Degree: If Blanche is the performer of the main event then her role is **ByMe**, the role of Jane who performs the contained event is **ByOther**. Admiration of Blanche for Jane is set to NEGATIVE = 0.6.

- Personality: Blanche is a *little bit extroverted* (0.4), *extremely agreeable* (0.99), *moderately conscientious* (0.8), *not neurotic* (0.2), and *extremely open* (0.99). On the other hand, Jane is *extremely extroverted* (0.99), *disagreeable* (0.2), *not conscientious* (0.2), *extremely neurotic* (0.99), and *somewhat open* (0.6).

- Emotion Elicitation: Using Figure 5.6, we first elicit emotions using the contained-character's role (Jane, **ByOther**) and the contained-event satisfaction (NOT SATISFACTORY = 0.8), from the main-character's perspective (Blanche). Elicited emotion is *anger* = 0.6.

  Now we need to evaluate the event using the main-character's role and contained-event satisfaction. It means, the role of Blanche (**ByMe**) and event Satisfaction is NOT SATISFACTORY = 0.8. Elicited emotion are *shame* = 0.8 and *remorse* = 0.8.

  To consider the main event satisfaction, we need to use a logic rule to decide for it. The rule is as follows:
  IF contained-event.SatisfactionScale = NOT SATISFACTORY
  *AND action = NOT "**believe**"*
  THEN main-event.SatisfactionScale = SATISFACTORY AND byMe.emotions = pride = 0.8 OR gratification = 0.8

  It means that as Blanche does not think that a Not Satisfactory event will occur, then it becomes Satisfactory. As we can see, elicited emotions for role **ByMe** are different; therefore, we select the ones obtained from the rule.

  The final set of emotions is: *Anger = 0.6, Pride = 0.64, Gratification = 0.64*. From this set we chose the ones with the greatest values.

5.9 Summary

The novelty of our approach is the representation of context by means of a semantic model, not only as events in the world, but also as the internal characteristics of the character which when related with the events, give as result believable emotional responses. This chapter presented an overview of previous works on context representation and how they have been related with the creation of virtual characters; as well as the description, definition and implementation of the ontologies that form part of the semantic model. Finally, an use case demonstrated not only how to use these ontologies, but the obtained results after the simulation of a set of events.

Chapter 6

Affective Model for Mood Generation

Personality is to a man what perfume is to a flower.
Charles M. Schwab

It is known that behavior, social interaction and communication, action planning and response to the environment are guided and regulated through emotions [17]. Nevertheless, other traits like mood and personality have also a strong influence on emotions and behaviors.

Hence the achievement of more complex and richer affective characters, or agents, will depend on the interrelation between ***emotions***, ***mood*** and ***personality***.

In the previous chapter we went through the process of context appraisal to obtain a set of emotions that are experimented by the character in certain situation. In this chapter, we explain how to "enrich" those emotions with mood and personality. As result we have a set of pleasure, arousal and dominance values, corresponding to the resultant mood of the character.

This chapter is organized as follows. Section 6.1 introduces the affective layer used for regulation and generation of moods, based on the PAD model proposed by Albert Mehrabian [105]. Section 6.2.1 provides a detailed description of the affective model used to process the emotions received from the semantic layer (Chapter 5) in order to generate the values for different moods. Finally, Section 6.3 offers a summary of the chapter.

6.1 Affective Model

As explained in Chapter 4, the affective layer is the one that takes as input the emotions produced in the semantic layer, and processes them to generate as output a temporal mood in the character. Figure 6.1 shows an extract of the framework that corresponds to the affective layer.

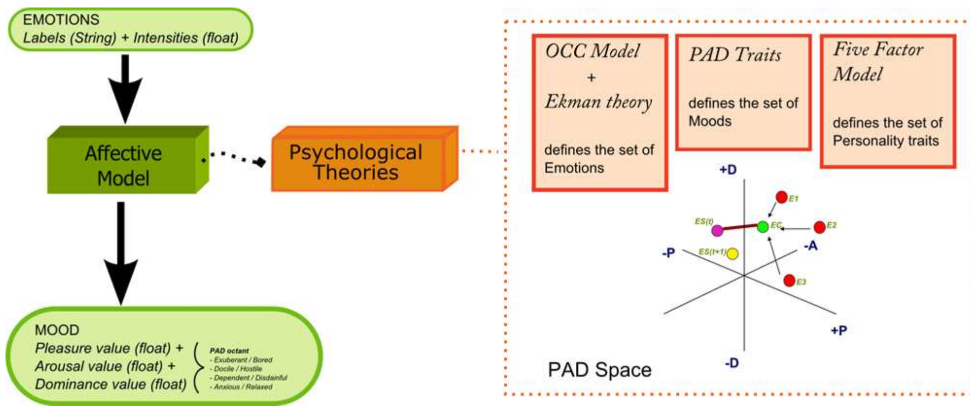


Figure 6.1: Affect Representation Schema

In our work emotions are generated based on the OCC model and personality traits are chosen from the Five Factor Model (FFM). To relate emotions, moods and personality in the same space, we use the Pleasure-Arousal-Dominance space (PAD) because it allows us to obtain mood values in terms of pleasure, arousal and dominance dimensions.

The PAD space is considered a dimensional model, and the motivation to choose it for mood representation is derived from the ideas explained by Cochrane [29]. One attraction for a dimensional approach is that it respects a fundamental observation that emotions can vary very smoothly, and the information they provide is typically dynamic in content. The other idea relates to language; therefore extracting dimensions from language can allow one to transcend its constraints to some extent and break down affective terms into descriptive terms that convey the same meaning for different people both within and across cultures.

6.1.1 PAD Space – Pleasure, Arousal and Dominance

The PAD model [105] is a framework for definition and measurement of different emotional states, emotional traits, and personality traits in terms of three nearly orthogonal dimensions: Pleasure, Arousal, and Dominance.

The notations +P and -P for pleasure and displeasure, +A and -A for arousal and nonarousal, and +D and -D for dominance and submissiveness, respectively, are used throughout this work.

Pleasure–displeasure distinguishes positive affective states from negative ones. Arousal-nonarousal is defined in terms of a combination of mental alertness and physical activity. Dominance-submissiveness is defined in terms of control versus lack of control over events, one's surroundings, or other people. The resulting octants and mood categories, corresponding to various combinations of high versus low pleasure, arousal, and dominance [104]. These are indicated in Table 6.1.

Exuberant (+P +A +D)	Bored (-P -A -D)
Docile (+P -A -D)	Hostile (-P +A +D)
Dependent (+P +A -D)	Disdainful (-P -A +D)
Relaxed (+P -A +D)	Anxious (-P +A -D)

Table 6.1: Octants in the PAD space: Moods

6.1.2 Reasons to use PAD in a Computational Model of Affect

Some of the advantages of the PAD model are mentioned in the following:

- **Context representation.** Some examples of the context we want to represent, specifically how the emotional states and some other psychological characteristics predispose a person toward certain sets of behavior, were already exposed by Mehrabian. For instance:
  - A more pleasant emotional state predisposes a person to act in a friendly and sociable manner with others; conversely, an unpleasant emotional state (e.g., a headache) tends to heighten chances that the individual will be unfriendly, inconsiderate, or even rude with others.
  - A more pleasant and, for most tasks, a less aroused emotional state enhances one's desire to work (so, if your office is uncomfortably cold or hot, you are less likely to want to do the jobs that await your attention)
- **Personality models**. The possibility of mapping personality, emotions and emotional states parameters into the same space constitutes one of the main advantages

for choosing this model. For example, one could be able to map the Big Five personality model, or de AB5C personality model, into the PAD space and obtain the same set of temperaments, or moods [104].

- **Widely used.** In the last few years this model has been one of the most used to represent personality, emotions and mood. According to Garvin [62], referencing other authors, the components within the PAD scale have shown to have good reliability and nomological validity through the many studies that have utilized them. Actually, the PAD space has not only been used by researchers in Affective Computing like Gebhard [63], Becker-Asano [12], Kessler et al. [82], Kasap et al. [80], Ben Moussa and Thalmann [111], Courgeon et al. [30] among others, but also by researchers in areas like computer vision to recognize facial expressions [24], in design of theme parks [108], for integration of emotional strategies in spoken dialogues [19], or for marketing and communications, product development and personnel management [103].

- **Mathematical description.** When Mehrabian proposed the PAD space, he designed a set of equations based on his numerous observations, which allowed the mapping of personality traits and emotions into the three dimensions of Pleasure, Arousal and Dominance. Thus, having a dimensional model instead of a discrete model allows more variability in the results and a wider ranger of mood responses. The other aspect to note about the PAD is its dynamic nature, which is seen by the variations that can occur in emotions and personality when the P, A, and D values are changed over time.

- **Easiness of assessment.** To evaluate the affective output of the PAD space there is a non-verbal, visually oriented questionnaire based on the three dimensions of pleasure, arousal and dominance: the Self-Assessment Manikin (SAM) [22]. SAM depicts each PAD dimension with a graphic character arranged on a linear scale, and subjects rate each input according to this character, obtaining fast evaluations and very accurate results.

For the aforementioned reasons, the PAD model would provide us the theoretical framework to create more "believable" characters capable of react in different situations. The following section explains how emotions elicited in the Semantic Layer are mapped into the PAD Space and through the Affective Layer, moods are generated and expressed in terms of pleasure, arousal and dominance.

6.2 Affective Layer

For the elicitation of moods we implement a module for computation of affect, based on the ALMA model [63]. The advantage of the model is that it is based in the PAD space and it provides a mathematical representation of the influence of moods, emotions and personality on each other.

Figure 6.2 shows schematically each of the elements of the affective model that will be further explained. As can be noticed, the "**CONTEXT**" is the one that supplies the output of the semantic model, which are in this case the elicited emotions.

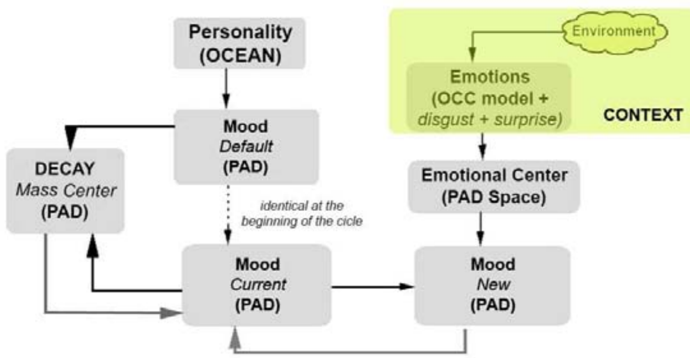


Figure 6.2: Schema of the affective model

6.2.1 Representation of Mood, Personality and Emotions

Mood, Default Mood and Emotion

A mood **M** is defined as a point in one of the eight octants of the PAD space. Therefore, it is defined by the values of pleasure, arousal, and dominance as $\mathbf{M} = (P, A, D)$, where $P \in [-1, 1], A \in [-1, 1], D \in [-1, 1]$. Figure 6.3 shows the mood in the space.

The mood intensity m is defined by its distance to the zero point of the PAD mood space, and it is computed as the norm of the vector $\left\|\vec{OM}\right\|$ denoted by $\sqrt{P^2 + A^2 + D^2}$. Because this three dimensional space has maximum absolute values of 1.0, the longest distance in a mood octant is $\sqrt{3}$.

As mentioned by Gebhard in his research [64], people have better understanding of descriptions when quantified words are used instead of numbers. Hence we applied the same categorization for mood intensities:

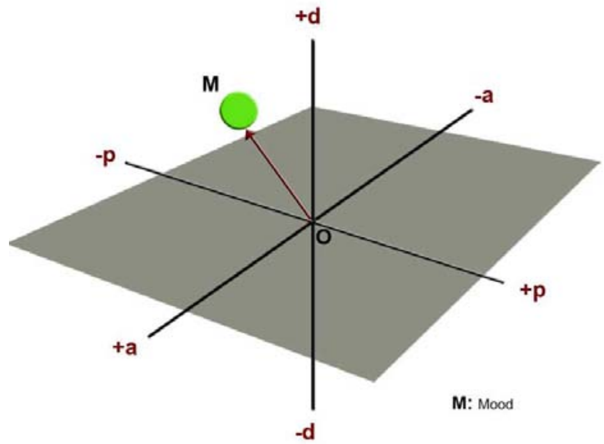


Figure 6.3: Mood in the PAD space

- *slightly*, if $m \in [0.0, \frac{1}{3}\sqrt{3}]$
- *moderate*, if $m \in (\frac{1}{3}\sqrt{3}, \frac{2}{3}\sqrt{3}]$
- *highly*, if $m \in (\frac{2}{3}\sqrt{3}, \sqrt{3}]$

Personality can also be mapped into the PAD space as the ground, or **default mood**, **G**, which is the mood start value. It is considered the *normal* state of the character according to its personality. This concept is based on the relationship established by Mehrabian between the Five Factor Model and the PAD traits, expressed in Eq. 6.1.

$$\begin{aligned} P &= (0.21 \cdot E) + (0.59 \cdot A) + (0.19 \cdot N) \\ A &= (0.15 \cdot O) + (0.30 \cdot A) - (0.57 \cdot N) \\ D &= (0.25 \cdot O) + (0.17 \cdot C) + (0.60 \cdot E) - (0.32 \cdot A) \end{aligned} \tag{6.1}$$

For example, Eq. 6.2 computes the default mood of a person with a very extroverted and very agreeable personality ($personality = (0.1, 0.2, 0.9, 0.9, 0.1)$). Then, $\mathbf{G} = (0.739, 0.2280, 0.311)$ which is translated into a *moderate Exuberant* mood.

$$\begin{aligned} P &= (0.21 \cdot 0.9) + (0.59 \cdot 0.9) + (0.19 \cdot 0.1) && = 0.739 \\ A &= (0.15 \cdot 0.1) + (0.30 \cdot 0.9) - (0.57 \cdot 0.1) && = 0.2280 \\ D &= (0.25 \cdot O.1) + (0.17 \cdot 0.2) + (0.60 \cdot 0.9) - (0.32 \cdot 0.9) && = 0.311 \end{aligned} \tag{6.2}$$

Finally, the emotions felt by the character at certain moment are also mapped into the PAD space. These emotions are the ones obtained from the semantic model and influence the change of mood in the character.

An emotion **E** is located in the space according to its values of pleasure, arousal and dominance, which were obtained empirically by Mehrabian and completed by Gebhard [63, 65]. Table 6.2 shows these values, which indicate how much of pleasure, arousal and dominance exists in each emotion. The intensity e of an emotion is given by the values obtained in the semantic model. Figure 6.4 shows how the default mood and emotions are represented.

Emotion	**P**	**A**	**D**	**Mood**
Admiration	0.5	0.3	-0.2	+P+A-D Dependent
Anger	-0.51	0.59	0.25	-P+A+D Hostile
Disliking	-0.4	-0.2	0.1	-P-A+D Disdainful
Disappointment	-0.3	-0.4	-0.4	-P-A-D Bored
Sadness	-0.5	-0.42	-0.23	-P-A-D Bored
Fear	-0.64	0.60	-0.43	-P+A-D Anxious
Gloating	0.3	-0.3	-0.1	+P-A-D Docile
Gratification	0.6	0.5	0.4	+P+A+D Exuberant
Gratitude	0.4	0.2	-0.3	+P+A-D Dependent
Hate	-0.6	0.6	0.3	-P+A+D Hostile
Hope	0.2	0.2	-0.1	+P+A-D Dependent
Joy	0.4	0.2	0.1	+P+A+D Exuberant
Liking	0.40	0.16	-0.24	+P+A-D Dependent
Love	0.3	0.1	0.2	+P+A+D Exuberant
Pity	-0.4	-0.2	-0.5	-P-A-D Bored
Pride	0.52	0.22	0.61	+P+A+D Exuberant
Relief	0.2	-0.3	0.4	+P-A+D Relaxed
Resentment	-0.3	0.1	-0.6	-P+A-D Anxious
Reproach	-0.3	-0.1	0.4	-P-A+D Disdainful
Remorse	-0.2	-0.3	-0.2	-P-A-D Bored
Satisfaction	0.50	0.42	0.47	+P-A+D Exuberant
Shame	-0.3	0.1	-0.6	-P+A-D Anxious

Table 6.2: Mapping of Emotions into PAD space

Emotions and Emotional Center

When more than one emotion are active at the same time, it results in different points located in the same, or different octants. Therefore, we need to compute another point that represents all of them, which will induce the displacement of the mood. This point

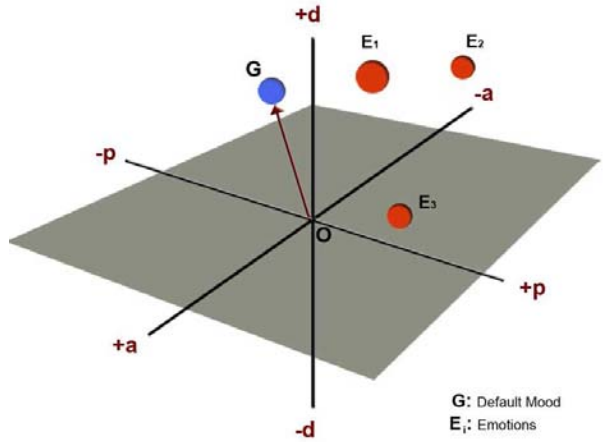


Figure 6.4: Representation of Emotions

is named *emotional center* $\bar{\mathbf{E}}$, and it is the center of mass of all the emotions $\mathbf{E_i}$. Eq. 6.3 depicts the intensity of the emotional center, computed as the norm of this vector from the origin of the PAD space. Figure 6.5 shows how the emotional center is represented.

$$\bar{\mathbf{E}} = \frac{\sum_{i=1}^{n}(P_{E_i}, A_{E_i}, D_{E_i})e_i}{\sum_{i=1}^{n} e_i}, \quad where \quad e_i \in (0.0, 1.0] \tag{6.3}$$

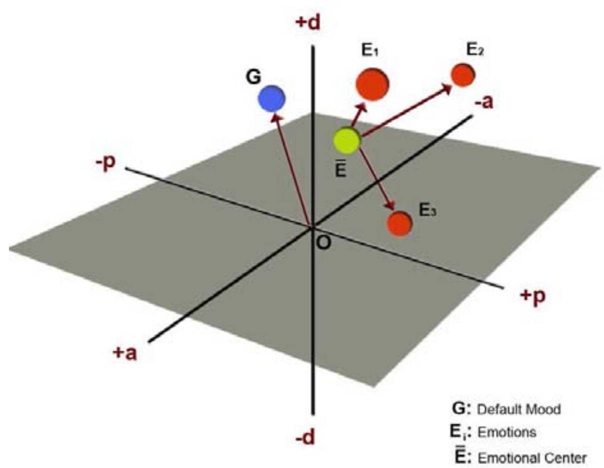


Figure 6.5: Representation of the Emotional Center

Current Mood

When the default mood $\mathbf{G}$ is changed by the emotional center $\bar{\mathbf{E}}$ in an instant t, it becomes the *current mood* of the character. The current mood, denoted by $\mathbf{M}(t)$, is computed through the center of mass between $\mathbf{G}$ and $\bar{\mathbf{E}}$. Equation 6.4 shows this computation, where $\mathbf{M}(t)$ is the current mood, $\mathbf{G}$ is the default mood, g its intensity, $\bar{\mathbf{E}}$ is the emotional center and $\bar{e}$ its intensity. Figure 6.6 shows the current mood $\mathbf{M}(t)$.

$$\mathbf{M}(t) = \frac{g \cdot \mathbf{G} + \bar{e} \cdot \bar{E}}{g + \bar{e}} \tag{6.4}$$

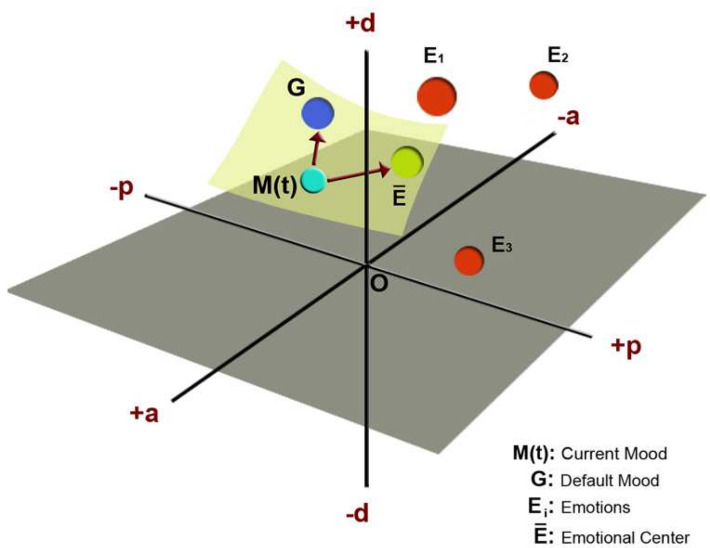


Figure 6.6: Changing of mood in an instant t - Current Mood

New Mood

In a more realistic model, when the character experiments new emotions, these will not be affected by the default mood $\mathbf{G}$, but by the current mood $\mathbf{M(t)}$.

Then, a *new mood* at instant $t+1$, $\mathbf{M(t+1)}$, is the result of the emotions experienced at instant t (represented by the emotional center $\bar{\mathbf{E}}$) and the current mood $\mathbf{M}(t)$. Figure 6.7 shows the generation of the new mood $\mathbf{M}(t+1)$. Again, the new mood is computed as the center of mass between the current mood and the emotional center.

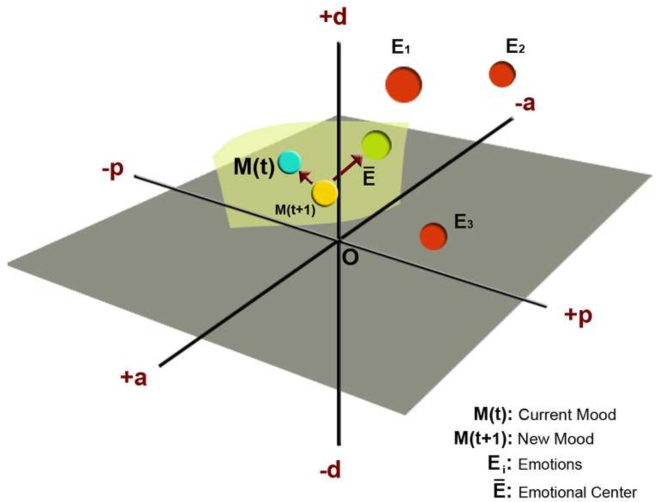


Figure 6.7: Changing of mood in an instant t - New Mood

The new mood represents the change of mood of the character along time. It is worth noting that these changes are progressive, as it happens for people in their daily lives. It will not happen that the character changes its mood from one extreme of the PAD space to the other. The reason is that, according to Watson [150], extremely high levels of one type of mood are rare in everyday life. Instead, daily experiences show low to moderate intensity states. For example, someone who is mildly nervous may be very enthusiastic.

Decay

Finally, an important aspect that has to be considered is *decay*. It occurs when the character has no active emotions, which means that no new emotions have been elicited, and therefore his or her current mood will tend to go back to the ground, or default mood.

This change has to be progressive, that is why we compute the decayed new mood, $\mathbf{M(t+1)}$ as the center of mass between the default mood $\mathbf{G}$ and the current mood $\mathbf{M}(t)$, according to Eq. 6.5. By successive repetitions of this equation, the current mood will eventually become the default mood, unless new emotions are experienced. Figure 6.8 shows how the vector $\mathbf{M}(t)$ is moved towards $\mathbf{G}$ in the PAD space.

$$\mathbf{M}(t+1) = \frac{g \cdot \mathbf{G} + m \cdot \mathbf{M}(t)}{g+m} \tag{6.5}$$

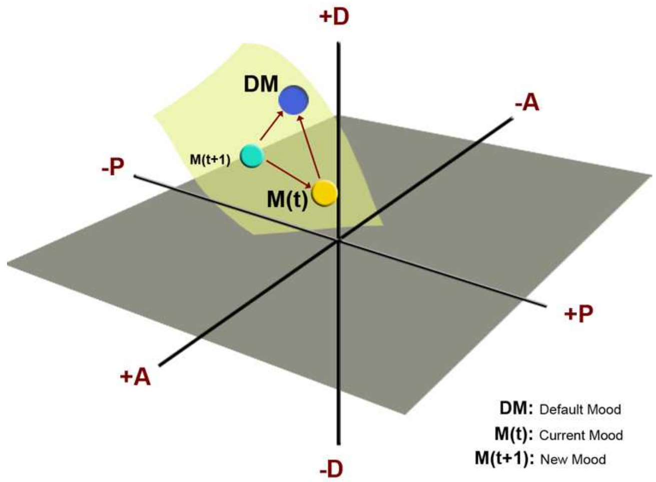


Figure 6.8: Mood Decay

6.3 Summary

As can be seen, our model is a modified version of the ALMA model. We have decided for computations based on center of mass, contrary to the vectorial computations in ALMA, because it allowed us to represent in a simplified and effective way the influence of the points representing personality and emotions on mood.

In this way, we obtained a model that served well enough to our purposes, allowing us to represent a character's mood and its changes along time depending on the personality. The representation was based on terms of pleasure, arousal and dominance, providing a novel way for mood simulation and visualization.

Chapter 7

Visualization of Affect in Faces

No man, for any considerable period, can wear one face to himself, and another to the multitude, without finally getting bewildered as to which may be the true.
Nathaniel Hawthorne

Non-verbal expressions of affect can be performed using voice, gestures, body positions, and facial expressions. For example, anger can be manifested through a raise in the tone of the voice; but if the person in anger is introverted, then he or she would just frown.

In this work, the main focus are facial expressions because they have been found to be the richest source of information about emotions, and one of the richer and more accurate ways of expressing affect [46].

One of the first scientists who studied the facial expressions in men and animals was Charles Darwin. All his observations were captured in his book "The Expression of Emotions in Man and Animals" [33]. He associated different facial movements with certain emotions, which were observed in different persons in different countries under the same emotional state. This led to the formulation of the principle of the universality of emotions.

In the previous chapters we went through the process of context appraisal to obtain a set of emotions, and explained how these emotions are modulated and contribute to the elicitation of moods. In this chapter, we explain how to visualize these affective traits.

This chapter is organized as follows. Section 7.1 gives an overview of previous works on visualization of facial expressions. First the two most used standards for creating parameterized facial expressions, MPEG-4 and FACS, are explained. Then, it is presented the two facial animation engines and other applications used for generation of the facial expressions. Afterwards, the algorithms and techniques used in the generation of emotion and mood expressions, as well as personality cues are detailed. Finally, a summary of the chapter is presented.

7.1 Overview of the Visualization Module

One of the novelties of this work is the visualization of moods using FACS based on the Pleasure, Arousal and Dominance space; the other novelty is the visualization of personality based on visual cues. To achieve this the following requirements should be fulfilled:

- Facial expressions should represent a strong emotion felt by the character at some instant. We consider two types of emotions: universal ones (*joy, anger, sadness, disgust, surprise*, and *fear*) and intermediate emotions (the ones proposed in the OCC model, e.g. *disappointment, remorse*). As there are no parameters established for the intermediate ones, these should be obtained from already defined emotions.

- Emotions should have different intensities. For example: "*does the lowering of the eyebrow control the intensity of an angry face, and will a greater lowering of the eyebrows make the person look angrier?*" [54].

- Facial expressions should express the mood in an interval of time. Regarding mood, Faigin sets the question: "to what extent are day-to-day moods visible on the face?" To answer it, he cites the example of fear: "*... if we are terrified enough our response will be etched on the face*". But in the case of a long-term mood like *anxiety*, Faigin says that it depends on coping as well-socialized adults, "*we still go about our daily life in spite of a disruptive inner mood of anxiety*".

- Personality can be expressed in terms of visual cues that enhance or attenuates certain facial expressions. A visual cue is defined as that action or characteristic that is associated to a personality trait.

Considering the requirements mentioned above, this section describes the last module of our computational model, which concerns to the generation and visualization of facial expressions in virtual characters. Figure 7.1 shows an extract of the framework that corresponds to the visualization layer.

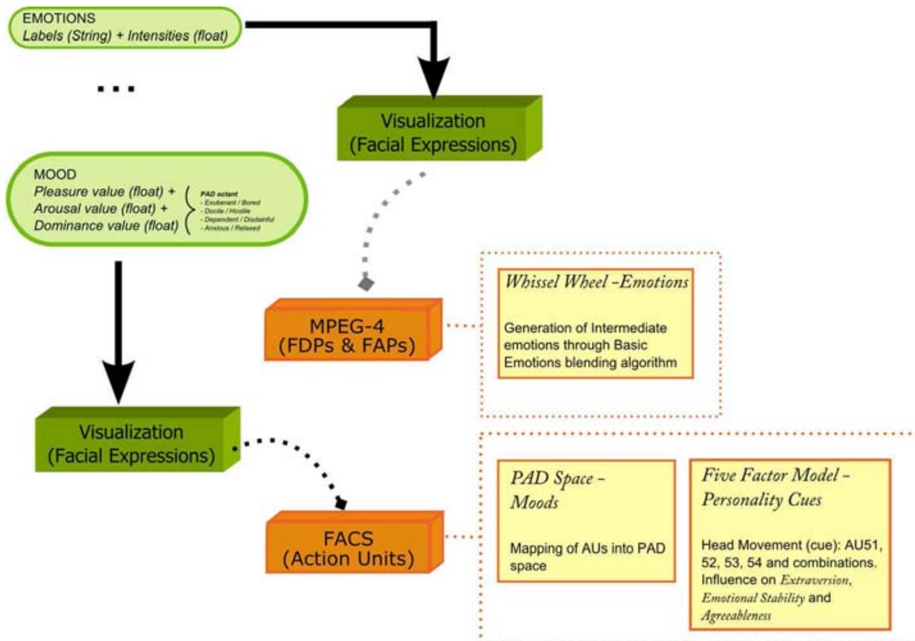


Figure 7.1: Visualization Schema

As can be seen, two types of facial expressions are visualized: expressions for emotions and expressions for moods. Expressions of emotions are generated using the output of the Context Representation module -or Semantic model. For their visualization we use the MPEG-4 standard.

Expressions of moods are generated from the output of the Affective Model. The obtained values are mapped into the Pleasure-Arousal-Dominance (PAD) space, which allows to visualize any variation of mood. In this case, only FACS were used.

Concerning personality, its visualization relies on visual cues, which in this work are head pose and eye gaze. In this case, also FACS is the only standard used.

7.2 Expression Coding Systems

The visualization of facial expressions is considered one of the most challenging tasks in the field of animation. On the one hand, the slightest inconsistency can be rapidly recognized by the human eye and lead to a lack of believability; and on the other hand, the human face is very complex, and to capture all its details can become a very difficult task.

The techniques used for generation of facial expressions can be grouped into: geometry-based and image-based techniques.

Geometry-based techniques include key-framing with interpolation, direct parameterization, pseudo-muscle-based approach and muscle-based approach. Image-based techniques could be divided into morphing between photographic images, texture manipulation, image blending and vascular expressions [129].

There is another method called performance-driven methods, which captures real people's movements and uses them to animate virtual characters. To implement techniques that belong this last method two standards or coding systems have been stated as the most important ones: the MPEG-4 standard and the Facial Animation Coding System (FACS).

7.2.1 MPEG-4

MPEG-4 is an ISO/IEC standard developed by the MPEG (Moving Picture Experts Group) [58], [144]. One of the objects provided by the standard is a facial object that represents a human face, as well as facial data: *Facial Definition Parameters* (FDPs), *Facial Animation Parameters* (FAPs), and *Facial Animation Parameters Units* (FAPUs).

- *Facial Definition Parameters* (FDPs) are defined by the locations of *feature points* and are used to customize a given face model to a particular face. There are 84 feature points, which are used as reference to calculate the facial movement. Figure 7.2 shows how FDPs are defined in a human face.

- *Facial Animation Parameters* (FAPs) define the normalized displacement of particular feature points from their neutral position and are closely related to muscle actions. There are 68 FAPs: 66 low-level parameters associated with the lips, jaw, eyes, mouth, cheek, nose; and two high-level parameters (FAPs 1 and 2) associated with expressions and visemes.

  In our work all FAPs are coded, and for each group there is a mask indicates which specific FAPs are represented in the bitstream, where a 1 indicates that the corresponding FAP is present in the bitstream.

- *Facial Animation Parameter Unit* (FAPUs) are the units used to defined FAP values. A FAPU is computed from spatial distances between major facial features on the model in its neutral state, and they are defined as fractions of distances between key facial features (Figure 7.3). Measurement units are presented in Table 7.1.

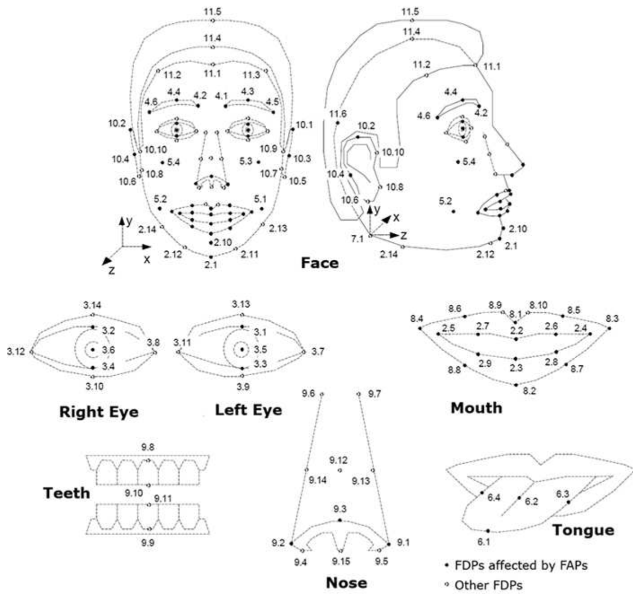


Figure 7.2: FDPs groups

Feature	Description	FAPU
IRISD0	Distance between upper ad lower eyelid	IRISD = IRISD0/1024
ES0	Eye separation	ES = ES0/1024
ENS0	Eye - nose separation	ENS = ENS0/1024
MNS0	Mouth - nose separation	MNS = MNS0/1024
MW0	Mouth width	MW =MW0/1024
AU	Angle unit	10^{-5}

Table 7.1: FAPUs and their definitions

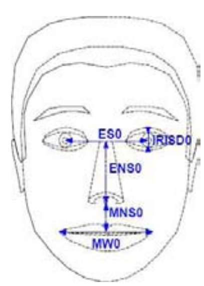


Figure 7.3: FAPUs

Some of the most renowned works that used MPEG-4 are:

- Pasquariello and Pelachaud [122], who developed the Simple Facial Animation Engine (SFAE) to animate Greta, a 3D facial model compliant with MPEG-4 specifications.
- Courgeon et al. [31] developed MARC, an MPEG-4 based facial animation system that also supports FACS' action units based animation and BML (Behavior Markup Language) external control.
- Kasap et al. [80] had Eva, a virtual character whose facial movements for each type of emotional response were encoded using the MPEG-4 standard.
- Malatesta et al. [92] used MPEG-4 facial animation parameters to obtain facial expressions for predicted intermediate and final emotional states.
- Raouzaiou et al. [131] proposed a framework based on the MPEG-4 standard [58] to achieve two goals: modeling of primary expressions using MPEG-4's Facial Animation Parameters (FAPs); and development of a rule-based technique for analysis and synthesis of intermediate facial expressions.
- Arya et al. [6] proposed iFace, a general-purpose software framework that implements the "face multimedia object", which are based on top of the MPEG-4 standard.
- Balci [8] developed XFace, a set of open source tools for creation of embodied conversational agents using MPEG4 and keyframe based rendering driven by SMIL-Agent scripting language.

7.2.2 FACS - *Facial Action Coding System*

The Facial Action Coding System (FACS) is a method introduced by Paul Ekman, Wallace V. Friesen, and Joseph C. Hager to measure facial behaviors [48] and to systematically categorize facial expressions. It was developed by determining how the contraction of each facial muscle (singly and combined) changes the appearance of the face.

FACS measurement units are Action Units (AUs), and not muscles. One of the reasons for this is that some changes involve more than one muscle, and then they are mapped into one AU. Another reason is that changes produced by one muscle are separated into different AUs to describe the actions produced by the same muscle.

FACS consists of 56 AUs in total, 44 of those used to describe facial expressions and the remaining 12 to describe head and eye movement. Appendix B has a list with all the existent AUs.

There are FACS that are more accentuated in one side of the face or in both. From this point of view, FACS can be unilateral or bilateral. For example, in a "smile" the AUs are present in both sides of the face. Therefore, we can read: AU12 (*lip corner puller*). But in the "contempt" expression, the AU12 is present just in one side of the face. Therefore, we read it as: L/R12, meaning that it can be the left (L) or the right (R) side. Other locations of the AUs would be bottom (B) and top (T). Nevertheless, in our work for easiness of use, we will treat AUs as unilateral.

Regarding previous works, FACS have been mainly used in the field of facial expression recognition. In the field of generation of facial expressions, FACS have been used for quite some by:

- Platt and Badler [124], who designed the first model based on muscular actions using FACS as basis for the control of facial expressions.
- Grammer and Oberzaucher [67] modeled all AUs as a system of morph targets at their maximum contraction directly on the head mesh in a modeling program.
- Bee et al. [14] created a facial animation system based on Ekman's FACS, which allows the creation and animation of facial expressions.

7.2.3 Reasons to use MPEG-4 and FACS

Like Mosmondor et al. [110], we preferred MPEG-4 to procedural approaches and the more complex muscle-based models because it is very simple to implement, and therefore easy to port to various platforms. It is also the state of the art standard for parameterized facial expressions in academia. Nevertheless, in the last few years MPEG-4 has shown a decreased use, probably this was due to the lack of quality that was obtained in animations and the difficulty for describing all kind of facial movements.

On the other hand, FACS is the system developed to classify facial expressions through the use of action units (AUs); therefore, it provides the necessary data to generate facial expressions. Another reason is the independence that FACS provides from other animation standards or methodologies. Instead of using standard-specific-compliant facial mesh in order to generate and animate the expressions, one can have a 3D facial model with its corresponding *action units* deformations and obtain a variety of facial expressions. As stated by Kaiser and Wehrle [78]:

The Facial Action Coding System (FACS) allows the reliable coding of any facial action in terms of the smallest visible unit of muscular activity (Action Units), each referred to by a numerical code. As a consequence, coding is independent of prior assumptions about prototypical emotion expressions. Using FACS we can link facial expressions to emotions, mood, and personality.

That is why many film studios are heading towards FACS in their animations of 3D characters (*Monster House*,*King Kong* [137] and *Avatar*), which makes it a strong standard to take into consideration not only for facial recognition, but for facial animation.

As data set for facial expressions of universal emotions, and some intermediate emotions and moods, we used the Facial Expression Repertoire (FER) [20], developed by the Filmakademie Baden-Württemberg. It provides an extensive data set with different expressions and their corresponding AUs. These data will be used to create the required expressions. Intensity for each AU is given by the output of the affective model and the corresponding correlations with pleasure, arousal, and dominance dimensions.

7.3 Facial Animation Engines and Applications

In this section we outline the facial animation engines we have used to generate facial expressions, based on FACS and MPEG-4.

7.3.1 Game Engine from the University of Augsburg

The game engine of the University of Augsburg is a facial animation system based on FACS, designed to create facial expressions for animated agents in an easier, more intuitive and faster way than conventional animation tools [14].

To implement FACS, morph targets (or blend shapes) were used. In the implementation of the 3D model "Alfred", each morph target corresponds to one AU. In total, 23 AUs were implemented.

Regarding Alfred, he was modeled using "Luxology modo" and Autodesk 3D Studio Max®, through subdivision surfaces and sculpting techniques. Textures are either digital handpainted (color & specular map) or baked from a high-resolution mesh (normal map). Head has a polycount of about 21.000 triangles.

The created facial expressions can be saved and loaded in a XML format. The configuration of the controllers, the basic expressions and their reduced controller sets are based on data from the FER Database. Figure 7.4 shows the development environment, the XML file that is used to set up the AUs and the resultant face.

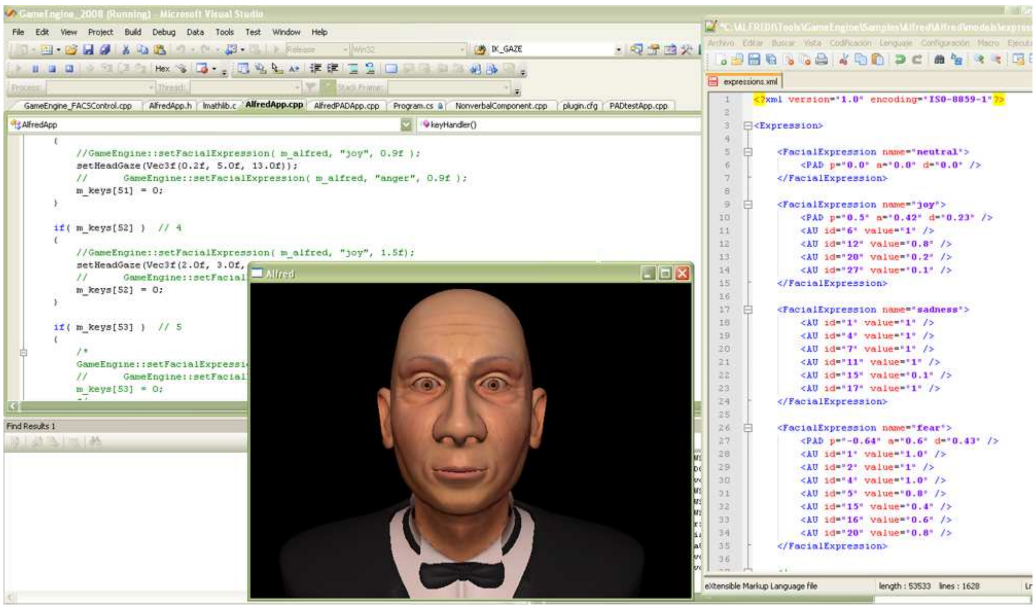


Figure 7.4: Game Engine of the University of Augsburg: development environment, configuration file and facial mesh

The reasons that led us to use this Game Engine are:

- It provides the framework to work with FACS in a very straightforward manner.
- The possibility to evaluate the influence of **gaze orientation** and **head tilt** in the affective output, given that the engine allows head and eye movement.
- The facial animation system can render the facial expressions in real time.

7.3.2 Xface Toolkit

Xface is open source, platform independent toolkit with four pieces of software for developing 3D embodied conversational agents compliant with the MPEG-4 standard. The core Xface library allows developers to embed 3D facial animation to their applications. The

XfaceEd editor provides an easy to use interface to generate MPEG-4 ready meshes from static 3D models. The XfacePlayer is a sample application that demonstrates the toolkit in action; and the XfaceClient is used as the communication controller over network.

All the pieces in the toolkit are operating system independent, and can be compiled with any ANSI C++ standard compliant compiler. For animation, the toolkit relies on OpenGL and is optimized enough to achieve satisfactory frame rates (minimum 25 frames per second are required for FAP generating tool) with high polygon count (12000 polygons).

The Xface module we use is XfaceEd, where we import the facial mesh in VRML (*Virtual Reality Modeling Language*) format. Once in the editor, we can assign values to the FDPs and FAPs parameters. In one of the tabs of the editor we define how each FDP will influence its neighbor vertices according to muscle models (Fig. 7.5).

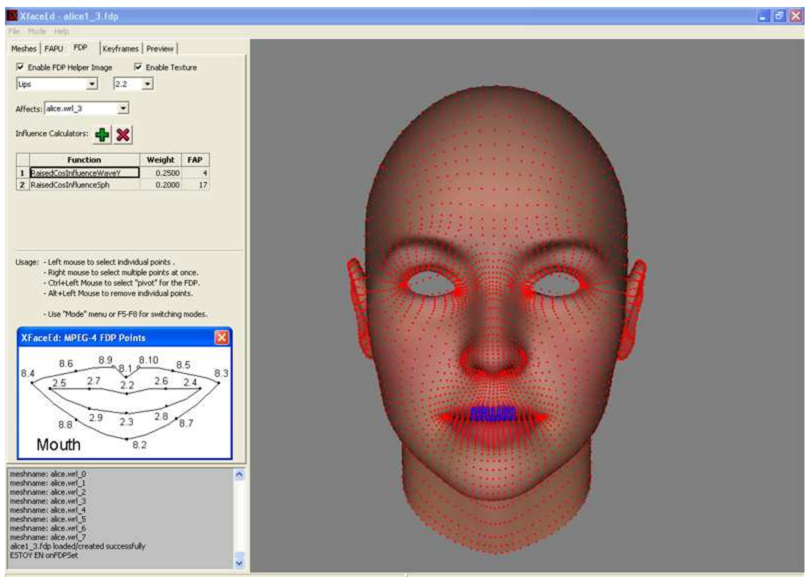


Figure 7.5: Tab in XfaceEd where FDPs are assigned to the facial mesh

In the FAPs previsualization tab, XfaceEd loads the facial mesh from a file with all the FDPs definitions. Then, it loads the FAP values which are specified in a file of FAPs frames. Finally, it decodes these values into the face and the expression can be played.

XfaceEd also offers the possibility to change and visualize each FAP at a time. Through a modification made in the Xface editor, we are able to change all the FAPs directly into the model and write them into the FAPs file.

7.4 Visualization of Emotions

The emotions that will be visualized in this work belong to one of two groups: *universal* emotions (also named *basic* or *primary*) and *intermediate* emotions. The standard used for the generation of emotional expressions is MPEG-4.

7.4.1 Universal (or Basic) Emotions

"What is a basic emotion" and what are emotions are topics which answers still raise debates between psychologists. In our research we use as universal emotions the ones proposed by Ekman: *Joy, Sadness, Anger, Disgust, Fear*, and *Surprise*, mainly because they are perceived as such in different cultures and because they are the state of art of universal or basic emotions.

When generating expressions using MPEG-4, each emotion has a set of FAPs. Let E_i be the i-th emotion generated and P_i the set of activated FAPs for E_i.

Each FAP j in P_i has a range of variation $X_{i,j} \in [minValue, maxValue]$, indicating the minimum and maximum values along which the FAP can be displaced. As for j, it is defined as $j = \{1, ..., 64\}$ given that the standard defines 64 FAPs.

The variation ranges $X_{i,j}$ for universal emotions were obtained by manual manipulation of FAPs to simulate the expressions of joy, sadness, fear, disgust, anger, surprise, and neutral drawn by Faigin [54]. These models are seen in Figure 7.6, and the generated universal facial expressions are shown in Figure 7.7.

7.4.2 Intermediate Emotions

As mentioned in previous chapters, intermediate emotions are taken from OCC model, except for *happy-for* and *fear-confirmed* because their expressions can be represented as *joy* and *fear*, respectively.

Based on the work of Raouzaiou et al. [131] we generated a set of intermediate emotions using the MPEG-4 standard. They identified eight fundamental emotions: acceptance, fear, surprise, sadness, disgust, anger, anticipation and joy, which were the starting points for interpolation. There were two different ways to generate new expressions: if the new emotion E_n is very similar to the fundamental emotion E_i, i.e., if their facial expressions differ mainly in strength of muscle contraction, then the new expression E_n can be computed as a category of the expression E_i. If the new emotion E_n does not clearly belong

Figure 7.6: Faigin's universal facial expressions. *Up*: Anger, Disgust, Fear. *Down*: Joy, Sadness, Surprise

Figure 7.7: Universal facial expressions generated using MPEG-4. *Up*: low intensities of Anger, Disgust, Fear, Joy, Sadness and Surprise. *Down*: high intensities of Anger, Disgust, Fear, Joy, Sadness and Surprise

to a fundamental category, its facial expression is computed by interpolation between the shifted expressions of the two emotions E_1 and E_2 that are closest to E_n.

In the same manner, we generate intermediate expressions either by categorizing an universal emotion, or by mixing two universal emotions (Figure 7.8).

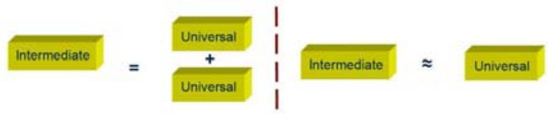


Figure 7.8: Combination of universal emotions to obtain intermediate emotions

Instead of combining the data from the Whissell and Plutchik [132] studies, as Raouzaiou et al. did, we only used the data from Whissell. The reason to use only the Whissell's Dictionary of Emotions [153] is that it provides a complete list of terms with affective connotations described in terms of their *activation* (or arousal) and *evaluation* (or pleasantness). From these values, we can locate the emotions in a 2D space and compute their angular distances, establishing similarity among them. Figure 7.9(a) shows the emotions located into the activation-evaluation space.

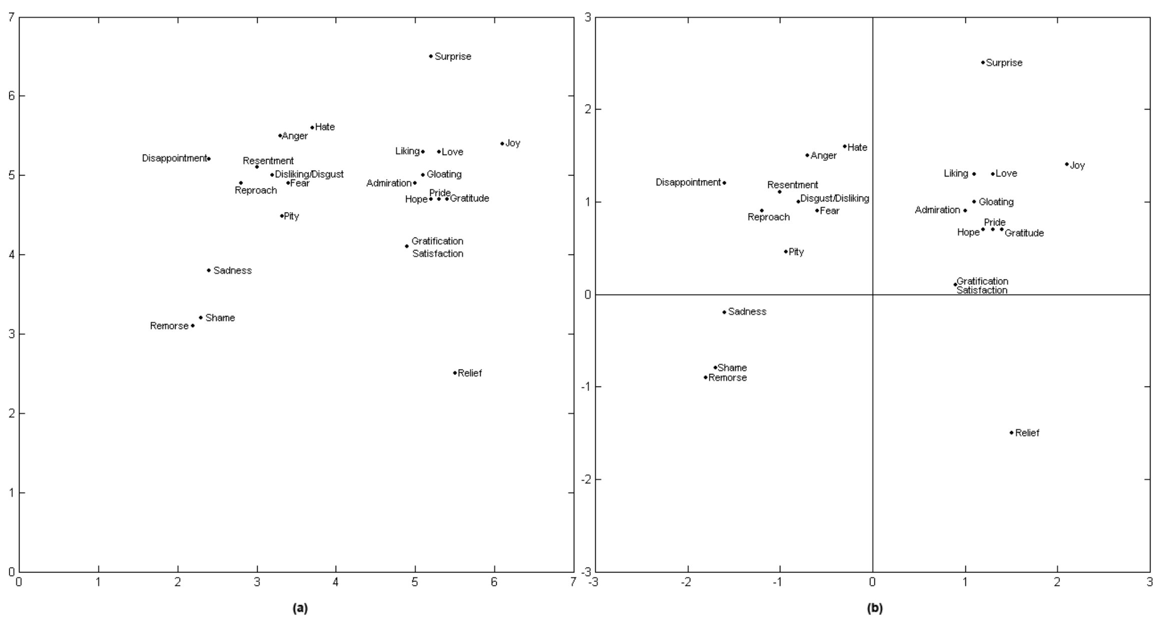


Figure 7.9: Whissell Emotions: **(a)** Not centered values, **(b)** Centered values

For a better visualization of the angular distances we center the emotions with respect to the origin $(0,0)$ using the mean values of the activation and evaluation dimensions ($\bar{a} = 4.00$ and $\bar{e} = 4.00$) obtained by Whissell. In this way, emotions can be spread along negative and positive axis maintaining the angular proportion between them.

Equation 7.1 shows how to obtain the angle of an emotion with its centered activation value $a_{center} = a - \bar{a}$ and centered evaluation value $e_{center} = e - \bar{e}$. Then, we use the rules in Table 7.2 to locate the angle in its corresponding quadrant, given that the returned ω is between 0° and 90°. Figure 7.9(b) shows the centered emotions.

$$\omega = \arctan \frac{a_{center}}{e_{center}} \tag{7.1}$$

if	$(a_{center} > 0 \wedge e_{center} < 0)$	then	$\omega = 180 - \omega$
else if	$(a_{center} < 0 \wedge e_{center} < 0)$	then	$\omega = 180 + \omega$
else if	$(a_{center} < 0 \wedge e_{center} > 0)$	then	$\omega = 360 - \omega$

Table 7.2: Rules to locate the angles in the 2D activation-evaluation space

Once emotions have been properly located in the activation-evaluation space we can decide if an intermediate emotion will be obtained as a category or as a combination of universal emotions.

In this work, the universal emotions used to obtain the intermediate ones, as well as their activation, evaluation and angular values are given in Table 7.3.

In the case of categorization, **Method 1** is applied. It changes the intensity of an universal emotion, resulting in an intermediate emotion that is a category of one universal emotion. Another way to realize if an emotion is in certain category is its closeness to certain universal emotion in the 2D activation-evaluation space.

In the case of mixing universal emotions, **Method 2** combines two universal emotions, resulting in an intermediate emotion that has features of the two original ones.

7.4.3 Generation of Intermediate Emotions

When working with MPEG-4 an emotion is defined by FAPs. Let E_1, E_2 y E_n be the two universal emotions 1 and 2, and the intermediate emotion n; a_1, a_2, a_n, e_1, e_2, e_n are the centered activation and evaluation values for each emotion. The set of activated FAPs in each emotion is given by: P_1, P_2, P_n. Each P_i has a range of variation $X_{i,j}$, such

Emotion	*Activation*	*Evaluation*	*Angle*	*Universal emotions*
Joy	5.4	6.1	33.7°	
Sadness	3.8	2.4	187.1°	
Disgust	5.0	3.2	128.6°	
Anger	5.5	3.3	171.3°	
Fear	4.9	3.4	115.0°	
Surprise	6.5	5.2	64.3°	
Admiration	4.9	5.0	41.9°	joy + surprise
Disappointment	5.2	2.4	143.1°	surprise + sadness *or* disgust + sadness
Gloating	5.0	5.1	42.2°	joy + surprise
Gratification	4.1	4.9	6.3°	joy
Gratitude	4.7	5.4	26.5°	joy – without raise_eyebrows.
Hate	5.6	3.7	100.6°	anger
Hope	4.7	5.2	30.25°	joy
Liking	5.3	5.1	49.7°	joy + surprise
Love	5.3	5.3	45.0°	joy + surprise
Pity	4.5	3.1	150.9°	sadness + fear
Pride	4.7	5.3	28.3°	joy
Relief	2.5	5.5	315.0°	joy
Remorse	3.1	2.2	206.6°	sadness
Reproach	4.9	2.8	143.1°	disgust
Resentment	5.1	3.0	132.2°	sadness + disgust
Satisfaction	4.1	4.9	6.3°	joy
Shame	3.2	2.3	154.8°	sadness

Table 7.3: Whissell activation and valuation values, angles and combinations of emotions

as $P_i = \{X_{i,j}\}$, where i is the emotion, $j = \{1, ..., 64\}$ is the FAP number, and $X_{i,j} \in [minValue, maxValue]$. Also, $minValue \in [-1000, 1000]$ and $maxValue \in [-1000, 1000]$.

Method 1: *Categorization of an Universal Emotion*

The objective is to obtain the range of variation $X_{n,j}$ of each FAP j in E_n. For this, a “ proportionality constant” A is computed using Equation 7.2, which is the proportion in which the activation value of the universal emotion E_i will be present in the intermediate emotion E_n. Then, A is multiplied by the range of variation $X_{i,j}$ of the universal emotion E_i to get $X_{n,j}$, according to Equation 7.3. $X_{n,j}$ is the translated range of $X_{i,j}$ due to the activation value of E_n. Figure 7.10 shows an example of categorization.

$$A = \frac{a_n}{a_i} \tag{7.2}$$

$$X_{n,j} = A(X_{i,j}) \tag{7.3}$$

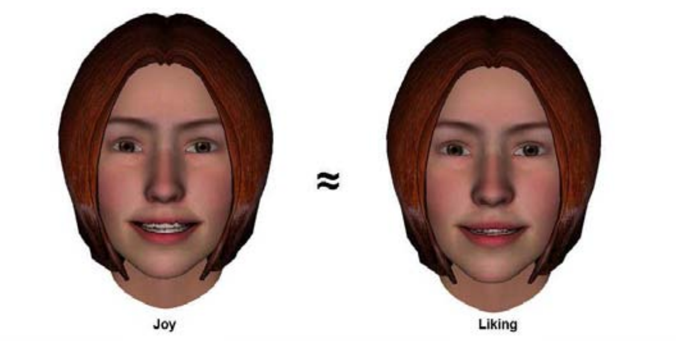


Figure 7.10: Intermediate emotions from one universal emotion

Method 2: ***Combination of two Universal Emotions***

The second method for generating E_n is applied when it is between two universal emotions that can be considered close to each other. Then we have to combine the FAPs of both universal emotions according to the following rules:

- **Rule I:**

  If FAP j is involved in the set of activated FAPs P_1, P_2 with the same sign (which represents the same direction of movement):

  (a) First we compute the weighted translations of $X_{1,j}$ and $X_{2,j}$, according to Equations 7.2 and 7.3. Let these translations be $t(X_{1,j})$ and $t(X_{2,j})$, which represent sub-ranges of the FAPs of E_1 and E_2. Figure 7.11 is a representation of how the range is translated.

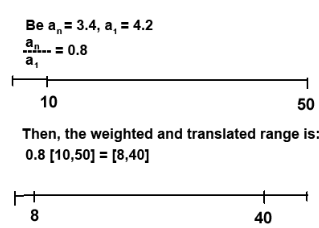


Figure 7.11: Example of a translated variation range

(b) Then, we compute the *center* $c_{1,j}$, $c_{2,j}$ and the *length* $s_{1,j}$, $s_{2,j}$ of the translated ranges $t(X_{1,j})$ and $t(X_{2,j})$. The *center* is the mean between $minValue$ y $maxValue$ of the translated ranges. The *length* is the number of elements per range.

(c) In order to compute the center $c_{n,j}$ and length $s_{n,j}$ of E_n, first we need to compute the angles ω_1 and ω_2 for E_1 and E_2 using Equation 7.1.

(d) Using the angles obtained in (c), we compute two constants α_1 and α_2. α_1 indicates the proportion of $\angle E_1E_2$ in $\angle E_nE_1$. α_2 indicates the proportion of $\angle E_1E_2$ in $\angle E_nE_2$. This is done using Equations 7.4 and 7.5.

$$\alpha_1 = \frac{\omega_n - \omega_1}{\omega_2 - \omega_1} \tag{7.4}$$

$$\alpha_2 = \frac{\omega_2 - \omega_n}{\omega_2 - \omega_1} \tag{7.5}$$

Figure 7.12 shows that the values represented by α_1 and α_2 are the proportion E_1 needs to move to get to E_n.

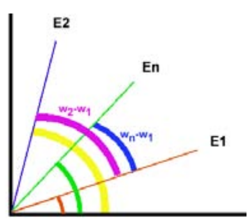


Figure 7.12: Angles equivalence

(e) Finally, using Equations 7.6 and 7.7 we compute the center and length of the ranges of variation of E_n multiplying α_1 and α_2 by the center and length of the translated ranges or E_1 and E_2. With these values we can compute the final variation range for E_n.

$$s_{n,j} = \alpha_1 s_{1,j} + \alpha_2 s_{2,j} \tag{7.6}$$

$$c_{n,j} = \alpha_1 c_{1,j} + \alpha_2 c_{2,j} \tag{7.7}$$

- **Rule II:**

  If FAP j is involved in both P_1, P_2 but with contradictory sign, then $X_{n,j}$ is null because FAPs are cancelled given that an intersection between the ranges of E_1 and E_2 is never found.

- **Rule III:**

  If FAP j is involved only in one of P_1 or P_2, then the range of variation $X_{n,j}$ will be averaged with the ranges of the neutral face, according to Equation 7.2 and 7.8.

$$X_{n,j} = A\frac{X_{i,j}}{2} \tag{7.8}$$

As a result of these three rules, we obtain a set of FAPs with a range of variation that indicates all the possible intensities of the emotion. Figure 7.13 shows the expression obtained by combining the universal emotions *joy* and *surprise*. Figure 7.14 shows some facial expressions obtained for intermediate emotions.

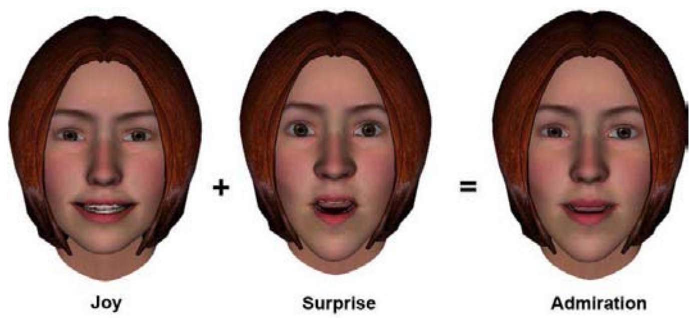


Figure 7.13: Intermediate emotions from two universal ones

Generalization of the generation of emotional expressions

The methods previously explained can also be applied to other standards as demonstrated by Albrecht et al. [1], who modified the work of Raouzaiou et al., aimed at an MPEG-4 based model, to a physics-based facial animation system.

In the same fashion, and to prove that the algorithm can be implemented independently of the animation system, we use FACS to generate intermediate emotions from universal emotions and the Game Engine of the University of Augsburg.

Figure 7.14: Examples of Intermediate Emotions (left to right): Love, Disappointment, Hate, Pity.

For the universal emotions, we followed the same methodology as with FAPs. In this case, we use the Facial Expression Repertoire (FER) [20] to obtain the AUs corresponding to each expression, as shown in Figures 7.15 and 7.16.

(a) Disgust (b) Fear (c) Joy

Figure 7.15: Basic emotions (I): *disgust, fear, joy*

To generate intermediate emotions using FACS we also use the two methods applied with MPEG-4.

Let E_1, E_2 y E_n be the two universal emotions 1 and 2, and the intermediate emotion n; a_1, a_2, a_n, e_1, e_2, e_n are the centered activation and evaluation values for each emotion. The set of "activated" AUs in each emotion is given by: P_1, P_2, P_n. Each P_i has a range of variation $X_{i,j}$, such as $P_i = \{X_{i,j}\}$, where i is the emotion, j is the number that identifies the AU according to the FACS manual [48], and $X_{i,j} \in [0, 1]$. The main difference with

(a) Sadness (b) Anger (c) Surprise

Figure 7.16: Basic emotions (II): *sadness, anger, surprise*

the methodology used with MPEG-4 is that in this case $X_{i,j}$ is considered a single value, the intensity of the AU j.

Figure 7.17show a set of facial expressions obtained for intermediate emotions.

(a) Love (b) Disappointment

(c) Hate (d) Pity

Figure 7.17: Upper row: Love, Disappointment. Lower row: Hate, Pity

7.5 Visualization of Mood

The motivation for the visualization of mood comes from the fact that there is almost no literature where it is explained how to represent them through facial expressions. That is why we establish a correspondence between FACS Action Units (AUs) and a mood model, so it would be possible to know which AUs would describe moods.

The mood model we have selected is the Pleasure-Arousal-Dominance model (PAD), therefore we consider the PAD octants as the mood values: *Exuberant*, *Bored*, *Disdainful*, *Dependent*, *Docile*, *Hostile*, *Anxious* and *Relaxed*. This model has been completely explained in Chapter 2.

As seen in Figure 7.18, we know how to describe emotional expressions in function of action units (AUs), and we know how to map emotions into the PAD space. The only missing element is the mapping of AUs into the PAD space.

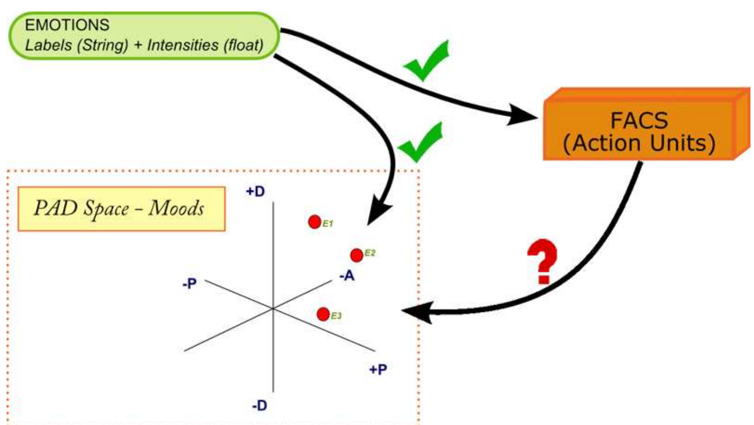


Figure 7.18: Relation between Emotions, AUs and PAD Space

The methodology to map AUs into PAD is: **(1)** mapping of emotions into the PAD space, **(2)** AUs analysis of facial expressions of emotions using the Facial Expression Repertoire (FER) and **(3)** AUs mapping in PAD Space.

7.5.1 (1) Mapping of emotions into the PAD space

The ALMA model [63] and the work of Russell and Mehrabian [136] provides us with the PAD values for a set of emotions. These values are in Table 7.4 and some are represented in Figure 7.19

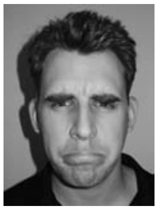
Emotion	**P**	**A**	**D**	**Mood**
Admiration	0.4	-0.49	-0.24	+P-A-D Docile
Anger	-0.51	0.59	0.25	-P+A+D Hostile
Arrogance	0.0	0.34	0.5	-P+A+D Hostile
Confusion	-0.53	0.27	-0.32	-P+A-D Anxious
Disliking	-0.4	-0.2	0.1	-P-A+D Disdainful
Disappointment	-0.3	-0.4	-0.4	-P-A-D Bored
Rage	-0.44	0.72	0.32	-P+A+D Hostile
Sadness	-0.5	-0.42	-0.23	-P-A-D Bored
Fear	-0.64	0.60	-0.43	-P+A-D Anxious
Gloating	0.3	-0.3	-0.1	+P-A-D Docile
Gratification	0.6	-0.3	0.4	+P+A+D Exuberant
Gratitude	0.2	0.5	-0.3	+P+A-D Dependent
Hate	-0.4	-0.2	0.4	-P-A+D Disdainful
Hope	0.2	0.2	-0.1	+P+A-D Dependent
Joy	0.5	0.42	0.23	+P+A+D Exuberant
Liking	0.40	0.16	-0.24	+P+A-D Dependent
Love	0.3	0.1	0.2	+P+A+D Exuberant
Pity	-0.4	-0.2	-0.5	-P-A-D Bored
Pride	0.52	0.22	0.61	+P+A+D Exuberant
Relief	0.2	-0.3	0.4	+P-A+D Relaxed
Resentment	-0.3	0.1	-0.6	-P+A-D Anxious
Reproach	-0.3	-0.1	0.4	-P-A+D Disdainful
Remorse	-0.2	-0.3	-0.2	-P-A-D Bored
Satisfaction	0.50	0.42	0.47	+P-A+D Exuberant
Shame	-0.3	0.1	-0.6	-P+A-D Anxious
Terror	-0.62	0.82	-0.43	-P+A-D Anxious
Worry (insecure)	-0.57	0.14	-0.42	-P+A-D Anxious
Fatigue	-0.18	-0.57	-0.29	-P-A-D Bored

Table 7.4: Mapping of Emotions into PAD space [64], [136]

7.5.2 (2) AUs analysis of Facial Expressions of Emotions

The AUs that describe the different emotional expressions are obtained from the Facial Expression Repertoire (FER) [20]. It is an on-line database developed by the Filmakademie Baden-Württemberg, which maps over 150 emotional expressions to FACS and explains in detail which AUs must be activated for certain facial expressions. It provides an extensive data set with different expressions and their corresponding AUs, that will be used to create the required expressions.

The expressions we use for the analysis are presented in Table 7.5.


(a) Enraged


(b) Embarrassment smile


(c) Ingratiating Smile


(d) Contempt


(e) Arrogance


(f) Qualifier smile


(g) Coy smile


(h) Fear


(i) Terror

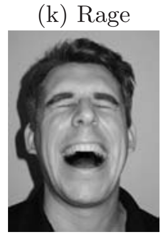

(j) Worry

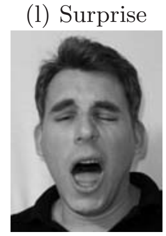

(k) Rage


(l) Surprise

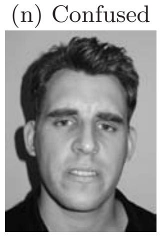

(m) Disgust


(n) Confused


(o) Uproarious laughter


(p) Yawning


(q) Tired


(r) Disdain


(s) Relief Happiness


(t) Slight Sadness

Table 7.5: FER expressions for emotion analysis

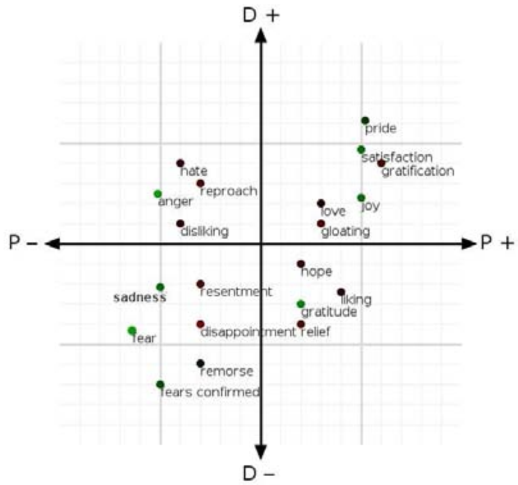


Figure 7.19: Location of example emotions in PD space

7.5.3 (3) AUs mapping into the PAD Space

Given that an emotion is located in certain PAD region, and that this emotion has a set of AUs, we need to figure out the correspondence between a PAD region and all of the AUs.

The methodology consists in using the emotions in Table 7.4 and identify the AUs that describe their movements. This gives us a rough idea of where the AUs are mainly active. The difficulty lies in deciding the PAD region where the AU should be active when it belongs to emotions in different octants. For example, $AU1$ is active in *fear* which is in the **-P -D** quadrant, but is also active in other emotions in the **+P -D** quadrant.

The analysis is divided in: analysis of the AUs in the Pleasure-Dominance (PD) space, and analysis of the AUs in the Arousal (A) space. One of the reasons for this divisions is that it facilitates the analysis of the dimensions where the AUs could be activated. Another reason is that there are AUs that can be easily associated with arousal or activation, as opening of the mouth or the eyes.

From these analysis we can formulate a function dependent on the Pleasure-Dominance or Arousal dimension for each AU, which depicts the area where the AU is active.

As for the analyzed AUs, we consider a reduced set of AUs that results potentially sufficient to express, in a readily recognizable manner a set of facial expressions [53]. The final set of AUs used in this research are presented in Table 7.6.

AU	***Facial Action Code***	***Muscular Basis***
1	Inner Brow Raiser	Frontalis, Pars Medialis
2	Outer Brow Raiser	Frontalis, pars lateralis
4	Brow Lowerer - Frown	Depressor Glabellae, Corrugator, Depressor supercilii
5	Upper Lid Raiser	Levator Palpebrae Superioris
7	Lid Tightnener	Orbicularis oculi, Pars palebralis
10	Upper Lip Raiser	Levator labii superioris
12	Lip Corner Puller	Zygomaticus major
15	Lip Corner Depressor	Triangularis
17	Chin Raiser	Mentalis
25	Lips part	Depressor labii inferioris OR Relaxation of mentalis OR Orbicularis oris
26	Jaw Drop (mouth only)	Masseter, relaxed Temporalis and Internal Pterygoid
43	Eyes closed	Relaxation of Levator palpebrae superioris

Table 7.6: Mood AUs configurations

In the following we present the emotions and methodology used in the analysis of each AU. Table 7.8 contains all the equations to map each AU into the different dimensions.

- $AU1$ **- Inner Brow Raiser**

  This AU is found to be activated in *sadness*, which according to Lance and Marsella [86] is low in pleasure and dominance. It is also found in emotions of *liking* and *relief*, which have positive pleasure.

  For this reason, two analysis were performed: one in **negative Pleasure** (-P) and one in **positive Pleasure** (+P); along **negative Dominance** dimension (-D).

  For the **-P-D** quadrant, we use *sadness* as guide emotion. The FER expression that was compliant with this emotion was *slight sadness* (Figure 7.5 (s)). For the **+P-D** quadrant, the emotion we use for analysis is *relief*. The FER expression that seemed to be compliant with it is *relief happiness* (Figure 7.5 (t)).

  After the AU analysis, we formulate a linear function that returns the area in the -P-D where $AU1$ is activated. We use the values of *sadness* ($p = -0.5$, $d = -0.25$) according to Equation 7.9.

$$AU1_{intensity} = \begin{cases} (-4.0)d & \text{if } d \in (-0.25, 0.0] \\ 1.0 & \text{if } d \in [-1.0, -0.25] \end{cases} \tag{7.9}$$

To map the $AU1$ into the +P-D quadrant using *relief* ($p = 0.2$ and $d = -0.4$) according to Equation 7.10, which is similar to Equation 7.9, but with an offset of -0.4 because *relief* is the point where $AU1$ begins to change.

$$AU1_{intensity} = \begin{cases} 0.0 & \text{if } d \in [-0.4, 0.0) \\ (-4.0)(d + 0.4) & \text{if } d \in (-0.65, -0.4) \\ 1.0 & \text{if } d \in [-1.0, -0.65] \end{cases} \quad (7.10)$$

Figure 7.20 shows the area where $AU1$ is activated.

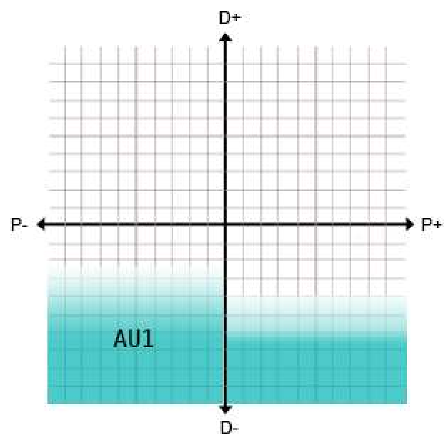


Figure 7.20: Mapping of $AU1$ in PAD

- $AU2$ **- Outer Brow Raiser**

  This AU is also found to be activated in the **negative Dominance** dimension (-D), along the Pleasure dimension. As with $AU1$, two analysis were performed: one in the **negative Pleasure** space (-P), and one in the **positive Pleasure** space (+P).

  For the **-P-D** quadrant, we use *sadness* and *fear* to compute the area. It results in a progression beginning at the location of *sadness* ($p = -0.5$ and $d = -0.25$), and ending where *fear* is located ($p = -0.65$ and $d = -0.45$).

  For the **+P-D** quadrant we used the same analysis as for $AU1$. Figure 7.21 shows the area where $AU2$ is activated. The functions to obtain the areas are in Table 7.8.

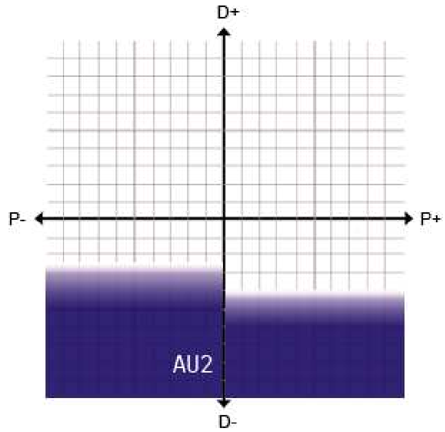


Figure 7.21: Mapping of $AU2$ in PAD

- $AU4$ **- Brow Lowerer**

  $AU4$ is found in the **negative Pleasure** (-P) along the Dominance dimension.

  To map this AU in the **-P+D** quadrant we use *anger* ($p = -0.5$ and $d = 0.25$) because it is located in that quadrant. In FER the expressions considered as anger variants are: *enraged (compressed lips)* and *sternness*, which have about the same dominance value on the -P side (Figure 7.5).

  For the **-P-D** quadrant we use *sadness* ($p = -0.5$ and $d = -0.25$) to compute the intensity of $AU4$. Figure 7.22 shows the area where $AU4$ is activated and the equations to obtain this area are shown in Table 7.8.

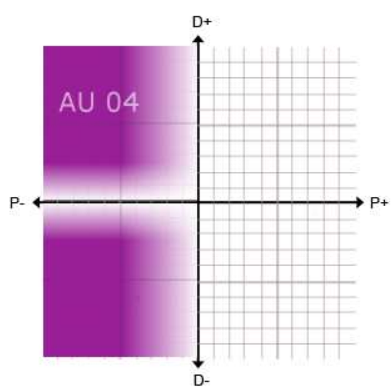


Figure 7.22: Mapping of $AU4$ in PAD

- *AU*6 **- Cheek Raiser**

  The feature *raised cheeks* is a key element for *joy* and appears in displays of genuine emotion, but is missing in fake smiles masking other feelings. Therefore, we map this AU to the **positive Pleasure** (+P) along the Dominance dimension.

  *AU*6 is seen in the FER expressions for *embarrassment smile* and *ingratiating smile* (Figure 7.5), which are representative for *shame*. Nevertheless, shame tends not to be represented with a smile. Therefore, we concluded that the mentioned expressions of smile are a sign of agreeableness towards the interlocutor. That is why we use *liking* ($p = 0.4$ and $d = -0.24$) for the negative dominance (+P-D).

  For the positive dominance (+P+D) we use the emotions *joy* ($p = 0.5$ and $d = 0.25$) and *satisfaction* ($p = 0.5$ and $d = 0.47$). Figure 7.23 shows the area where it is activated and Table 7.8 shows the equations to obtain the area of activation.

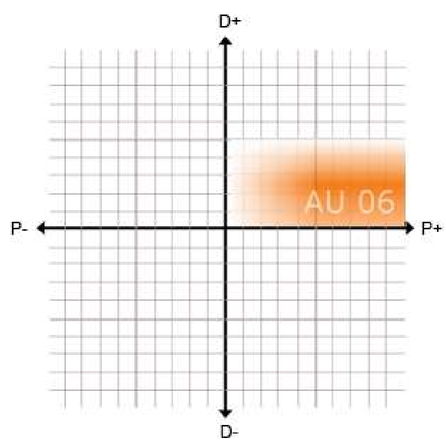


Figure 7.23: Mapping of *AU*6 in PAD

- *AU*10 **- Upper Lip Raiser**

  This AU corresponds to the **positive Dominance** and **negative Pleasure** dimensions (-P+D), since it is a key feature of *contempt*. Similar emotions are *disdain* or *arrogance* (Figure 7.5).

  To compute its intensity we used the emotion *arrogance* ($p = 0.0$ and $d = 0.5$). Table 7.8 presents the equation to compute the activation of this AU, and Figure 7.24 shows its area of activation.

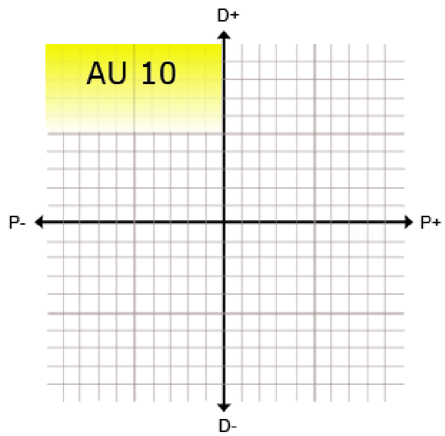


Figure 7.24: Mapping of $AU10$ in PAD

- $AU12$ **- Lip Corner Puller**

  Based on previous studies, it is known that positive pleasure influences the lip corners. For *joy* they are pulled to the ears. Thus, $AU12$ is mapped into the **positive Pleasure** (+P) along the Dominance dimension.

  Regarding FER expressions, on **+P-D** quadrant we can find the *qualifier smile*, the *coy smile* and the *embarrassment smile*, all showing raised lip corners (Figure 7.5).

  On the**+P+D** quadrant we can find the emotion *joy* and its many variants. Thus *joy* is the emotion which is more representative for the activation of this AU.

  Figure 7.25 shows where $AU12$ is located in the space. Table 7.8 presents the equation for its computation.

- $AU14$ **- Dimpler**

  This AU appears in a smiling mouth. This marks a key feature for the **positive Pleasure** dimension (+P).

  One of the FER expressions described by this AU is *enjoyable contempt* (Figure 7.5), which can be seen as the positive pleasure variety of *arrogance*.

  Thus, $AU14$ is mapped to the **+P+D** quadrant. However, as its region of activation is closer to the maximum dominance values and lower positive pleasure values, for computation of this AU we take into account both P and D. Figure 7.26 shows the area where $AU14$ is activated.

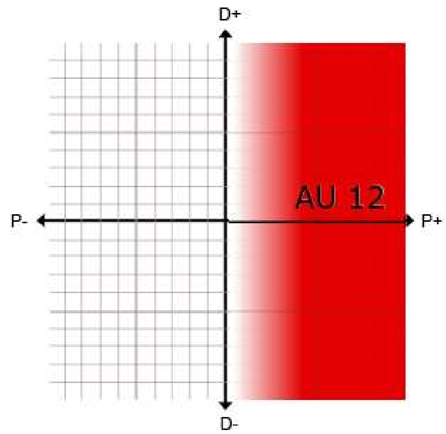


Figure 7.25: Mapping of $AU12$ in PAD

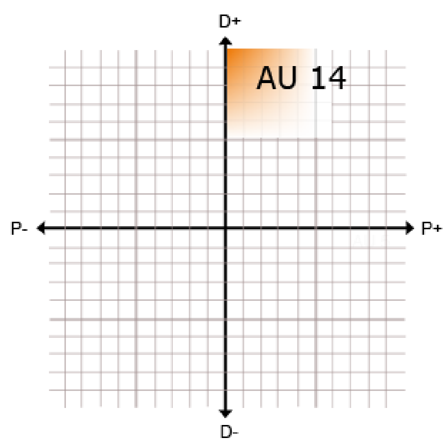


Figure 7.26: Mapping of $AU14$ in PAD

- *AU*15 **- Lip Corner Depressor**

  This AU, similarly to *AU*12, describes the movement of the corner lips, but downwards as in *sadness*, *fear* and *anger*.

  Therefore, *AU*15 is mapped into the **negative Pleasure** dimension (-P) along the Dominance axis. To compute its intensity, we take into consideration the values for *sadness*. Figure 7.27 shows where *AU*15 is located in the space.

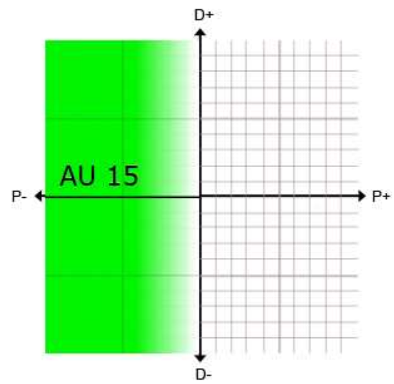


Figure 7.27: Mapping of *AU*15 in PAD

- *AU*5 **- Upper Lid Raiser**

  This AU is found in emotions with a high arousal component such as *fear* ($a = 0.6$), *terror* ($a = 0.82$) or *worry* ($a = 0.l4$). That is why we just considered the **positive Arousal** dimension (+A) to locate *AU*5.

  Regarding FER expressions, we used the ones corresponding to fear, terror and worry, allowing us to define the AU intensity between *terror* and *worry*. Figure 7.28 shows where the AU has values in the Arousal dimension.

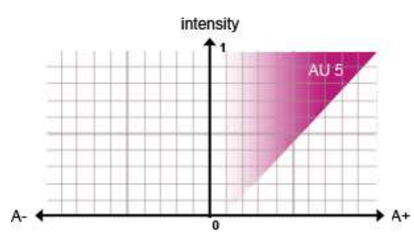


Figure 7.28: Mapping of AU5 in the Activation dimension

- *AU*25 **- Lips Part**

  According to FER, the *AU*25 is found in emotions like *rage*, *surprise*, *disgust*, or in expressions like *dazzled smile*, which would correspond to a confused expression (Figure 7.5). All these emotions have distinctive values in the **positive Arousal** dimension.

  We use *confusion* ($a = 0.27$) and *rage* with $a = 0.72$ to compute the AUs activation. Figure 7.29 shows how the AU increased its intensity only in the activation dimension.

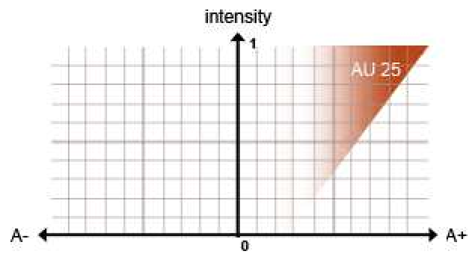


Figure 7.29: Mapping of AU25 in the Activation dimension

- *AU*26 **- Jaw Drop**

  The *AU*26 describes a similar movement as *AU*25, but it involves a movement of the bone, which might result sometimes in a more exaggerated opening of the mouth. Nevertheless, *AU*26 is also found in *surprise*, *fear* or *disgust*, among other FER expressions like *uproarious laughter* and *yawning* (Figure 7.5).

  We use the values of *fear* ($a = 0.6$) and *disgust*, ($a = 0.35$) to compute this AU intensity. Figure 7.30 shows how the AU increased its intensity only in the activation dimension.

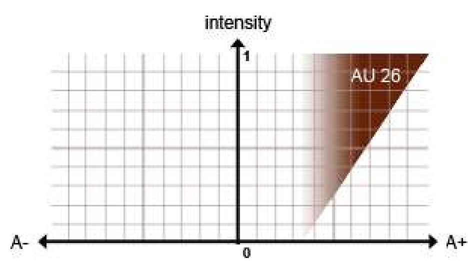


Figure 7.30: Mapping of AU26 in the Activation dimension

- *AU*43 **- Eye Closure**

  *AU*43 describes a movement that is associated emotions or states like *tiredness*, *disdain* or *relief happiness* (Figure 7.5). Thus it belongs to the **negative Arousal** dimension (-A).

  To compute the area where *AU*43 is activated we use the arousal value of *fatigued* ($a = -0.57$). Figure 7.31 shows the location of this AU in the activation dimension.

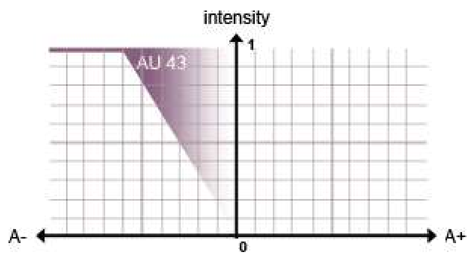


Figure 7.31: Mapping of AU43 in the Activation dimension

As a result, the set of AUs in each mood are shown in Table 7.7.

Mood	+P (AUs)	-P (AUs)	+A (AUs)	-A (AUs)	+D (AUs)	-D (AUs)
Exuberant	1, 2, 6, 12, 14	–	5, 25, 26	–	4, 6, 10, 12, 14, 15	–
Bored	–	1, 2, 4, 10, 15	–	43	–	1, 2, 4, 6, 12, 15
Docile	1, 2, 6, 12, 14	–	–	43	–	1, 2, 4, 6, 12, 15
Hostile	–	1, 2, 4, 10, 15	5, 25, 26	–	4, 6, 10, 12, 14, 15	–
Anxious	–	1, 2, 4, 10, 15	5, 25, 26	–	–	1, 2, 4, 6, 12, 15
Relaxed	1, 2, 6, 12, 14	–	–	43	4, 6, 10, 12, 14, 15	–
Dependent	1, 2, 6, 12, 14	–	5, 25, 26	–	–	1, 2, 4, 6, 12, 15
Disdainful	–	1, 2, 4, 10, 15	–	43	4, 6, 10, 12, 14, 15	–

Table 7.7: Set of AUs for each mood in PAD space

Table 7.8 is a summary of all the equations formulated with the previous analysis, and it also contains the graphs that depict the areas where the AUs are activated in the PAD space.

AU	Emotions	Equations	Comments
AU1	sadness	$AU1 = \begin{cases} (-4.0)d; & d \in (-0.25, 0.0] \wedge p \in [-1.0, 0.0) \\ 1.0; & d \in [-1.0, -0.25] \wedge p \in [-1.0, 0.0) \end{cases}$	Linear function from $d = 0.0$ to $d = -0.25$
	relief	$AU1 = \begin{cases} 0.0; & d \in [-0.4, 0.0) \wedge p \in (0.0, 1.0] \\ (-4.0)(d + 0.4); & d \in (-0.65, -0.4) \wedge p \in (0.0, 1.0] \\ 1.0; & d \in [-1.0, -0.65] \wedge p \in (0.0, 1.0] \end{cases}$	offset of -0.4 because $AU1$ begins to change in *relief*
AU2	sadness, fear	$AU2 = \begin{cases} 0.0; & d \in (-0.25, 0.0] \wedge p \in [-1.0, 0.0) \\ (-4.0)d; & d \in (-0.45, -0.25] \wedge p \in [-1.0, 0.0) \\ 1.0; & d \in [-1.0, -0.45) \wedge p \in [-1.0, 0.0) \end{cases}$	progression begins at *sadness*, ending at *fear*
	relief	$AU2 = \begin{cases} 0.0; & d \in [-0.4, 0.0] \wedge p \in (0.0, 1.0] \\ (-4.0)(d + 0.4); & d \in (-0.65, -0.4) \wedge p \in (0.0, 1.0] \\ 1.0; & d \in [-1.0, -0.65] \wedge p \in (0.0, 1.0] \end{cases}$	
AU4	anger	$AU4 = \begin{cases} (4d)(-2p); & p \in (-0.5, 0.0] \wedge d \in (0.0, 0.25) \\ (-2.0)p; & p \in (-0.5, 0.0] \wedge d \in [0.25, 1.0] \\ (4.0)d; & p \in [-1.0, -0.5] \wedge d \in (0.0, 0.25) \\ 1.0; & p \in [-1.0, -0.5] \wedge d \in [0.25, 1.0] \end{cases}$	this AU is dependent on pleasure and dominance
		$AU4 = \begin{cases} (-4d)(-2p); & p \in (-0.5, 0.0] \wedge d \in (-0.25, 0.0] \\ (-2.0)p; & p \in (-0.5, 0.0] \wedge d \in (-1.0, -0.25] \\ (-4.0)d; & p \in [-1.0, -0.5] \wedge d \in (-0.25, 0.0] \\ 1.0; & p \in [-1.0, -0.5] \wedge d \in [-1.0, -0.25] \end{cases}$	
AU6	liking, joy, pride	$AU6 = \begin{cases} (2.0)(d + 0.25); & d \in (-0.25, 0.25) \\ (4.0)(0.5 - d); & d \in [0.25, 0.5) \\ 1.0; & d \in [0.5, 1.0] \end{cases}$	
AU10	arrogance	$AU10 = \begin{cases} (2.0)(d - 0.5); & d \in [0.5, 1.0] \\ 0.0; & d \in [0.0, 0.5) \end{cases}$	

AU12	joy	$AU12 = \begin{cases} 0.0; & p \in [-1.0, 0.0) \\ (2.0)p; & p \in [0.0, 0.5) \\ 1.0; & p \in [0.5, 1.0] \end{cases}$	Joy is representative along dominance
AU14	enjoyable contempt	$AU14 = \begin{cases} 2(0.5 - p)2(d - 0.5); & p \in [0.0, 0.5) \wedge d \in (0.5, 1.0] \\ 0.0; & else \end{cases}$	Enjoyable contempt: arrogance with positive pleasure
AU15	sadness	$AU15 = \begin{cases} 0.0; & p \in (0.0, 1.0] \\ (-2.0)p; & p \in (-0.5, 0.0] \\ 1.0; & p \in [-1.0, -0.5] \end{cases}$	
AU5	worry, terror	$AU5 = \begin{cases} 0.0; & a \in [-1.0, 0.1] \\ \frac{a-0.1}{0.7}; & a \in (0.1, 0.8) \\ 1.0; & a \in [0.8, 1.0] \end{cases}$	progression begins at *worry*, ending at *terror*
AU25	confusion, rage	$AU25 = \begin{cases} 0.0; & a \in [0.0, 0.3] \\ \frac{a-0.3}{0.4}; & a \in (0.3, 0.7) \\ 1.0; & a \in [0.7, 1.0] \end{cases}$	progression begins at *confusion*, ending at *rage*
AU26	disgut, fear	$AU26 = \begin{cases} 0.0; & a \in [0.0, 0.35] \\ \frac{a-0.35}{0.25}; & a \in (0.35, 0.6) \\ 1.0; & a \in [0.6, 1.0] \end{cases}$	progression begins at *disgust*, ending at *fear*
AU43	fatigue	$AU26 = \begin{cases} 0.0; & a \in [0.0, 1.0] \\ \frac{a}{-0.6}; & a \in (-0.6, 0.0) \\ 1.0; & a \in [-0.6, -1.0] \end{cases}$	

Table 7.8: Equations to obtain the degree of activation of each AU in the PAD space

7.6 Visualization of Personality Traits

Our research in the visualization of personality is motivated by the observation that over time people can make assumptions, and even determine the personality of another known person based on certain characteristics. Therefore, we raise the question: *is it possible to perceive personality from the face of a character?*. Moreover, the former question raises another question: *how to visualize personality in a character?*

To give an answer to these questions, we explore through experimentation the characteristics, or visual cues, that are taken into account when perceiving personality. Visual cues are defined as those facial actions, movements or states that can be static or dynamic. Examples of visual cues are age, gender or attractiveness.

Our premise is based on the work of Arya et al. [7], where it is said that ‘*‘personality types should be able to affect all possible facial actions directly and independently of the mood*”. It also applies to expressions of emotions. In this way more believable characters could be created since its personality would be manifested in a much clearly manner.

We focus on the perception of the personality traits *Extraversion*, *Agreeableness*, and *Emotional Stability* taken from the Five Factor model, when using two visual cues: ***head orientation*** and ***eye gaze***. These visual cues are given by the FACS Action Units: $AU51$, $AU52$, $AU53$, $AU54$ for head orientation, and $AU61$, $AU62$, $AU63$, $AU64$ for eye gaze.

Extraversion can be defined by seven components: venturesomeness, affiliation, positive affectivity, energy, ascendance, and ambition [151]. On the other hand, people low in extraversion are described as quiet, reserved, retiring, shy, silent, and withdrawn.

Neuroticism, or low Emotional Stability, represents individual differences in the tendency to experience distress, and in the cognitive and behavioral styles that follow from this tendency. In addition, individuals low in Neuroticism may be defined as they are simply calm, relaxed, even-tempered, and unflappable.

The Agreeableness factor was taken into consideration because the idea is to generate agents that the user can interact with, and this factor measures the level of friendliness, cooperation, generosity, among other socially, or human related characteristics.

7.6.1 Head Pose and Eye Gaze

As mentioned previously, the aim of this research is to explore the influence of static visual cues on the perception of a character's personality. The idea of using the these two visual cues: eye gaze and head tilts, was obtained from the work of Bee et al. [15], who studied their influence when a virtual agent is expected to express social dominance; and Arya et al. [7] who defined a set of visual cues (among them head turn, head tilt, head down and averted gaze) to map personality dimensions Dominance and Affiliation.

Finally, we decided to also study neuroticism for being the other personality trait that is present in all personality models, from Eysenck [52] to these days.

7.6.2 Hypothesis

In the experiment that is going to be explained in the following, we assess the relationship between these non-verbal facial cues and their influence on the perception of a character's personality. We expect the following outcomes:

- The perception of the three personality traits Extraversion, Agreeableness, and Emotional Stability is not influenced whether the virtual character's head points to the left or to the right.
- The perception of Extraversion, Agreeableness, and Emotional Stability is influenced by the different directions where the head is pointing to. It makes a difference if the virtual character, for example, is looking upwards-sideways or downwards-center.
- Depending on the personality trait, direction plays a role in how these traits are perceived. We expect that it makes a difference, for example, how Extraversion is perceived in contrast to Agreeableness when the character is looking upwards.
- Not only head orientation influences the perception of the personality traits. Also variations of eye gaze directions further influence how the personality traits of the virtual character are perceived.

7.6.3 Methodology

The methodology consisted of:

1. Creating different static images with combined head poses (upwards, center, downwards, sideways) and different eye gaze (upwards, center, downwards, sideways)
2. Carrying out an online survey to measure the perception of personality on those images

3. Evaluating the results to associate visual cues to extraversion, agreeableness, or emotional stability.

7.6.4 Experimental Study

To carry out the experiment we used the virtual agent Alfred, from the Game Engine of the University of Augsburg 7.3.1.

The visual cues: head movement and gaze orientation were calculated by varying horizontal and vertical angles, each in three symmetric steps.

For both vertical and horizontal axis, the neutral center position remained at 0.0°. The positions for turning the head sideways were set as 8.5° for looking left, from the agent's point of view, and -8.5° for looking right. For tilting the head vertically, the high target was located at 8.0° degrees, whereas the low one was at -8.0°. Since the distance between neck and eye joints weakened the visible effect on the eye movement, the vertical angles had to be doubled for the eye targets.

All limits were chosen in regard to the goal that the pupils should remain visible, even when the eyes look in the opposite direction of the head.

By combining these angles, nine different targets could be provided for the survey. These were then converted to Cartesian coordinates using a fixed radius for all target angles, and sent to the virtual agent's IK component for every combination of head pose and eye gaze. The 81 resulting expressions were captured as screenshots.

However, to ensure a sufficient number of votes per picture, the number of samples had to be reduced and redundant combinations eliminated. To do this, previous observations were performed with a reduced group of users, obtaining as a result that the direction of lateral head movements would not cause much of a difference. Thus we decided to merge both *left* and *right* looking images into one "sideways" category. To keep the natural variation, about half of the required images were chosen randomly to either gaze in one or the other direction. The associated eye gaze targets were mirrored to keep the proper relation between head and eye movements.

In the end, we worked with a reduced set of 54 images (6 head directions $\times$ 9 eye directions) of Alfred. Combinations of orientations were written: *vertical-horizontal*, e.g. "upwards-center". Table 7.9 shows some samples of head orientations.

Description	Image	Description	Image
head neutral		head turned left	
head turned right		head up	
head down			

Table 7.9: Varying head orientation.

Questionnaire

133 subjects (47 female and 86 male) participated in the experiment through an online questionnaire. The mean age was 26.6 ($SD = 8.8$). The questions were provided in English, German or Spanish, depending on the subject's mother tongue.

The questionnaire consisted of 54 static images, where each image was judged at least 10 times. The images corresponded to a virtual character in which head orientation (upwards-center, upwards-sideways, middle-center, middle-sideways, downwards-center, downwards-sideways) and eye gaze (upwards-center, downwards-center, upwards-sideways, downwards-sideways) were combined.

Then the experimental stimuli which consisted of 15 images per user were presented one at a time, in random order. For each stimulus the participant had to answer to six items of the Ten-Item Personality Inventory (TIPI) [66] presented in a 7-item Likert Scale, where 1 corresponded to "Disagree Strongly" and 7 to "Agree Strongly". Table 7.10 shows the items presented for each image of the questionnaire.

Trait	Item
Extraversion	Extraverted, enthusiastic Reserved, quiet
Agreeableness	Critical, quarrelsome Sympathetic, warm
Emotional Stability	Anxious, easily upset Calm, emotionally stable

Table 7.10: Questionnaire items for perception of head orientation.

7.6.5 Results

The following results show the mean values μ and standard deviations σ related to how was Alfred perceived over all ratings:

- Neither as extroverted nor as introverted: $\mu = 3.7$, $\sigma = 1.2$
- As neutral regarding agreeableness: $\mu = 3.8$, $\sigma = 1.4$
- As slightly emotional stable: $\mu = 4.3$, $\sigma = 1.4$.

Looking to the Right and to the Left

To study if the side where the agent is looking to has an influence on the perception of personality, we assumed that in general there are *no noticeable difference* among the personality traits whether the agent looks to the right or to the left.

The method was to apply a two-tailed independent t-test to the overall values for Extraversion, Agreeableness, and Emotional Stability dependent on which side the virtual agent is looking.

The results of the t-test with 329 degrees of freedom for the trait of **Extraversion**, $t(329) = -1.2$, $p = .25$, $r = .07$, showed that there was no significant difference for Extraversion between Alfred looking to the left ($\mu = 3.8$, $\sigma = 1.2$) and looking to the right ($\mu = 3.9$, $\sigma = 1.3$), given that the obtained p-value is above the probability threshold. Moreover, the effect size r has a value below .1, which demonstrates the weak relationship between Extraversion and the side to where the character is looking to. Therefore, we can accept the assumption of no noticeable difference in Extraversion when the agent looks to the left or to the right.

Agreeableness also did not show any significant differences for the virtual character Alfred between looking to the left ($\mu = 3.8$, $\sigma = 1.5$) and looking to the right ($\mu = 3.7$, $\sigma = 1.4$), $t(329) = .62$, $p = .54$, $r = .03$. Again, given that the obtained p-value is above the threshold and the effect size r is below .1, a weak relationship between Agreeableness and the side to where the character is looking to is shown. Hence, we also can accept the assumption of no noticeable difference.

Finally, **Emotional Stability** as well did not show any significant differences between looking to the left ($\mu = 4.4$, $\sigma = 1.4$) and looking to the right ($\mu = 4.4$, $\sigma = 1.2$), $t(329) = -.35$, $p = .73$, $r = .02$. In the latter case, as with Extraversion and Agreeableness, the effect size r is for all three personality dimensions below .1 and thus can be further interpreted as not even a small effect.

Extraversion

Positioning the head to the ***upwards-sideways*** got the **highest rating** for Extraversion, while redirecting the head ***downwards-center*** got the **lowest rating** for Extraversion (Figures 7.32 and 7.33).

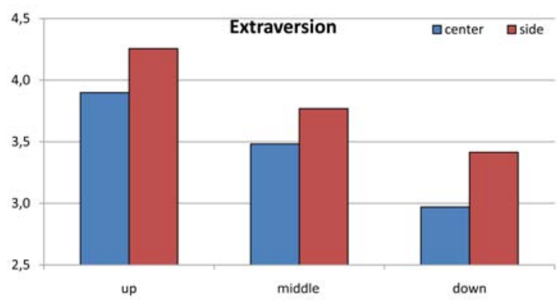


Figure 7.32: Mean values for *Extraversion* dependent on the head orientation.

The one-way ANOVA showed that there was a significant effect on the perception of Extraversion on levels of the different head orientations, $F(5, 663) = 15.4$, $p < .001$, $\omega^2 = .10$.

Tukey post hoc tests revealed several significant differences within the perception of Extraversion dependent on the head orientation. Table7.11 shows these results, where each row and column corresponds to the combination of vertical and horizontal positioning, e.g. **U-C** means "upwards-center".

Figure 7.33: The head orientation (*downwards-center*) with the lowest rating (left) and the one (*upwards-sideways*) with the highest rating (right) for *Extraversion*.

	U - S	U - C	M - S	M - C	D - S	D - C
U - S	—	n.s.	*	***	***	***
U - C	n.s.	—	n.s.	+	*	***
M - S	*	n.s.	—	n.s.	n.s.	***
M - C	***	+	n.s.	—	n.s.	*
D - S	***	*	n.s.	n.s.	—	+
D - C	***	***	***	*	+	—

Table 7.11: Post-hoc comparisons for *Extraversion* and the varying head orientations. Vertical orientations: U = upwards, M = middle, D = downwards. Horizontal orientations: S = sideways, C = center. + $p < .1$, * $p < .05$, *** $p < .001$, n.s. = not significant.

Alfred with its head pointing upwards-sideways ($\mu = 4.3$, $\sigma = 1.2$) was perceived significantly less extraverted than the heads pointing to the middle-sideways ($\mu = 3.8$, $\sigma = 1.3$, $p < .05$), to the middle-center ($\mu = 3.5$, $\sigma = 1.2$, $p < .001$), downwards-side ($\mu = 3.4$, $\sigma = 1.1$, $p < .001$), and downwards-center ($\mu = 3.0$, $\sigma = 1.1$, $p < .001$).

An upwards-center head position ($\mu = 3.9$, $\sigma = 1.2$) is perceived as less extraverted than the heads looking to the center ($\mu = 3.5$, $\sigma = 1.2$, $p < .1$), downwards-side ($\mu = 3.4$, $\sigma = 1.1$, $p < .05$), and downwards-center ($\mu = 3.0$, $\sigma = 1.1$, $p < .001$).

A head directed middle-sideways ($\mu = 3.8$, $\sigma = 1.3$) is perceived as less extraverted than a head looking downwards-center ($\mu = 3.5$, $\sigma = 1.2$, $p < .001$).

As we applied a two-tailed post hoc test, the significant results are also valid vice versa.

In general we can see that when Alfred has the head sideways, the perception of Extraversion is increased independently of the vertical orientation (Figure 7.32). Nevertheless, the vertical orientation has also influence in the perception. A raised head is perceived as more extraverted than a head oriented to the middle or downwards.

Regarding eye gaze, we could not find any significant differences among the six head orientations within the nine eye directions.

Agreeableness

The **highest value** for Agreeableness was achieved when the virtual character looked ***downwards-center***. The **lowest value** was achieved for a virtual character looking ***upwards-center*** (Figures 7.34 and 7.35).

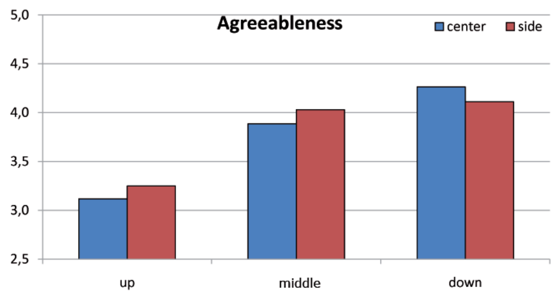


Figure 7.34: Mean values for *Agreeableness* dependent on the head orientation.

Figure 7.35: The head orientation (*upwards-center*) with the lowest rating (left) and the one (*downwards-center*) with the highest rating (right) for *Agreeableness*.

There was a significant effect on the perception of Agreeableness on levels of the different head orientations, $F(5, 663) = 14.4$, $p < .001$, $\omega^2 = .09$.

Table 7.12 shows the results of the Tukey post hoc tests, which revealed several significant differences within the perception of Agreeableness dependent on the head orientation

	U - S	U - C	M - S	M - C	D - S	D - C
U - S	—	n.s.	***	**	***	***
U - C	n.s.	—	***	***	***	***
M - S	***	***	—	n.s.	n.s.	n.s.
M - C	**	***	n.s.	—	n.s.	n.s.
D - S	***	***	n.s.	n.s.	—	n.s.
D - C	***	***	n.s.	n.s.	n.s.	—

Table 7.12: Post-hoc comparisons for *Agreeableness* and varying head orientation. Vertical orientations: U = upwards, M = middle, D = downwards. Horizontal orientations: S = sideways, C = center. ** $p < .01$, *** $p < .001$, n.s. = not significant

The head directed upwards-sideways ($\mu = 3.3$, $\sigma = 1.3$) was perceived as less agreeable than a head directed to the middle-sideways ($\mu = 4.0$, $\sigma = 1.4$, $p < .001$), a centered head ($\mu = 3.9$, $\sigma = 1.3$, $p < .01$), a head downwards-sideways ($\mu = 4.1$, $\sigma = 1.4$, $p < .001$), or downwards-center ($\mu = 4.3$, $\sigma = 1.2$, $p < .001$).

Alfred with the head looking upwards-center ($\mu = 3.1$, $\sigma = 1.3$) was perceived as less agreeable than when looking to the center-sideways ($\mu = 4.0$, $\sigma = 1.4$, $p < .001$), to the center ($\mu = 3.9$, $\sigma = 1.3$, $p < .001$), downwards-sideways ($\mu = 4.1$, $\sigma = 1.4$, $p < .001$), and downwards-center ($\mu = 4.3$, $\sigma = 1.2$, $p < .001$).

The lowest values for Agreeableness were achieved for the virtual character looking upwards. Higher values could be achieved for Alfred with centered head, and even slightly higher values were achieved for looking downwards (Figure 7.34).

Regarding eye gaze, also for Agreeableness we could not find any significant differences for the varying eye gaze directions dependent on the six head orientations.

Emotional Stability

Alfred looking ***middle-side*** achieved the **highest ratings** for Emotional Stability and the ***upwards-center*** orientation achieved the **lowest ratings** (Figures 7.36 and 7.37).

There was a significant effect on the perception of Emotional Stability on levels of the different head orientations, $F(5, 663) = 3.6$, $p < .01$, $\omega^2 = .02$.

Tukey post hoc tests revealed only one significant difference within the perception of Emotional Stability dependent on the head orientation.

Alfred's head directed to the middle-sideways ($\mu = 4.7$, $\sigma = 1.2$) was perceived with significantly lower Emotional Stability than directed upwards-center ($\mu = 4.0$, $\sigma = 1.3$)

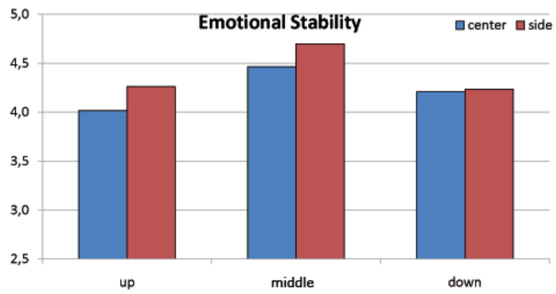


Figure 7.36: Mean values for *Emotional Stability* dependent on the head orientation.

Figure 7.37: The head orientation (*upwards-center*) with the lowest rating (left) and the one (*middle-sideways*) with the highest rating (right) for *Emotional Stability*.

with $p < .001$.

Looking to the middle-sideways ($\mu = 4.7$, $\sigma = 1.2$) was perceived as more emotional stable than looking downwards-center ($\mu = 4.2$, $\sigma = 1.5$, $p < .1$).

For Emotional Stability the highest value were perceived when Alfred's vertical head orientation was directed to the middle, independently if it was centered or side-oriented. Furthermore, looking upwards or downwards got in general the lowest values for Emotional Stability (Figure 7.36).

7.6.6 Discussion

The obtained results provided us with data that could be used to improve the modeling of personality in virtual agents and therefore, the interaction between real users and these agents. An important aspect was the study of visual cues for certain personality traits that have been not studied before, as emotional stability and agreeableness.

With the experiment we concluded that, for the Alfred character the "upwards-sideways" head orientation is related to extraversion, "downwards-center" head orientation to agreeableness, and "center-sideways" head orientation to emotional stability. We also found that the side to where the character is facing (left or right) and eye gaze do not influence the perception of personality traits.

7.7 Summary

This chapter described the algorithms and methods we used to visualize emotions, mood and personality.

Emotions were visualized in a MPEG-4 based avatar, in which we implemented an algorithm that using expressions of universal emotions is capable of generating expressions for intermediate emotions, either by combining two universal emotions or categorizing one of them. As a result we obtained a set of facial expressions which were correctly identified by a group of subjects, demonstrating the validity of the algorithm.

One of the novelties of this work is the generation of facial expressions for moods. Our main contribution is the development of a set of FACS-based functions which locate AUs into the PAD Space model, allowing us to associate those AUs with the moods corresponding to the PAD model. In this way, we can generate facial expressions for the moods using the AUs activated in the corresponding octants of the space.

Finally, for personality we performed an experiment to explore how the visual cues: head pose and eye gaze, influence the perception of three personality traits: extraversion, agreeableness and emotional stability. In result we obtained that for the evaluated character, extraversion was associated with a head in an upwards-sideways position, agreeableness with the head in a downwards-center position, and emotional stability with a center-sideways position. Using this subjective information about how personality is perceived we could enhance facial expressions, achieving more believable characters.

Chapter 8

Evaluation

Not everything that can be counted counts, and not everything that counts can be counted.

Albert Einstein

The results of formal evaluations are presented in this chapter aiming at assessing the degree of user's perception, the believability of the characters and the effectiveness of the computational affective model we have presented.

To achieve our objective, we performed a number of individual experiments with different subjects. That was the most accurate way to evaluate each part of the framework and guarantee its functionality, given that a quantitative evaluation of the whole system was infeasible.

The chapter is organized as follows. First, we present the general objectives of this evaluation and what we want to achieve. Then, the following subsections explain in detail the subjects, apparatus and procedures used in each experiment. Finally, a summary of the chapter is given.

8.1 Objectives of Evaluation

As seen in the previous chapters, the framework we have developed has three differentiated modules, each one with a specific functionality. The first module corresponds to the semantic module, which uses ontologies and logic rules for context representation and elicitation of emotions given certain context. The second module is the affective module, which takes the emotions elicited by the semantic model, maps them into a Pleasure-Arousal-Dominance space (PAD) and process them to obtain the mood of the character. Finally, the third module is the visualization module, which implements the algorithms and methods for the generation of facial expressions of emotions and mood.

Nevertheless, an evaluation of the whole framework, all in once is a difficult task because there would be too many variables to take into consideration. That is why we broke down the evaluation process and designed various experiments which will validate our work and will give us hints of how to improve the generation of context and the visualization of affective traits. The evaluation objectives are:

1. Validation of the expressions of basic and intermediate emotions, and their perception as such by the subjects.

2. Validation of the expressions of mood elicited by the Affective Module, and their perception as such by the subjects.

3. Evaluation of how the emotions elicited in different scenes of the Context Representation Module are perceived by the subjects.

In the following we explain how we achieve the former objectives through subjective experiments.

8.2 Experiment: Visualization of Emotions

In this section we present an experiment that validates the facial expressions for *universal* and *intermediate* emotions that were generated using the MPEG-4 standard.

8.2.1 Hypothesis

Before carrying on this experiment we formulated the following hypothesis:

- Expressions of universal emotions are better perceived than expressions of intermediate emotions, obtaining higher success rates in static images.

- Given that intermediate emotions are obtained from the combination of two universal ones, subjects would be capable of identify at least one of the universal emotions that composed the intermediate one.

Regarding the second hypothesis, we did not ask for recognition of the specific intermediate emotion because, as Ekman mentioned in [48], the name one can give to an emotion depends a lot on context and the situation in which that emotion arises.

8.2.2 Methodology

To perform the evaluation, first we selected a group of images correspondent to a set of the generated facial expressions. This selection was the result of previous observations, where we realized that different emotions shared the same facial expression. Table 8.1 contains a list with the emotions which expressions were evaluated.

Nr.	**Emotion**	**Nr.**	**Emotion**
1	Joy	9	Love
2	Sadness	10	Disappointment
3	Disgust	11	Satisfaction
4	Anger	12	Pity
5	Surprise	13	Admiration
6	Fear	14	Reproach
7	Gloating	15	Gratitude
8	Hate	N	Neutral

Table 8.1: Evaluated emotions

To evaluate the validity of the generated expressions, we carried out a subjective study with the following methodology:

1. Fulfillment of an *in-situ* paper survey to measure the perception of emotions on the generated images.

2. Evaluation of the results to validate the recognition of expressions of universal emotions, and to validate the algorithm for generation of expressions of intermediate emotions.

8.2.3 Experimental Study

To carry out the experiment we used the virtual agent Alice, modeled using the FaceGen software [76] and animated using the Xface toolkit (Section 7.3.2).

75 students of the 2nd year of Computer Science at the Universitat de les Illes Balears, Spain, with no previous knowledge about emotion recognition participated in the survey.

Their age ranged between 18 and 42 years old ($\mu \approx 22$).

The images were projected in a screen of 120 x 120 cm, and the subjects needed to fill the paper questionnaire in Spanish. The total evaluation time was 40 minutes.

The item we wanted to evaluate was the **recognition of universal emotions in images corresponding to 16 facial expressions**. With this experiment we verified the efficacy of the algorithm used for generation of intermediate emotions.

Questionnaire

The experimental stimuli consisted on a set of 16 images: 15 images corresponding to high intensity emotions, and 1 image of the neutral expression.

Each image was projected during 30 seconds before continuing with the next one. For each image, subjects needed to choose which universal emotion was associated to the projected image. The options were:

- (**CN**): neutral expression
- (**A**): high joy
- (**T**): high sadness
- (**E**): high anger
- (**D**): high disgust
- (**S**): high surprise
- (**M**): high fear
- (**Other**): specify another affective word to be associated to the expression.

Results

Table 8.2 shows the results of recognition of universal emotions on each of the 16 expressions. First column presents the emotion associated to the evaluated expression. Second column presents the emotions that are combined to generate the corresponding intermediate emotion. The following columns present the percentages of the number of hits (%), regarding recognition of the facial expressions.

Evaluated Expression	**Universal Emotion(s)**	**Neutral**	**J**	**Sa**	**D**	**A**	**Su**	**F**
Neutral	–	**80**	9	1	2	0	0	0
Joy	J	1	**93**	0	1	0	2	0
Sadness	Sa	0	0	**87**	8	2	0	0
Disgust	D	1	0	2	**60**	28	2	0
Anger	A	0	0	3	3	**84**	2	0
Surprise	Su	0	1	0	2	5	**70**	15
Fear	F	2	0	3	6	1	52	**33**
Gloating	J/Su	16	**42**	1	2	2	**26**	6
Hate	A	0	0	2	18	**68**	0	1
Love	J/Su	2	**59**	0	0	0	**27**	1
Disappointment	D/Sa	18	1	**38**	**17**	0	11	7
Satisfaction	J	4	**84**	1	0	2	2	0
Pity	Sa/F	1	0	**24**	21	1	1	**43**
Admiration	J/Su	4	**46**	0	0	1	**41**	2
Reproach (**H**)	D/A	4	1	0	**54**	**33**	1	0
Gratitude (**H**)	J	5	**83**	0	2	1	1	1

Table 8.2: % of recognition of universal emotions in 31 facial expressions. **J**: Joy, **Sa**: Sadness, **D**: Disgust, **A**: Anger, **Su**: Surprise, **F**: Fear

- **Universal Emotions**. 6 expressions for universal emotions were studied. Figure 8.1 depicts the recognition hits percentages presented in Table 8.2.

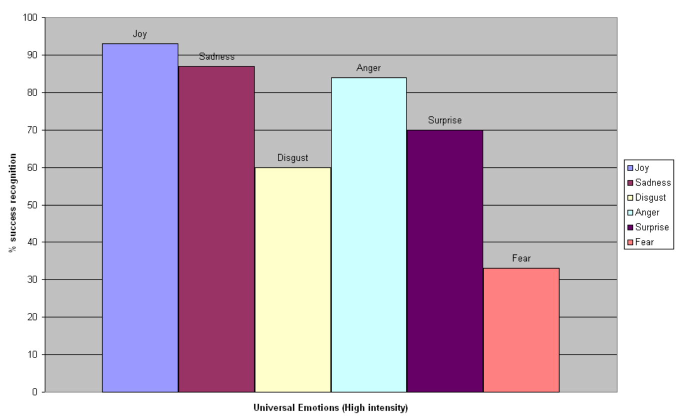


Figure 8.1: % of recognition success for Universal emotions.

As can be seen in Figure 8.1, in most of the cases expressions of *joy, sadness, anger* and *surprise* where recognized. On the other hand, *disgust* and *fear* obtained lower success rate. *Disgust* tended to be confused with *anger*, and *fear* with *surprise*.

This last result has to do with the fact that our expressions for *surprise* and *fear* share some facial configurations as raised eyebrows and open mouth. Nevertheless, this result was expected because both expressions are mainly differentiated through context where the event is taking place and timing issues, which cannot be represented on a still image.

Moreover, Ekman and Friesen [47] see *fear* differing from *surprise* in three ways:

1. Whilst surprise is not necessarily pleasant or unpleasant, even mild fear is unpleasant.
2. Something familiar can induce fear, but hardly surprise (for example, a visit to the dentist).
3. Whilst surprise usually disappears as soon as it is clear what the surprising event was, fear can last much longer, even if the event is known.

- **Intermediate Emotions**. 9 emotions where evaluated: 3 categorized from one universal emotion and 6 originated from the combination of two universal emotions. The emotions categorized from one universal emotion are *hate, satisfaction* and *gratitude*. The emotions obtained from the combination of two universal ones are *disappointment, gloating, love, pity, admiration* and *reproach*.

  From Figure 8.2 we can observe that all the expressions categorized from one universal emotion were correctly recognized by the majority of subjects.

  Regarding expressions for emotions generated from the combination of two universal ones, Figure 8.3 depicts the percentages of success rates when subjects evaluated these images. It can be seen that for all the expressions the recognition rates of both universal emotions used for generating the expression of the intermediate one obtained the highest percentages.

8.2.4 Discussion

At the beginning of this section two hypothesis were formulated. In the first hypothesis we wanted to see if expressions of universal emotions were better perceived than expressions of

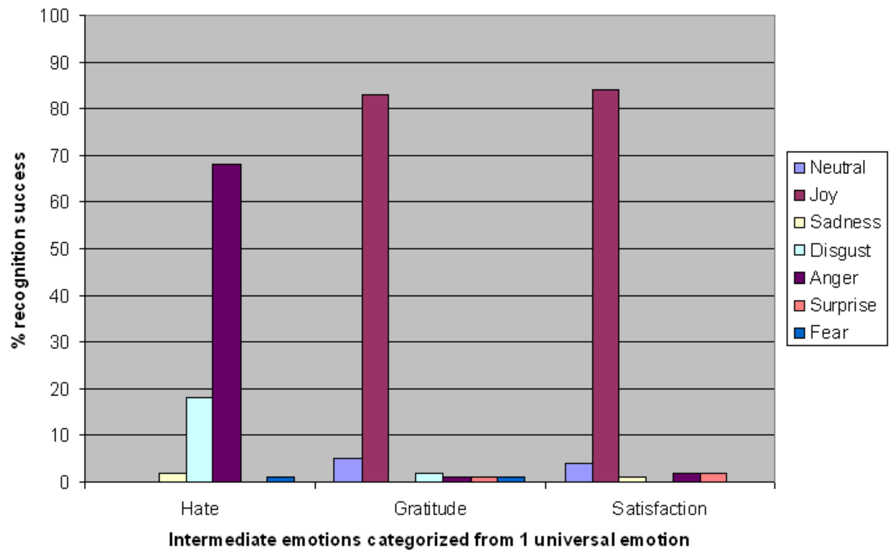


Figure 8.2: % of recognition success for Intermediate emotions categorized from 1 universal emotion

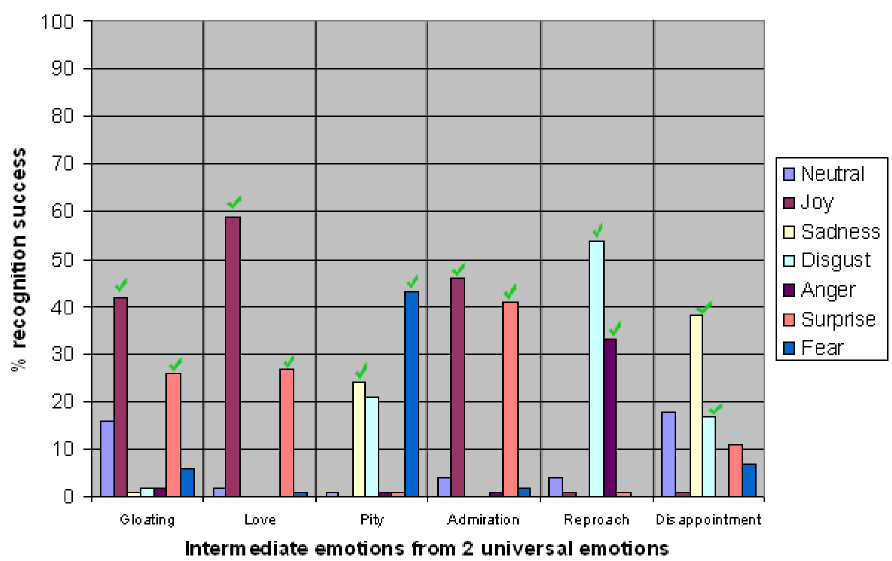


Figure 8.3: % success for Intermediate emotions generated from combining 2 universal emotions

intermediate emotions. From the results obtained we could observe that universal emotions were indeed easily recognized. This fact helped to the good results in the recognition of intermediate expressions, given that the universal ones we used to generate them were correctly assessed.

Regarding the second hypothesis, we wanted to know if subjects could identify the universal emotion (or emotions) used for the generation of the expression of the intermediate emotion. Indeed, it was proved with the results that showed that the great majority of the participants recognized in an high percentage the universal emotion from which the intermediate is obtained. Even more, the results showed that when it came to intermediate expressions generated from two universal ones, the two corresponding universal emotions obtained the highest recognition rates above the rest of universal emotions.

8.3 Experiment: Visualization of Moods

The aim of this experiment is to validate the rules and functions formulated in Section 7.5, and at the same time to generate expressions for each of the 8 moods defined by the PAD model (*Exuberant*, *Bored*, *Disdainful*, *Dependent*, *Docile*, *Hostile*, *Anxious* and *Relaxed*).

The set of facial expressions were obtained by combining different levels of pleasure (P), arousal (A) and dominance (D), where each level corresponded to *low* (values close to zero), *medium*, and *high* (values close to one) intensities. In this way, we obtained different AUs combinations, that described expressions that can be associated with different PAD values.

Then, these expressions were subjectively evaluated but a group of subjects, shedding light on the intensity of PAD combinations that results in expressions that would correspond to a correct identification of certain mood.

8.3.1 Hypothesis

The generation of facial expressions for moods is a topic that has been poorly addressed by previous researches. Therefore, this evaluation is a mixing of experimentation and validation, expecting to prove the following hypothesis:

- All 8 moods have corresponding facial expressions, which are described by the AUs activated in the PAD octant of that mood according to the rules formulated in Section 7.5.

8.3.2 Methodology

The methodology of this experiment goes from the creation of the expressions to evaluate to the analysis of the results. The methodology steps are:

1. Generation of a set of images per each mood. Given that each mood has 3 dimensions (pleasure, arousal and dominance) and 3 intensity values per dimension (low, medium, high), in total $(8)(3^3) = 216$ images were generated.

2. Execution of an online survey using a validated tool to measure the perception of mood in those images.

3. Evaluation of the results to verify that expressions associated to each mood exist, and to obtain the AUs that describe those expressions.

8.3.3 Experimental Study

As mentioned above, we generated for each of the 8 moods a total of $3^3 = 27$ images of expressions corresponding to the combinations of: {low pleasure, medium pleasure, high pleasure}, {low arousal, medium arousal, high arousal} and {low dominance, medium dominance and high dominance}. To establish these limits, the degree *low* corresponded to 0.1, *medium* to 0.5 and *high* to 1.0.

This gave us a total of 216 images that were randomly evaluated through an online survey. Expressions were generated using the virtual agent Alfred, from the Game Engine of the University of Augsburg 7.3.1. Some examples of the images we evaluated are presented in Figure 8.3.

Table 8.3: Facial expressions in the mood quadrants of the PAD Space. Upper row: Anxious, Bored, Dependent, Disdainful. Lower row: Docile, Exuberant, Hostile, Relaxed

We evaluated the expressions based on their PAD values and not on their adjectives, because we wanted to do it in a simpler manner that could be understood across cultures, avoiding the issue of translating each adjective and still maintain its correct meaning.

Questionnaire

109 subjects (59 male and 50 female) between 19 and 55 years old, with a mean age of 29.2 ($SD = 7.1$) participated in the experiment through an online questionnaire.

To assess the images we used the Self-Assessment Manikin questionnaire, which explanation was provided in English and Spanish, so we could get a greater sample of subjects.

The Self-Assessment Manikin (SAM) [22] is a non-verbal, graphic representation of the three dimensions: Pleasure, Arousal and Dominance. It directly assesses the pleasure, arousal and dominance associated in response to an object or event. SAM ranges from a smiling, happy figure to a frowning, unhappy figure when representing the pleasure dimension; from an excited, wide-eyed figure to a relaxed, sleepy figure for the arousal dimension; and from a small to a large figure that indicates maximum control in the situation in the case of the dominance dimension.

The experimental stimuli consisted of 18 static images, randomly selected from the pool of 216 images. Then, each subject had to rate each of these 18 images using SAM, which was presented in a 5-item Likert Scale, where 1 corresponded to the minimum value of the dimension and 5 to the maximum. For analysis purposes, this scale was normalized between -1 and 1. The questions were of the form:

(1) *How is Alfred feeling?*. Possible answers corresponded to the SAM items for pleasure: very displeased (-1), displeased (0.5), neutral (0.0), pleased (0.5), very pleased (1.0).

(2) *How energetic seems Alfred?*. Possible answers corresponded to the SAM items for arousal: very relaxed (-1), relaxed (0.5), neutral (0.0), excited (0.5), very excited (1.0).

(3) *How dominant is Alfred?*. The possible answers corresponded to the SAM items for arousal: very submissive (-1), submissive (0.5), neutral (0.0), dominant (0.5), very dominant (1.0).

Figure 8.4 shows a page of the online questionnaire.

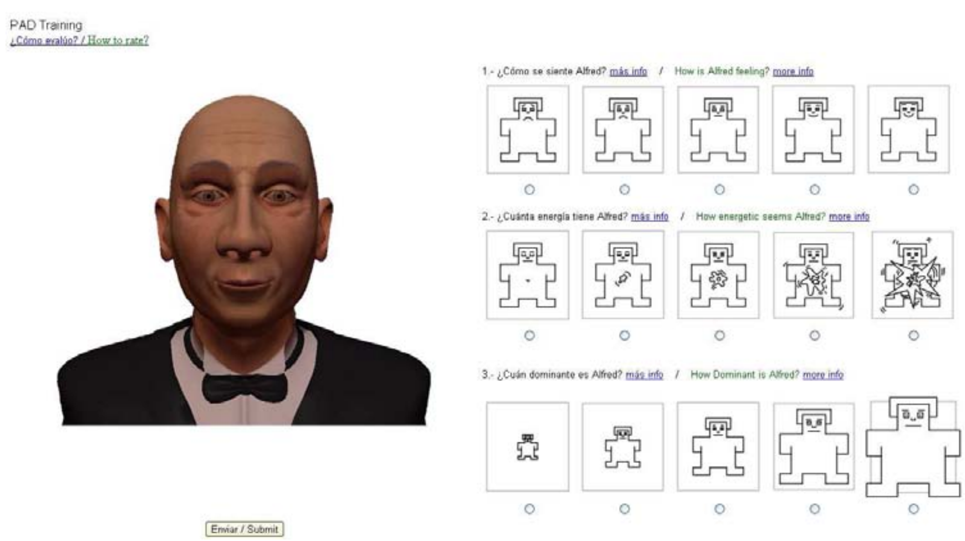


Figure 8.4: On-line questionnaire for measuring mood using SAM

The first two images presented to the subjects were for training purposes. They corresponded to the moods Exuberant and Bored with their maximum values: +P+A+D and -P-A-D, respectively. Thus the subject could evaluate these images using the SAM figures, and then continue with the remaining 16 random images.

8.3.4 Results

The obtained results opened the possibility to associate facial expressions to moods defined by the values of pleasure, arousal and dominance.

When analyzing the results, we could observe that each image was evaluated among 5 and 13 times (with a mean value $\approx$ 10). The explanation for this variability is the randomness of the image generation.

Table 8.4 presents the mean values and standard deviations after analyzing each PAD dimension in all images corresponding to one of the eight moods. Figure 8.5 shows graphically the mean values for each dimension for each mood. Blue bars correspond to pleasure (P) values, red bars to arousal (A) and green bars to dominance (D).

Mood		**Pleasure**		**Arousal**		**Dominance**	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Anxious	-P+A-D	-0.5	0.43	0.0	0.57	-0.3	0.61
Bored	-P-A-D	-0.4	0,50	-0,5	0,50	-0,5	0,50
Dependent	+P+A-D	0.5	0.37	0.3	0.44	0.3	0.48
Disdainful	-P-A+D	-0.4	0.45	-0.1	0.61	-0.1	0.61
Docile	+P-A-D	0.5	0.31	-0.1	0.49	0.0	0.56
Exuberant	+P+A+D	0.4	0.44	0.4	0.44	0.4	0.48
Hostile	-P+A+D	-0.5	0.44	0.4	0.54	0.2	0.62
Relaxed	+P-A+D	0.4	0.35	-0.2	0.52	0.1	0.52

Table 8.4: Mean analysis of recognition of facial expressions

Given that the three dimensions pleasure, arousal and dominance are independent, we need to analyze each image to obtain the best combination of dimensions intensities, and hence to obtain the significant image(s) representing each mood.

In the following, a detailed analysis is presented, so we can know exactly which expressions were recognized as representatives for each mood.

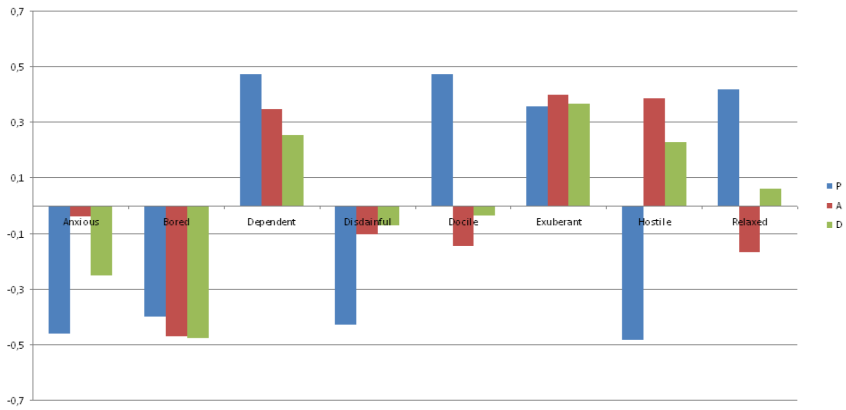


Figure 8.5: Mean analysis of recognition of facial expressions

Mood: *Anxious*

This mood corresponds to the **-P+A-D** quadrant of the PAD model. Therefore, we expect a set of expressions corresponding to this mood to be recognized as with negative pleasure and dominance, and positive arousal.

Figure 8.6 presents the distribution of the mean recognition values for each of the 27 images corresponding to this mood

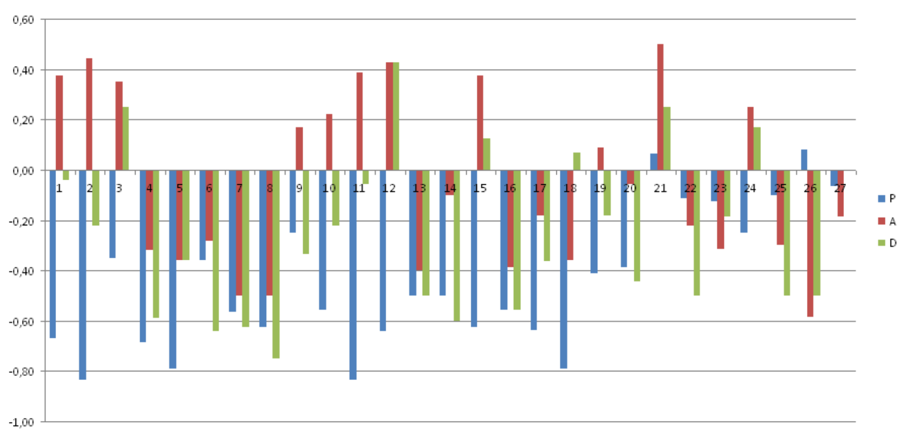


Figure 8.6: Mean values of the analysis of facial expressions of mood *anxious*

Table 8.5 presents the mean values and standard deviations of the expressions recognized as *anxious*. The mean values representing the average recognition rate of each dimension, and the standard deviations representing its variability showed that a set of six images were identified as -P+A-D.

Image	**Pleasure**		**Arousal**		**Dominance**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
01-An-HHH	-0.67	0.32	0.38	0.52	-0.04	0.54
02-An-HHM	-0.83	0.35	0.44	0.30	-0.22	0.71
09-An-HLL	-0.25	0.27	0.17	025	-0.33	0.51
10-An-MHH	-0.56	0.39	0.22	0.61	-0.22	0.56
11-An-MHM	-0.83	0.35	0.39	0.60	-0.06	0.84
19-An-LHH	-0.41	0.37	0.09	0.53	-0.18	0.64

Table 8.5: Mean values and Standard Deviations for expressions of Anxiousness

The former results constrain our analysis of the images, thus we could assess its validity through the recognition hit rates for each image. Table 8.6 shows the hit rates of the images that obtained higher scores and the number of subjects that evaluated each image. The expressions discarded are those in which their P, A or D was wrongly identified by more than half of the subjects.

Image	**-P**	**+A**	**-D**	**Number of Subjects**
02-An-HHM	8	7	6	9
10-An-MHH	7	5	5	10
19-An-LHH	7	6	6	11

Table 8.6: Hit rates for expressions of *anxious* mood

From the previous results we could observe that the images identified in the same quadrant of *anxious* have:
- Negative Pleasure intensities along the negative dimension
- Positive Arousal intensity in its maximum level
- Negative Dominance intensity between its medium and maximum level

Using these results we can see which AUs were activated according to the intensities of pleasure, arousal and dominance of the selected expressions, resulting in $AU1, AU2, AU4, AU15$ for pleasure and dominance and $AU5, AU25, AU26$ for arousal. These AUs correspond to the ones in the quadrant of *anxiousness*. Figure 8.7 shows the validated faces for this mood.

Figure 8.7: Facial expressions with their corresponding PAD intensities for *anxious*

Mood: *Bored*

This mood corresponds to the **-P-A-D** quadrant of the PAD model. Therefore, we expect expressions corresponding to this mood to be recognized as with negative pleasure, arousal and dominance.

Figure 8.8 presents the distribution of the mean recognition values of each of the 27 images corresponding to the mood *bored*.

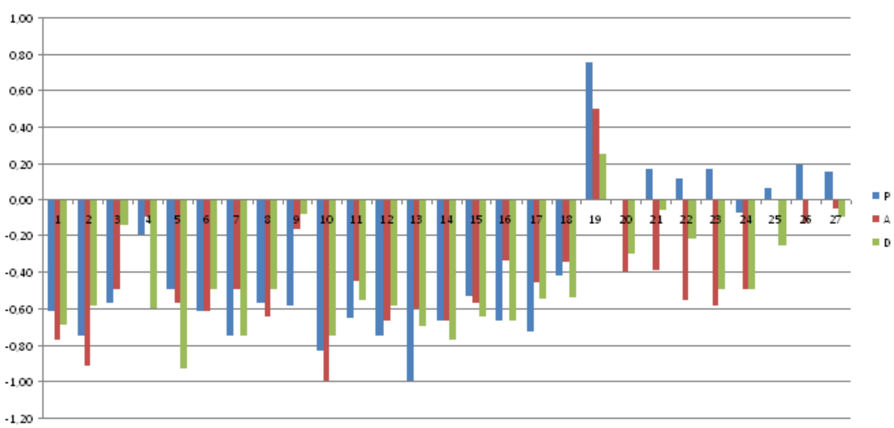


Figure 8.8: Mean values of the analysis of facial expressions of mood *bored*

Table 8.7 presents the mean values and standard deviations of the expressions recognized as *bored*. These results show that most of the images were identified as -P-A-D.

The former results constrain our analysis of the images, thus we could assess its validity through the recognition hit rates for each image. Table 8.8 shows the hit rates of the images that obtained higher scores and the number of subjects that evaluated each image. The

Image	Pleasure		Arousal		Dominance	
	Mean	SD	Mean	SD	Mean	SD
01-Bo-HHH	-0.61	0.36	-0.77	0.39	-0.7	0.43
02-Bo-HHM	-0.75	0.41	-0.92	0.20	-0.58	0.49
03-Bo-HHL	-0.57	0.45	-0.50	0.50	-0.14	0.56
04-Bo-HMH	-0.20	0.27	-0.10	0.22	-0.60	0.42
05-Bo-HMM	-0.50	0.5	-0.57	0.45	-0.93	0.18
06-Bo-HML	-0.61	0.33	-0.61	0.42	-0.50	0.43
07-Bo-HLH	-0.75	0.35	-0.5	0.52	-0.75	0.26
08-Bo-HLM	-0.57	0.35	-0.64	0.38	-0.50	0.29
09-Bo-HLL	-0.58	0.38	-0.17	0.52	-0.08	0.20
10-Bo-MHH	-0.83	0.25	-1.00	0.0	-0.75	0.27
11-Bo-MHM	-0.65	0.41	-0.45	0.50	-0.55	0.64
12-Bo-MHL	-0.75	0.27	-0.67	0.60	-0.58	0.58
13-Bo-MMH	-1.00	0.0	-0.60	0.54	-0.70	0.44
14-Bo-MMM	-0.66	0.35	-0.66	0.56	-0.77	0.26
15-Bo-MML	-0.54	0.30	-0.57	0.38	-0.64	0.41
16-Bo-MLH	-0.67	0.52	-0.33	0.61	-0.67	0.41
17-Bo-MLM	-0.73	0.34	-0.45	0.61	-0.55	0.47
18-Bo-MLL	-0.42	0.34	-0.35	0.43	-0.54	0.48
20-Bo-LHM	0.00	0.25	-0.40	0.55	-0.30	0.68
24-Bo-LML	-0.07	0.45	-0.50	0.41	-0.50	0.71

Table 8.7: Mean values and Standard Deviations for expressions of Boredness

expressions discarded are those in which their P, A or D was wrongly identified by more than half of the subjects.

From the previous results we observed that the images have these characteristics:
- Negative pleasure intensity is between high and medium
- Negative arousal and negative dominance intensity can have any degree (high, medium or low)

It is worth noting that the images that were not recognized as *bored* present low negative pleasure (almost neutral regarding pleasure), as can be seen in Figure 8.8. Also, the hit rates analysis resulted in a reduced set of expressions in compare to the ones obtained through mean values, mainly because the majority of subjects could not associate an arousal or dominance value to the expression.

Using these results we can see which AUs were activated according to the intensities of pleasure, arousal and dominance of the selected expressions, resulting in $AU1, AU2$ (activated only when $p > 0.5$), $AU4, AU15$ for pleasure and dominance and $AU43$ for arousal. These AUs correspond to the ones in the quadrant of *bored*. Figure 8.9 shows a subset of the expressions that obtained highest recognition scores.

Image	-P	-A	-D	Number of Subjects
01-Bo-HHH	11	11	12	13
02-Bo-HHM	5	6	4	6
05-Bo-HMM	4	5	7	7
06-Bo-HML	8	7	6	9
07-Bo-HLH	9	7	10	10
08-Bo-HLM	6	6	6	7
10-Bo-MHH	6	6	6	6
11-Bo-MHM	8	7	8	10
12-Bo-MHL	6	5	5	6
13-Bo-MMH	5	3	4	5
14-Bo-MMM	8	7	9	9
15-Bo-MML	12	11	11	14
16-Bo-MLH	4	3	5	6
17-Bo-MLM	10	7	7	11
18-Bo-MLL	9	10	10	13

Table 8.8: Hit rates for expressions of *bored* mood

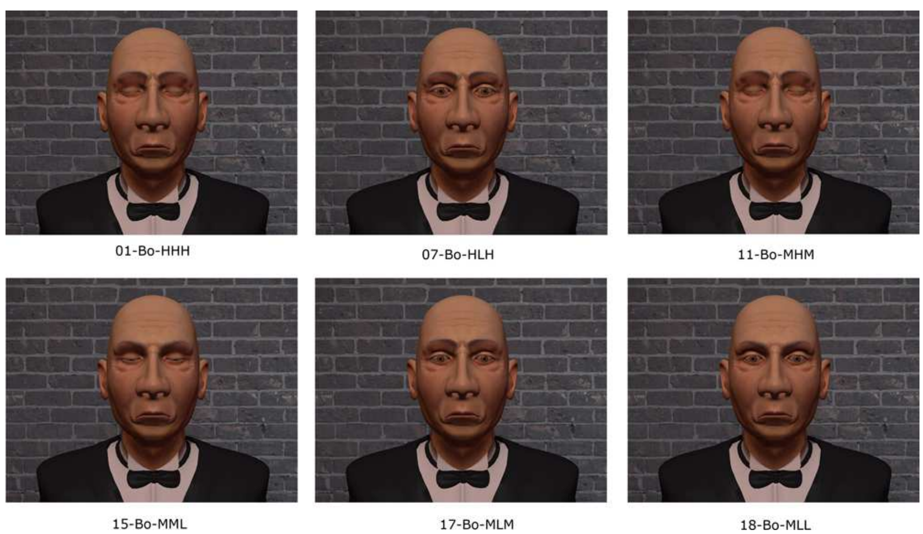


Figure 8.9: Facial expressions with their corresponding PAD intensities for *bored*

Mood: *Dependent*

This mood corresponds to the **+P+A-D** quadrant of the PAD model. Therefore, we expect expressions corresponding to this mood to be recognized as with positive pleasure, positive arousal and negative dominance. Figure 8.10 presents the distribution of the mean recognition values of the 27 images for this mood.

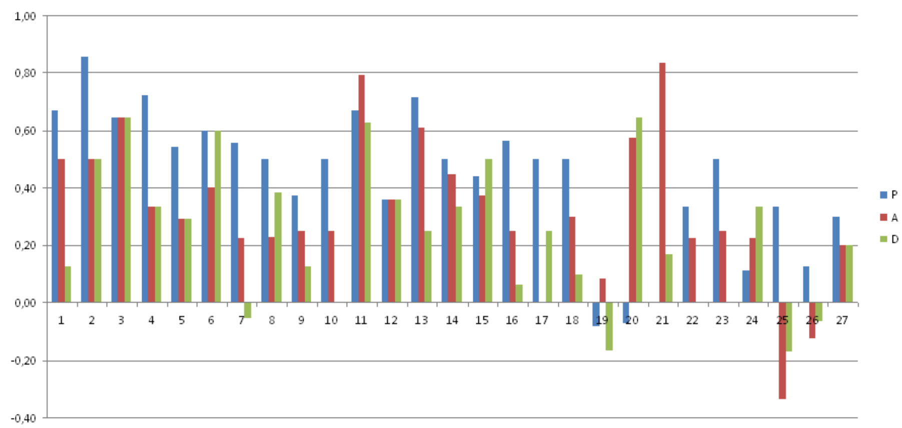


Figure 8.10: Mean values of the analysis of facial expressions of mood *dependent*

Table 8.9 presents the mean and standard deviation values of the expressions that were assessed as +P+A-D.

Image	Pleasure		Arousal		Dominance	
	Mean	SD	Mean	SD	Mean	SD
07-De-HLH	0.56	0.30	0.22	0.26	-0.06	0.39
10-De-MHH	0.50	0.38	0.25	0.71	0.00	0.53
22-De-LMH	0.33	0.25	0.22	0.36	0.00	0.35
23-De-LMM	0.50	0.00	0.25	0.29	0.00	0.00

Table 8.9: Mean values and Standard Deviations for expressions of Dependent

From the previous results, it can be seen that the value of dominance is very close to zero, or zero. Regarding the remaining images, the dimensions pleasure and arousal were correctly located in almost 90% of the cases. Nevertheless, dominance was assessed as negative in only 14.8% of the cases.

This results show the difficulty when assessing dominance in the expressions of the mood *dependent*. This issue is also seen when evaluating the recognition hit rates for each image, where each one obtains significant values for pleasure and arousal, but values close to zero for dominance, except for the expression 10-De-MHH. This expression is the only one in which dominance was recognized by half of the subjects. Table 8.10 shows the hit rates for the subset of the selected images.

Image	+P	+A	-D	Number of Subjects
07-De-HLH	8	4	3	9
10-De-MHH	6	5	4	8
22-De-LMH	6	5	2	9
23-De-LMM	4	2	0	4

Table 8.10: Hit rates for expressions of *dependent* mood

Figure 8.11 shows the expressions that could be assessed as being in +P+A-D. The AUs that describe these expression are $AU1, AU2$ and $AU12$, which are activated only for positive pleasure with medium to high intensity and theoretically for negative dominance with high intensity; and $AU5, AU25, AU26$ for positive arousal with any intensity.

07-De-HLH 10-De-MHH

Figure 8.11: Facial expressions with their corresponding PAD intensities for *dependent*

Mood: *Disdainful*

This mood corresponds to the **-P-A+D** quadrant of the PAD model. Therefore, we expect expressions corresponding to this mood to be recognized as with negative pleasure, negative arousal and positive dominance.

Figure 8.12 presents the distribution of the mean recognition values for expression corresponding to this mood.

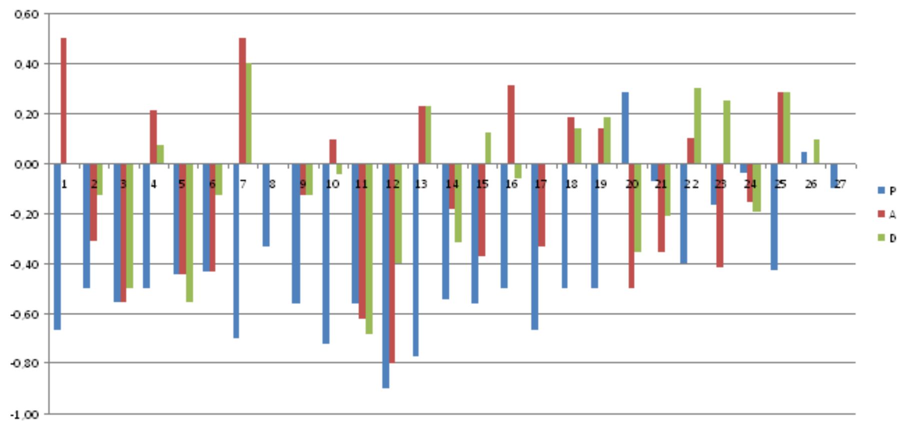


Figure 8.12: Mean values of the analysis of facial expressions of mood *disdainful*

Table 8.11 presents the mean and standard deviation values of the expressions recognized as with -P-A+D.

Image	Pleasure		Arousal		Dominance	
	Mean	SD	Mean	SD	Mean	SD
15-Di-MML	-0.56	0.32	-0.38	0.44	0.13	0.58
23-Di-LMM	-0.17	0.25	-0.42	0.58	0.25	0.52

Table 8.11: Mean values and Standard Deviations for expressions of Disdainful

From the previous results it can be seen that two expressions were associated with the dimensions of *disdain*. Standard deviation values show that there is a great variability among the subjects rating. Therefore, we constrain the analysis to assess the hit rates for these two images. Table 8.12 shows the hit rates for the subset of the selected images.

Image	-P	-A	+D	Number of Subjects
15-Di-MML	7	4	4	8
23-Di-LMM	2	4	3	6

Table 8.12: Hit rates for expressions of *disdainful* mood

The hit rates analysis demonstrates that from the two expressions identified in the *disdain* mood, the second one (23-Di-LMM) presents low rating for pleasure. It is expected given that the value for pleasure is *low*, therefore this expression shares some characteristics of the neutral expression, where the character has the corner lips slightly raised.

Thus the expressions recognized as *disdainful* shared the following characteristics:
- Negative pleasure between medium and low level
- Negative arousal in its medium level
- Positive dominance between medium and low level

These configurations correspond to the activated $AU4, AU15$ and $AU43$, all of them with medium to low intensities. Figure 8.13 shows the expressions that obtained highest recognition scores.

Figure 8.13: Facial expressions with their corresponding PAD intensities for *disdainful*

Mood: ***Docile***

This mood corresponds to the **+P-A-D** quadrant of the PAD model. Therefore, we expect expressions corresponding to this mood to be recognized as with positive pleasure and negative arousal and dominance.

Figure 8.14 presents the distribution of the mean recognition values of each of the 27 images corresponding to the mood *docile*.

Table 8.13 presents the numeric mean and standard deviation values of those expressions that were indeed recognized as +P-A-D.

The former results constrain our analysis to these expressions, which were further studied by obtaining the recognition hit rates for each dimension. An expression is considered correspondent to the mood *docile*, and therefore to the +P-A-D quadrant if more than half of the subjects identified its three dimensions as such. Table 8.14 shows the hit rates for the subset of the selected images.

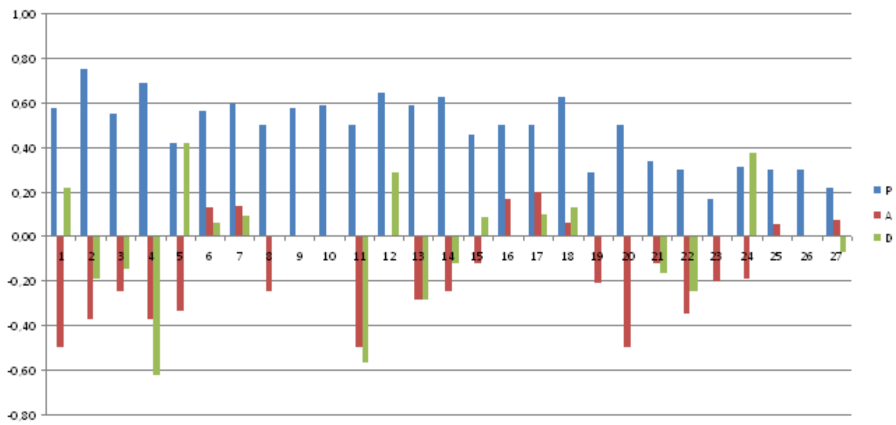


Figure 8.14: Mean values of the analysis of facial expressions of mood *docile*

Image	Pleasure		Arousal		Dominance	
	Mean	SD	Mean	SD	Mean	SD
02-Do-HHM	0.75	0.26	-0.38	0.51	-0.19	0.65
03-Do-HHL	0.55	0.15	-0.25	0.48	-0.15	0.41
04-Do-HMH	0.69	0.37	-0.38	0.58	-0.63	0.44
11-Do-MHM	0.50	0.28	-0.50	0.57	-0.57	0.34
13-Do-MMH	0.58	0.19	-0.29	0.49	-0.29	0.39
14-Do-MMM	0.63	0.25	-0.25	0.5	-0.13	0.85
21-Do-LHL	0.33	0.24	-0.13	0.37	-0.17	0.61
22-Do-LMH	0.30	0.34	-0.35	0.41	-0.25	0.59

Table 8.13: Mean values and Standard Deviations for expressions of Docile

Image	+P	-A	-D	Number of Subjects
04-Do-HMH	7	4	6	8
11-Do-MHM	6	5	6	7
13-Do-MMH	12	7	7	12
22-Do-LMH	5	7	7	10

Table 8.14: Hit rates for expressions of *docile* mood

The hit rates analysis demonstrates that the pleasure dimension was recognized in all the cases with a high percentage rate. Also, arousal and dominance were correctly identified, although in some cases arousal obtained a lower success rate than dominance.

Regarding the expressions that were recognized as *docile*, they shared the following characteristics:

- Positive pleasure with any intensity level
- Negative arousal between medium and high level
- Negative dominance between medium and high level

These configurations correspond to the activated $AU1, AU2, AU12$ and $AU43$. Figure 8.15 shows the expressions that obtained highest recognition scores.

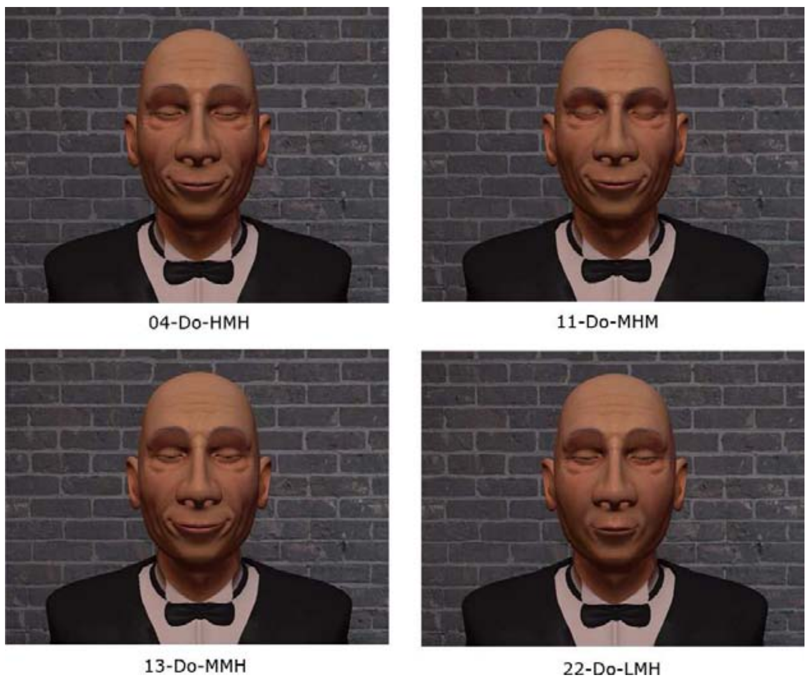


Figure 8.15: Facial expressions with their corresponding PAD intensities for *docile*

Mood: ***Exuberant***

This mood corresponds to the **+P+A+D** quadrant. Therefore, we expect expressions corresponding to this mood to be recognized as with positive pleasure, arousal and dominance.

Figure 8.16 presents the recognition values of each expression for this mood, and *exuberant*, while Table 8.15 contains the mean and standard deviation values of those expressions that were identified as with positive pleasure, positive arousal and positive dominance.

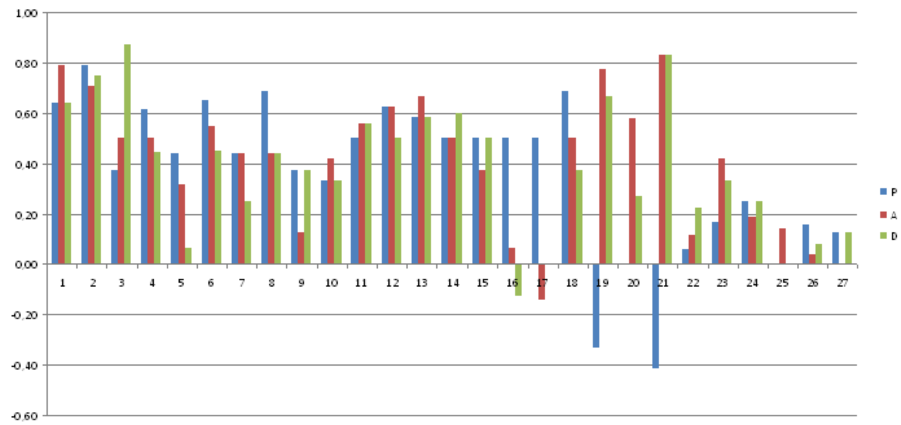


Figure 8.16: Mean values of the analysis of facial expressions of mood *exuberant*

Image	Pleasure		Arousal		Dominance	
	Mean	SD	Mean	SD	Mean	SD
01-Ex-HHH	0.64	0.37	0.79	0.26	0.64	0.37
02-Ex-HHM	0.79	0.25	0.71	0.25	0.75	0.39
03-Ex-HHL	0.38	0.75	0.50	0.40	0.88	0.25
04-Ex-HMH	0.61	0.33	0.50	0.5	0.44	0.30
05-Ex-HMM	0.44	0.32	0.31	0.37	0.06	0.62
06-Ex-HML	0.65	0.24	0.55	0.36	0.45	0.36
07-Ex-HLH	0.44	0.49	0.44	0.32	0.25	0.46
08-Ex-HLM	0.69	0.37	0.44	0.17	0.44	0.17
09-Ex-HLL	0.38	0.23	0.13	0.44	0.38	0.44
10-Ex-MHH	0.33	0.40	0.42	0.20	0.33	0.25
11-Ex-MHM	0.50	0.35	0.56	0.39	0.56	0.39
12-Ex-MHL	0.63	0.47	0.63	0.25	0.50	0.40
13-Ex-MMH	0.58	0.20	0.67	0.25	0.58	0.37
14-Ex-MMM	0.50	0.35	0.50	0.61	0.60	0.22
15-Ex-MML	0.50	0.26	0.38	0.35	0.50	0.46
18-Ex-MLL	0.69	0.25	0.50	0.26	0.38	0.35
22-Ex-LMH	0.06	0.39	0.11	0.22	0.22	0.26
23-Ex-LMM	0.17	0.25	0.42	0.49	0.33	0.60
24-Ex-LML	0.25	0.37	0.19	0.37	0.25	0.46
26-Ex-LLM	0.15	0.31	0.04	0.43	0.08	0.53

Table 8.15: Mean values and Standard Deviations for expressions of Exuberant

The former results constrain our analysis to these expressions, which were further studied by obtaining the recognition hit rates for each dimension. Table 8.16 shows the hit rates for the subset of the selected images.

The hit rates analysis shows that expressions with low pleasure were discarded, leaving those expressions with medium to high pleasure and any level of arousal and dominance.

From these results we concluded that the activated AUs are $AU6, AU12$ for medium to high positive pleasure values, and $AU5, AU25, AU26$ for arousal with any intensity level.

Image	+P	+A	+D	Number of Subjects
01-Ex-HHH	6	7	6	7
02-Ex-HHM	12	12	10	12
04-Ex-HMH	8	7	7	9
06-Ex-HML	10	8	7	10
07-Ex-HLH	6	6	4	8
08-Ex-HLM	7	7	7	8
09-Ex-HLL	6	4	6	8
10-Ex-MHH	3	5	4	6
11-Ex-MHM	7	7	7	9
12-Ex-MHL	3	4	3	4
13-Ex-MMH	6	6	5	6
14-Ex-MMM	4	4	5	5
15-Ex-MML	7	5	5	8
18-Ex-MLL	8	7	5	8

Table 8.16: Hit rates for expressions of *exuberant* mood

It is also interesting to note that expressions combining low +P, high +A and high, medium and low +D were identified as *hostile* mood. A possible explanation for these results is that in the area close to low pleasure (positive and negative), the $AU12$ responsible for pulling the corner lips is not active. This in combination with open eyes (feature of arousal) provokes a different effect than exuberance. Figure 8.17 shows a subset of the expressions corresponding to each image of these values.

Figure 8.17: Facial expressions with their corresponding PAD intensities for *exuberant*

Mood: *Hostile*

This mood corresponds to the **-P+A+D** quadrant of the PAD model. Figure 8.18 presents the distribution of the mean recognition values of each of the 27 images corresponding to the mood *hostile*.

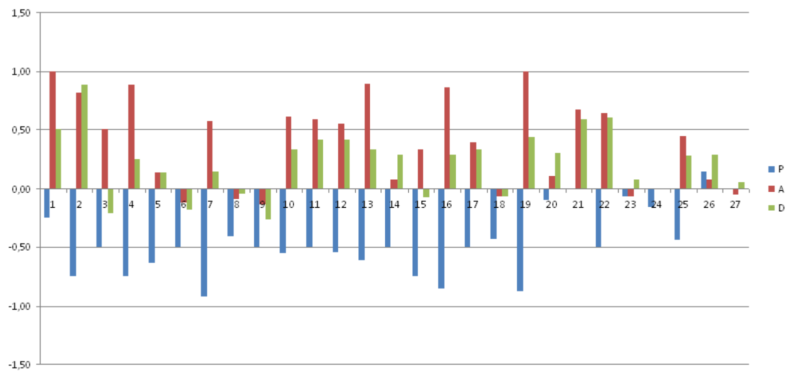


Figure 8.18: Mean values of the analysis of facial expressions of mood *hostile*

Table 8.17 presents the mean and standard deviation values of the expressions which dimensions were identified as -P+A+D.

Image	Pleasure		Arousal		Dominance	
	Mean	SD	Mean	SD	Mean	SD
01-Ho-HHH	-0.25	0.95	1.00	0	0.50	1
02-Ho-HHM	-0.75	0.46	0.81	0.25	0.88	0.23
04-Ho-HMH	-0.75	0.46	0.88	0.35	0.25	0.84
05-Ho-HMM	-0.64	0.32	0.14	0.50	0.14	0.55
07-Ho-HLH	-0.93	0.18	0.57	0.34	0.14	0.62
10-Ho-MHH	-0.56	0.46	0.61	0.65	0.33	0.75
11-Ho-MHM	-0.50	0.54	0.58	0.58	0.42	0.58
12-Ho-MHL	-0.55	0.41	0.55	0.47	0.41	0.70
13-Ho-MMH	-0.61	0.48	0.89	0.22	0.33	0.70
14-Ho-MMM	-0.50	0.40	0.07	0.45	0.29	0.48
16-Ho-MLH	-0.86	0.37	0.86	0.24	0.29	0.90
17-Ho-MLM	-0.50	0.35	0.39	0.41	0.33	0.56
19-Ho-LHH	-0.88	0.23	1.00	0	0.44	0.67
20-Ho-LHM	-0.10	0.41	0.10	0.54	0.30	0.57
22-Ho-LMH	-0.50	0.43	0.64	0.41	0.61	0.56
25-Ho-LLH	-0.44	0.39	0.44	0.30	0.28	0.50

Table 8.17: Mean values and Standard Deviations for expressions of Hostile

The previous results allowed us to constrain our analysis to those expressions in which subjects correctly recognized the -P+A+D dimensions. These let us with the 59.2% of the expressions, for which the recognition hit rates were obtained. Table 8.18 shows the hit rates for the subset of the selected images.

Image	**-P**	**+A**	**+D**	**Number of Subjects**
01-Ho-HHH	2	4	3	4
02-Ho-HHM	6	8	8	8
04-Ho-HMH	6	7	5	8
07-Ho-HLH	7	6	3	6
10-Ho-MHH	6	8	5	10
11-Ho-MHM	3	5	4	6
12-Ho-MHL	8	9	7	11
13-Ho-MMH	6	9	6	9
16-Ho-MLH	6	7	5	7
17-Ho-MLM	7	7	6	9
19-Ho-LHH	8	8	6	8
22-Ho-LMH	9	11	12	14
25-Ho-LLH	6	7	6	9

Table 8.18: Hit rates for expressions of *hostile* mood

From the previous analysis it is shown that the main issue with these expressions was the Dominance dimension, which presented very high standard deviations. Nevertheless, a considerable number of expressions were assessed as -P+A+D, from which we extract the following characteristics:

- Negative pleasure has any intensity level
- Positive arousal has also any intensity level
- Positive dominance is mainly assessed with intensity levels between medium and high

These results allow us to identify the AUs that are activated and describe the expressions that can be associated to the mood *hostile*. The AUs are $AU4, AU10, AU15$ for medium to high positive dominance values, and $AU5, AU25, AU26$ for arousal with any intensity level.

Figure 8.19 shows a subset of the expressions corresponding to -P+A+D.

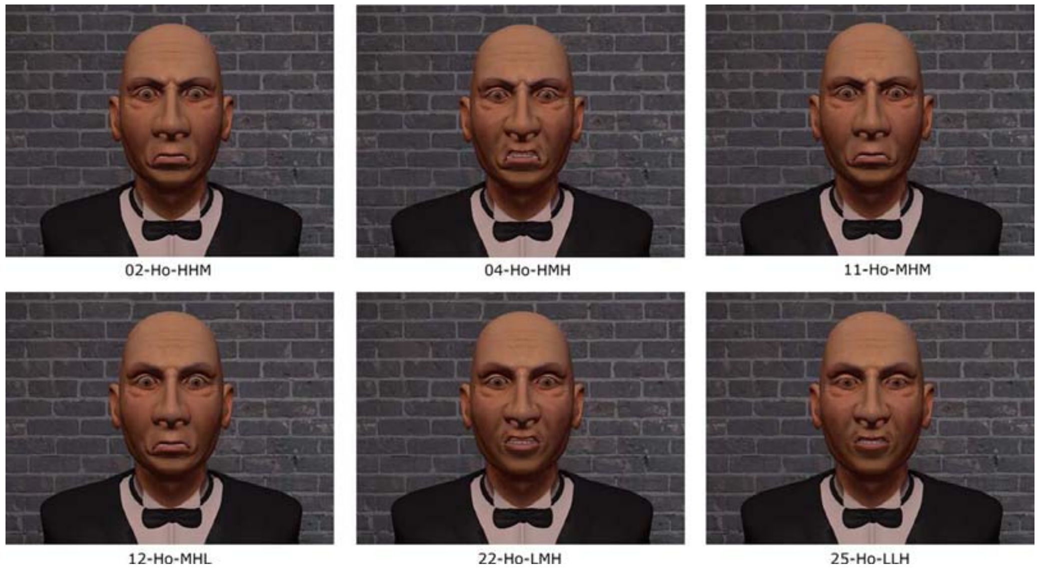


Figure 8.19: Facial expressions with their corresponding PAD intensities for *hostile*

Mood: *Relaxed*

This mood corresponds to the **+P-A+D** quadrant of the PAD model. Therefore, we expect expressions corresponding to this mood to be recognized as with positive pleasure and dominance, and negative arousal.

Figure 8.20 presents the distribution of the mean recognition values of each of the 27 images corresponding to the mood *relaxed*.

Table 8.19 presents the mean and standard deviation values of the expressions identified in +P-A+D.

Image	**Pleasure**		**Arousal**		**Dominance**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
04-Re-HMH	0.71	0.26	-0.07	0.67	0.14	0.55
05-Re-HMM	0.64	0.24	-0.43	0.34	0.21	0.48
06-Re-HML	0.43	0.45	-0.50	0.40	0.29	0.48
10-Re-MHH	0.64	0.23	-0.18	0.51	0.05	0.47
25-Re-LLH	0.25	0.26	-0.19	0.25	0.13	0.35
26-Re-LLM	0.25	0.27	-0.17	0.25	0.08	0.49
27-Re-LLL	0.13	0.22	-0.04	0.25	0.04	0.39

Table 8.19: Mean values and Standard Deviations for expressions of Relaxed

The previous results allowed us to constrain our analysis to those expressions in which

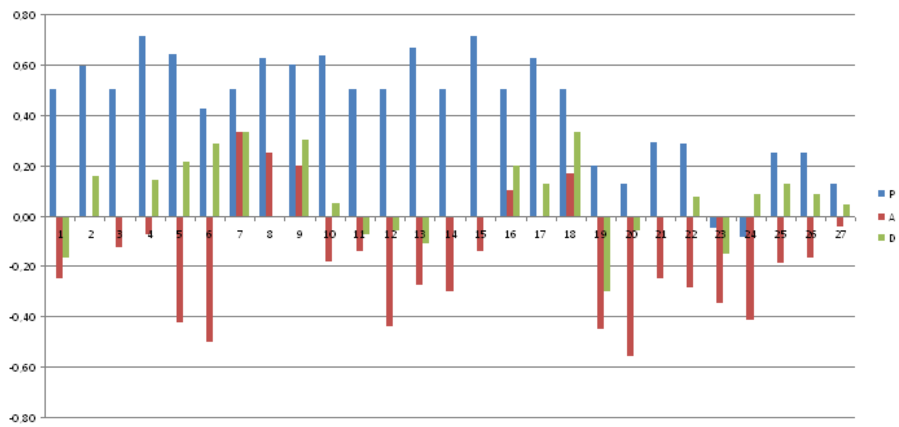


Figure 8.20: Mean values of the analysis of facial expressions of mood *relaxed*

subjects correctly recognized the +P-A+D dimensions. Therefore, we constrain the analysis to assess the hit rates for these two images. Table 8.20 shows the hit rates for the subset of the selected images.

Image	+P	-A	+D	Number of Subjects
04-Re-HMH	7	3	3	7
05-Re-HMM	7	5	3	7
06-Re-HML	6	5	4	7
10-Re-MHH	11	4	3	11

Table 8.20: Hit rates for expressions of *relaxed* mood

From the hit rates analysis we observed that a reduced number of expressions were indeed assessed as +P-A+D. The main issue was to evaluate the positive dominance, which in all the 27 expressions obtained mean values close to zero, meaning that to the question "How dominant is Alfred?" the majority of the subjects answered "i don't know". An example of this situation is the expressions tagged as 10-Re-MHH, which pleasure dimension obtained a 100% of recognition rates, but arousal and dominance less than 36%.

The expressions that in the end were associated to the *relaxed* mood shared the following characteristics:
- Positive pleasure with high intensity values
- Negative arousal with medium intensity values
- Positive dominance was independent of the other values

These results allow us to identify the AUs that are activated and describe the expressions that can be associated to the mood *relaxed*. The AUs are $AU6$, $AU12$ for high positive pleasure values, and $AU43$ for arousal with medium intensity.

Figure 8.21 presents some of the expressions associated with the mood *relaxed*.

Figure 8.21: Facial expressions with their corresponding PAD intensities for mood *relaxed*

8.3.5 Discussion

The experiment that has been presented answered the hypothesis formulated at the beginning of this section, which intended to prove that all moods have associated expressions which are described by the AUs activated in their corresponding pleasure, arousal and dominance dimension.

After the analysis of the results, we found that indeed the expressions associated with a mood are described by the AUs in the octant of that mood. Given that this was an exploratory experiment to see if the functions to locate AUs in the PAD space were valid, we did not establish any percentage of error or success. Therefore, we used mean values and standard deviations to compute the average perception of each expression. From this, we obtained subsets of expressions which should be further evaluated to exhaustively validate them.

Regarding the easiness of recognition of each dimension, the results concluded that:
- Pleasure was correctly identified in the vast majority of the cases, except for those in which its values were close to zero, and it is seen as the dimension that gives meaning to the expression.
- Arousal was also correctly identified in most of the cases, except on few cases when arousal was negative and most of the subjects did not know how to assess it.
- Dominance presented most of the perception problems. Subjects were not sure how to

measure it or what to take into consideration to do it.

These results are somehow expected given that pleasure and arousal are dimensions that can be represented in the expression, while dominance is a dimension that is manifested during interaction. Therefore, it was difficult to assess from an static image.

From the comments given by the majority of the subjects, the main issue with Dominance is that it is difficult to assess in a static image because, as it was said before, it is part of people's interactions. Nevertheless, the use of SAM icons helped considerably to successfully perform the questionnaire, because subjects understood what they were asked for.

Regarding the final set of AUs that describe the expressions for the moods, Table 8.21 present the AUs for each mood.

Mood	(AUs)
Exuberant	$AU6, AU5, AU12, AU25, AU26$
Bored	$AU1, AU2, AU4, AU15, AU43$
Docile	$AU1, AU2, AU12, AU43$
Hostile	$AU4, AU10, AU5, AU15, AU25, AU26$
Anxious	$AU1, AU2, AU4, AU5, AU15, AU25, AU26$
Relaxed	$AU6, AU12, AU43$
Dependent	$AU1, AU2, AU5, AU12, AU25, AU26$
Disdainful	$AU4, AU15, AU43$

Table 8.21: AUs describing expressions of mood

8.4 Experiment: Context Representation

One of the objectives of our work was the representation of context in order to generate believable emotions in the character. Moreover, from previous experiments we observed that a character can have the same facial expression for different emotions, and the interpretation of these expressions may fail if we do not know enough about that character, or the context in which that expression is occurring. Therefore, it is important not only to focus on creating believable expressions but also to associate some beliefs (given by the context) to those expressions.

8.4.1 Hypothesis

We expect the following outcomes:

- Given an emotion E produced in the character due to a context C, a subject will associate a facial expression of E to the context C.
- Given that exists a real facial expression for C (e.g. of an actor or an ordinary person), the facial expression of the character is similar to the real one under C.

8.4.2 Methodology

To validate the former hypothesis we used the following methodology to perform the experiment:

1. Selection and definition of scenes of a movie into the Context Representation Module. It will give as output a set of emotions, from which the one with the greatest value is chosen. If two emotions are elicited with the same intensity, we mix them using the algorithm to generate intermediate expressions.
2. Execution of an online survey to measure the perception of facial expressions inside a context.
3. Evaluation of the results.

8.4.3 Experimental Study

For this experiment we chose two movies: *Léon* (1994, directed by Luc Besson) and *Downfall (Der Untergang)* (2004, directed by Oliver Hirschbiegel). From each movie we selected three scenes where it could be clearly seen the facial expressions of the real actors.

In **Movie 1- *Léon*** we selected the part where the main character Mathilda, a 12 years-old girl enters her building, and finds out that her family has been brutally murdered. In **Movie 2- *Downfall*** we selected the part when Hitler, already tired and defeated wants to counterattack and his soldiers try to make him change his mind. In this last scenes, we focused on one of the soldiers and his emotional reactions.

From the scenes of **Movie 1** and **Movie 2**, we set up the events, character's preferences, descriptions of the locations, admiration among characters, in order to be introduced in the Context Representation module, and elicit the corresponding emotions. Tables 8.22 and 8.23 contains the elements used for the context representation.

Character:	Mathilda	
Goals:	- Stay alive	
Preferences:	Gangsters ($STRONGLYBAD = 1.0$) Family's apartment ($INDIFFERENT = 0.0$)	
Agent Admiration:	Little brother ($POSITIVE = 1.0$)	
Event	**Role of Character**	**Emotions elicited**
(Event 1) Mathilda comes home and notices a gangster in front of the family's apartment. *She acts as if nothing happens* ($NOTSATISFACTORY = 0.7$)	Mathilda *executes* the event (ByMe)	fear = 0.4
(Event 2) Mathilda hears that her little brother has been killed ($NOTSATISFACTORY = 1.0$)	The brother *receives* the event (OnOther)	pity = 1.0
(Event 3) Mathilda rings the doorbell of Léon and waits while the gangster is outside ($NOTSATISFACTORY = 1.0$)	Mathils *receives* the event (OnMe)	sadness = 1.0

Table 8.22: Events and context details for **Movie 1- *Léon***

The emotions presented in the former tables, generated by each event, were the ones that corresponded to the script of the movie annotated in a previous work that used the same set of scenarios [138]. This correspondence between the emotion elicited and the emotion in the script is a hint that the rules of the Semantic Model produce the right emotions to the events.

Using the emotions elicited, we generated the facial expressions of the characters. For

Character:	The Officer	
Goals:	- Stop the war - Convince Hitler to change his mind	
Preferences:	War ($STRONGLYBAD = 1.0$) Counterattack consequences ($STRONGLYBAD = 0.74$)	
Event	**Role of Character**	**Emotions elicited**
(Event 1) The Officer talks to Hitler about the negative consequences of a counterattack ($NOTSATISFACTORY = 0.5$)	The officer *executes* the event (ByMe)	fear = 0.5
(Event 2) The Officer convinces Hitler about the negative consequences ($NOTSATISFACTORY = 0.7$)	The officer *executes* the event (ByMe)	discourage = 0.7 (fear + shame)
(Event 3) The Officer cannot convince Hitler to change his mind of a counterattack ($NOTSATISFACTORY = 0.9$)	The officer *executes* the event (ByMe)	disappointment = 0.9 (disgust + sadness)

Table 8.23: Events and context details for **Movie 2- *Downfall***

movie *Léon* we used the character Alice, which resembled Mathilda. For the movie *Downfall* we used Alfred, who quite resembled The Officer. Table 8.24 shows the virtual characters and the actors in the events described in Tables 8.22 and 8.23.

These images were evaluated through an online survey with the intention to find (1) if the facial expression of the virtual actor is believable in correspondence with the event/scene, and (2) if the expressions of the real actor and the virtual character were perceived as similar by the subjects.

(a) *Léon* - Event (1): *fear*

(b) *Léon* - Event (2): *pity*

(c) *Léon* - Event (3): *sadness*

(d) *Downfall* - Event (1): *fear*

(e) *Downfall* - Event (2): *discourage*

(f) *Downfall* - Event (3): *disappointment*

Table 8.24: Virtual and real actors from the movies *Léon* and *Downfall*

Questionnaire

61 subjects (30 male and 31 female) between 18 and 55 years old (MEAN = 28, SD = 5.45) participated in the experiment through an online questionnaire.

The experimental stimuli consisted of 12 static images:
- 3 images of Alice showing fear, pity and sadness, respectively;
- 3 images of an actress showing fear, pity and sadness, respectively;
- 3 images of Alfred showing fear, discourage and disappointment, respectively;
- 3 images of an actor showing fear, discourage and disappointment, respectively.

Before evaluating the scenes of each movie, we gave a synopsis of what was happening to center the subject in the context. For the **Movie 1- *Léon*** the description was: "*Mathilda, a 12-year old girl, comes home from the grocery. When she finds that her family has been brutally murdered she seeks help from Léon, whose apartment is down the hall*".

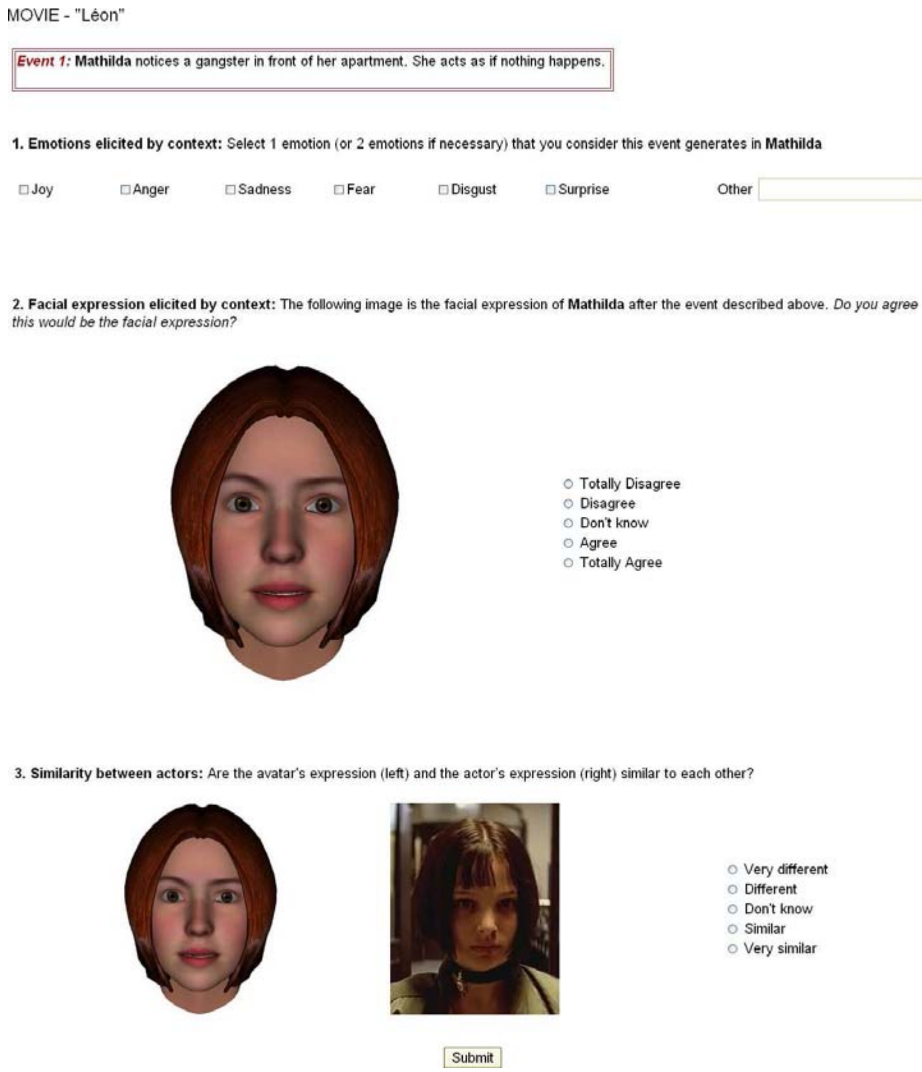
For the **Movie 2- *Downfall*** the description was: "*During the last days of the II WW, Hitler is sick and exhausted; the defeat of the Third Reich is imminent. Hitler and his officers are having a meeting in which he is planning impossible counterattacks and giving orders to men who are already dead.* ***His officers have serious doubts about their leader but do not dare to speak up because of the reprimands.***".

Then, for each event showed in Tables 8.22 and 8.23, we asked the following questions:

- **(Question 1)** Facial expression elicited by context: The following image is the facial expression of <*nombre_character*> after the event described above. Do you agree this would be the facial expression?
- **(Question 2)** Similarity between actors: Are the avatar's expression (left) and the actor's expression (right) similar to each other?

For **(Question 1)** we used the images of Alice and Alfred shown in Table 8.24. For **(Question 2)** we used the pair images Alice-actress and Alfred-actor shown in the same table.

Each question was rated using a 5-item Likert Scale, where 1 corresponded to the minimum degree (*totally disagree* or *very different*) and 5 to the maximum (*totally agree* or *very similar*). Figure 8.22 shows a page of the online questionnaire. The full questionnaire can be found in the following URL: http://dmi.uib.es/ ugiv/diana/contextmodel/.


MOVIE - "Léon"

Event 1: **Mathilda** notices a gangster in front of her apartment. She acts as if nothing happens.

1. Emotions elicited by context: Select 1 emotion (or 2 emotions if necessary) that you consider this event generates in **Mathilda**

☐ Joy ☐ Anger ☐ Sadness ☐ Fear ☐ Disgust ☐ Surprise Other

2. Facial expression elicited by context: The following image is the facial expression of **Mathilda** after the event described above. *Do you agree this would be the facial expression?*

○ Totally Disagree
○ Disagree
○ Don't know
○ Agree
○ Totally Agree

3. Similarity between actors: Are the avatar's expression (left) and the actor's expression (right) similar to each other?

○ Very different
○ Different
○ Don't know
○ Similar
○ Very similar

Submit

Figure 8.22: Questionnaire for evaluation of the context representation

8.4.4 Results

The results obtained allow us to validate the proposed Context Representation Module, as well as the generation of facial expressions in two avatars, one animated using MPEG-4 (Alice - *Léon*) and the other FACS (Alfred - *Downfall*).

Table 8.25 presents the results for each question of each of the events taken from Tables 8.22 and 8.23.

Movie	Event	Question	MEAN (μ)	SD (σ)	Number of Hits (Likert Scale)				
					1	**2**	**3**	**4**	**5**
1- Léon	(1)	(Question 1)Facial expression in context	3.08	1.00	3	19	9	30	0
		(Question 2)Similarity between actors	2.65	1.12	8	28	2	23	0
	(2)	(Question 1)	4.01	0.82	0	5	5	35	16
		(Question 2)	3.93	1.09	2	8	2	29	20
	(3)	(Question 1)	3.32	0.99	3	11	13	31	3
		(Question 2)	3.11	1.13	4	20	5	29	3
2- Downfall	(1)	(Question 1)	2.75	1.06	7	20	17	15	2
		(Question 2)	2.33	1.19	18	22	5	15	1
	(2)	(Question 1)	3.05	1.08	6	14	14	25	2
		(Question 2)	2.68	1.24	12	20	7	19	3
	(3)	(Question 1)	3.72	0.85	2	5	6	43	5
		(Question 2)	3.65	1.1	4	9	0	39	9

Table 8.25: Virtual and real actors from the movies *Léon* and *Downfall*

To analyze **Question (1)**, we use the number of hits per item of the Likert-scale. We observe that over 50% of the subjects agreed that the three expressions of Alice in *Léon* corresponded to the events that generate them.

As for Alfred in the *Downfall*, the only expression for which 70.5% of the subjects agreed that it was according to the scene was the one in Event (3) (Table 8.24), which was the one with greatest emotional load (the emotion *disappointment* had an intensity of 0.9). In the Event (1) subjects *disagreed* with the facial expression of the avatar, which indicates that the expression did not transmit the emotion of the scene. In the Event (2) 40.9% of the subjects agreed that the expression matched the situation, but 23% of the subjects could not decide.

In the analysis of **Question (2)**, subjects considered that the avatars were *similar* and *very similar* to the actors in the Event (2) of the movie *Léon* and in the Event (3) of the movie *Downfall*. In the remaining events, opinions of the participants were divided obtaining almost equally results (less than 50%) for agreement and disagreement between real and virtual expressions.

The reason why we did not use the mean values for the analysis is that they were +3.0 with a standard deviation of +1.0 approximately. Therefore, we could not get any conclusion based only on these values.

8.4.5 Discussion

Two hypothesis were formulated at the beginning of this section: (1) the generated facial expressions of the avatar are in correspondence to the context that is represented; (2) there is a similarity between the facial expressions generated in the avatar and those of the actors when simulating the same context.

As for the first hypothesis we conclude that the facial expressions transmitted the emotional content of the context, validating the output of our Context Representation module. The cases where it failed corresponded to the expressions of Alfred, which were not expressive enough due to the low intensity of the emotions in context.

As for the second hypothesis, although there were agreements of similarity, subjects also focused in features as sweating (in the movie *Downfall* the actor is sweating), shape of the mouth, and tears (in the case of *Léon*). Nevertheless, these observations gave us even more hints about what participants take into consideration when perceiving an emotion in the character even when context is given.

Chapter 9

Conclusions

I am not young enough to know everything

Oscar Wilde

The work that has been presented is the answer to those questions formulated at the beginning of this thesis with the aim of developing a contextual and affective framework that allows the creation of virtual characters capable of expressing emotions, mood and personality through facial expressions and visual cues.

Therefore, this thesis is the result of an exhaustive research on different topics that contribute to the representation and generation of context, as well as to the simulation and visualization of affect. Among these topics are psychological theories of emotions, mood and personality; computational models for the creation of interactive virtual characters; semantic web and ontologies; and visualization techniques for the generation of facial expressions.

We begin this chapter by briefly reviewing each of the previous chapters, in order to depict a general picture of the contributions and novelties presented in this thesis. Then, a discussion section will present a more detailed view of the aspects that were considered during this research, the results of the multiple experiments and evaluations which helped to prove stated hypothesis and shed light on new theories, and finally the tasks to perform as future work.

9.1 Summary

This thesis started as a quest for the elements that are necessary to create believable characters. Nevertheless, a large number of previous works have pursued this quest as well, obtaining as a result computational models based on psychological theories which can simulate up to a point believable characters.

But as the human being is complex enough, there are several elements which also have to be considered to **enrich** the believability of these characters. One of this elements is the context that surrounds the character, not only from a physical point of view, but also from an affective point of view. One needs to think of the different things that could happen to the characters, of all the things that they could do, what they like or dislike, what they aim for, an so on. In other words, what the world makes the character feel.

Another element that has been not so extensively researched is the expression of moods and personality. Thus we aimed to find a way to manifest these two affective elements in the face of the character, and use them to enhance the expressions given by emotions, making the character more believable.

Therefore, knowing which were the research objectives and the results we wanted to obtain, we started a deep investigation of psychological theories that define emotions, moods and personality (Chapter 2). Also, we researched on the different computational models that have been developed to simulate virtual characters (Chapter 3). From this state of art, we found that the majority of models share the same psychological background. It means, they use the OCC model to represent emotions, the Five-Factor Model to represent personality, and just until recently a few works have used the PAD Space to represent moods. On the other hand, the techniques implemented to simulate the behaviors of the characters goes from neural networks, to mathematical-logical functions or scripting.

However, the answer to our questions remained unsolved: how to represent the context of the character from a physical and affective point of view, and how to visualize the mood and personality. That is why we proposed a novel framework that comprises a context representation, affect processing and visualization of these affective traits (Chapter 4).

The context representation was achieved through the design and implementation of a Semantic Model, that making use of ontologies allowed us to define all those concepts that are important to model the internal and external world of the characters (Chapter 5). The novelty of our ontologies is that they do not just represent the concepts of the physical world and affective traits of the character, but allows inference on them, obtaining emotional responses to events individually appraised by each character of that world.

The affect processing, necessary to obtain the emotion, mood and personality parameters to be visualized, was performed by an Affective Model capable of establish the relations between emotions, mood and personality. Hence, the characters not only feel emotions, but they get in a certain mood according to these emotions and their personality traits (Chapter 6).

Finally, to visualize these affective traits we decided to use facial expressions. The main reason for that is that they are one of the richer and more accurate ways of expressing affect [46]. Moreover, one of the main objectives of this research was to provide moods with facial expressions.

Regarding emotions, we implemented an algorithm that combined expressions of universal emotions to generate expressions of intermediate emotions, and that can be extended to generate other expressions by combining intermediate emotions. Regarding mood, we proposed a set of functions to move facial features (in this case, FACS Action Units [48]) so we could achieve facial expressions that are associated to all the moods defined in PAD model. Regarding personality, we performed subjective evaluations to analyze which visual cues on a virtual character could be associated to personality traits. The visual cues taken into account were: head position and eye gaze. The visualization methods and their implementations are presented in Chapter 7.

9.2 Discussion

The contextual and affective framework proposed in this thesis required an exhaustive analysis and study of different fields that have been combined in order to create a complete process of character generation. That is why through the different chapters psychology, ontologies, affective computing, computer graphics and facial annotation standards are interlaced and treated to a depth that is sufficient to achieve the objectives of this thesis.

In the case of ontologies, we designed and implemented two ontologies that took into account external and internal aspects of the character and its virtual world. Our intention was not to provide new semantics and formal validation for them. Our real aim was to provide a tool that allows the definition of meta-concepts related to the character and its world, make inferences about them, and therefore, easily generate events that occur in that world and automatically obtain their influence on the character's emotional state. In this way, a storyteller could just define the events of the world and the psychological profile of the character, and then stories would be simulated by only re-using and combining this information.

Regarding affective computing and psychology, our intention was not to create a new paradigm or a new computational model for the creation of virtual characters. Our true objective was to use previous works and theories and combined them in a new way that permits to build a bridge between the contextual representation and the visual representation of affect. That is way we made use of the well-known OCC model, Five Factor model and PAD Space for generation of emotions, personality and mood, respectively; as well as of the ALMA model to get the basis of a system that simulated the interaction of these affective traits.

Finally, this thesis did not deal with new computer graphics techniques, instead we used low-cost and efficient facial animation and facial actions description standards like the MPEG-4 and FACS to implement algorithms for the generation of novel and original parameterizable facial expressions, like the expressions of all the intermediate emotions of the OCC. Moreover, due to the advantages of parameterization, these algorithms are independent of animation procedures, being extendible to other standards and visualization techniques. Another novelty in this work is the formulation and implementation of equations that allowed us to create the expressions for a very important affective trait, as it is the mood.

This thesis is also strongly grounded on experimentation and evaluation. The several hypothesis stated for visualization of affect and generation of context led to experiments that not only validated our results, but assessed the perception on the subject's side, giving hints and opening new ways to continue researching in topics that could enormously enhance the believability of characters.

In the case of the evaluation of expressions of emotions, the results demonstrated that subjects could recognized the expressions used for the generation of the expressions of intermediate emotions. Even more, in some cases, subjects rated the obtained intermediate expression with the proper emotional term. Besides suggestions related to the morphology of the character (e.g. hair, wrinkles), the numbers showed that expressions obtained in general highly recognition scores.

As for the moods, we performed a questionnaire where subjects could assess expressions of an avatar according to its pleasure (P), arousal (A) and dominance (D) intensity values. The results of this test conveyed two important conclusions. The first one is that all the 8 moods defined by the PAD model have their corresponding facial expressions. Some moods like exuberant, bored or hostile presented a large number of expressions, while other moods like docile or dependent presented one or two. This difference was mainly due to the difficulty of assessment of Dominance in static images. The second important conclusion is that the functions that were formulated to map AUs into the PAD Space were valid.

These results are of great significance because knowing the AUs that describe the expressions of certain mood, other emotional facial expressions can be enhanced and truly reflect the affective state of the character.

Another aspect that was studied from a purely experimental approach was the perception of personality traits. In this thesis we presented the initial steps of a research that can be easily branched out, because personality is a component that is always expressed but difficult to simulate in a procedural way.

To evaluate the perception of personality we produced a set of configurations for head position and eye gaze, in a way that they do not affect the facial features but somehow enhance the emotional expression. The results were very encouraging because subjects indeed associate *extraversion*, *agreeableness* and *neuroticism* to some configurations. For the Alfred character, the "upwards-sideways" head orientation was related to extraversion, "downwards-center" head orientation to agreeableness, and "center-sideways" head orientation to emotional stability. However, eye gaze did not influence the perception of personality traits.

All these previous findings represent a great advance in the area of visualization of affective traits, because we have more information about all the elements that should be considered when making a character look more believable from an affective point of view.

Finally, a very original experiment was the one to validate the Context Representation module. The idea was to see if subjects could better assessed a facial expression if the context of that expression was given.

The ground data we used to validate the module were the scenes of two movies, so we would have real facial expressions of real actors to compare with when the same context is elicited. The movies were *Léon* and *Downfall*, basically because they were scripted in a way we could easily use in our module, and second because the characters *Mathilda* in *Léon* and *The soldier* in the movie *Downfall*, resembled our characters Alice and Alfred, respectively.

Once again, the results proved that the ontologies we defined and the contextual module we implemented has the potential to feasible reproduce certain context and elicit suitable emotions. For the movie *Léon*, the participants could recognize in the expressions of Alice the emotions triggered by the events. For the movie *Downfall*, the results were not that satisfactory, mainly because of the repressed and passive emotional content of the chosen scenes, and the lack of notorious expressions in the actor, and in the character.

In summary, the framework we propose and the experiment results we obtained can be applied in different applications where it is required to have a story or the interaction between the character and its environment. For instance, educative applications, where the student needs to learn about certain topics with the help of a virtual tutor or simulations in a virtual world; story simulation (kind of storytelling) for representing movies; or theme-oriented situations where the story/script is basically generated by the interaction of the character and its world.

9.3 Future Work

This thesis opened several research lines in different fields as semantic web/ontologies, affect visualization, or animation of facial expressions; to be used in different scenarios like affective HCI applications, storytelling, or virtual worlds that could be use for entertainment (e.g. videogames) or for therapies (e.g. in therapies with autistic children).

Although the previous research showed us that we are on the right track, and we should move forward into this direction, there is still work to be done. The following are some of the tasks we expect to accomplish in the near future:

- **Study of the perception of other visual regarding personality and mood**. In this research we explored how both visual cues: head movement and eye gaze were associated with extraversion, agreeableness and emotional stability; as well as how different FACS configurations described facial expressions for moods. In the future, the idea would be to perform an in-depth study of how these visual cues are associated to openness and conscientiousness, so we have a theory of expressions of personality for the five personality traits. Also other factors could be taken into account when perceiving personality traits in visual cues as gender, age, nationality, and from that observe if perception is the same in different groups of subjects.

  Regarding mood, it is a broad topic in which active research is being performed. Through a more elaborated study to evaluate the already obtained expressions of mood, we could observe if there are other sets of AUs which would also enhance the emotional response of the character.

- **Generate expressions of emotions enhanced by the features of mood and personality**. The main objective would be to dynamically generate facial expressions of emotions with characteristics of mood and personality. To achieve this, it is necessary to study how exactly mood and personality affects emotion features from a physical point of view. For instance, how an anxious mood with a given AUs configuration would affect the AUs, or other facial features of an expression of happiness. Therefore, several tests should be perform to evaluate the results of the different combinations.

- **Implementation of the actual results in HCI applications**. One of the main goals is to provide a tool that complements the therapies to improve communication skills in autistic children and people with Asperger Syndrome. This is motivated by the work we carried on with the Spanish organization ***Autismo Burgos*** (http://www.autismoburgos.org/), who performed our paper questionnaire for perception of emotions in facial expressions with their autistic children and young adults. Although the number of tests was limited due the amount of subjects they had at the time of evaluation, it gave us hints about what it is needed in an software application to engage them (e.g. animations instead of static images; one single character to perform the experiment; the Alice character was found engaging although some facial features were not that accepted, like her hair).

  Therefore, having an application that implements the results obtained in this thesis, together with the improvements from the previous evaluations would be a great step forward in the field of assistive technologies.

9.4 Publications and contributions

The following subsections present the journals, conferences and workshops where this research work has been partially published. Appendix D contains the articles of these publications.

9.4.1 Journals

- D. Arellano, J. Varona, F J. Perales. *Why do I feel like this? - The importance of context representation for emotion elicitation.* International Journal of Synthetic Emotions (IJSE), 2(2), 2011. DOI: 10.4018/IJSE. ISSN: 1947-9093.

- D. Arellano, J. Varona and F. J. Perales. Generation and visualization of emotional states in virtual characters. Computer Animation and Virtual Worlds (CAVW), 19(3-4), pp. 259-270. 2008. DOI: 10.1002/cav.263.

9.4.2 Proceedings

- D. Arellano, N. Bee, K. Janowski, E. André, J. Varona, F. J. Perales. *Influence of Head Orientation in Perception of Personality Traits in Virtual Agents.* AAMAS 2011 (Short paper), Taiwan, May, 2011.

- D. Arellano, I. Lera, J. Varona and F. J. Perales. *Integration of a semantic and affective model for realistic generation of emotional states in virtual characters.* ACII09, Amsterdam, Netherlands, September, 2009.

- I. Lera, D. Arellano, J. Varona, C. Juiz and R. Puigjaner. Semantic Model for Facial Emotion to improve the human computer interaction in AML. In UCAmI 2008, Vol. 51/2009, Salamanca, Spain, pp. 139-148, 2008.

9.4.3 Workshops

- D. Arellano, I. Lera, J. Varona and F. J. Perales. Generating Affective Characters for Assistive Applications. EMOTIONS & MACHINES Workshop, Geneva, Switzerland, August 2009.

- D. Arellano, I. Lera, J. Varona and F. J. Perales. Virtual Characters with Emotional States. 2nd PEACH Summer School. Dubrovnik, Croatia, 2008.

9.4.4 Research placements

- Institut für Informatik, Lehrstuhl für Multimedia-Konzepte und Anwendungen. University of Augsburg. Germany. From May 12^{th}, 2010 until November 8^{th}, 2010.

Bibliography

[1] I. Albrecht, M. Schröder, J. Haber, and H. Seidel. Mixed feelings: Expression of non-basic emotions in a muscle-based talking head. *Journal of Virtual Reality. Special issue on "Language, Speech and Gesture for Virtual Reality*, 8(4):201–212, 2005.

[2] R. D. Aldrich. What ever happened to baby jane? [film]. Film, 1962. Warner Bros.

[3] E. André, M. Klesen, P. Gebhard, S. Allen, and T. Rist. Integrating models of personality and emotions into lifelike characters. In *Affective Interactions*, Lecture Notes in Computer Science, pages 136–149. Springer, 1999.

[4] D. Arellano, I. Lera, J. Varona, and F. J. Perales. Integration of a semantic and affective model for realistic generation of emotional states in virtual characters. In *Proceedings of 2009 International Conference on Affective Computing & Intelligent Interaction (ACII 2009)*, pages 642–648, 2009.

[5] M. Argyle. *Bodily communication.* Methuen & Co. Ltd, 1988.

[6] A. Arya, S. DiPaola, L. Jefferies, and J. T. Enns. Socially communicative characters for interactive applications. In *WSCG'2006*, 2006.

[7] A. Arya, L. N. Jefferies, J. T. Enns, and S. DiPaola. Facial actions as visual cues for personality. *Journal of Visualization and Computer Animation*, 17(3-4):371–382, 2006.

[8] K. Balci. XfaceEd: Authoring tool for embodied conversational agents. In *ICMI*, pages 208–213, 2005.

[9] C. Bartneck. Integrating the occ model of emotions in embodied characters. In *Proceedings of the Workshop on Workshop on Virtual Conversational Characters: Applications, Methods, and Research Challenges*, 2002.

[10] C. Bartneck, M. J. Lyons, and M. Saerbeck. The relationship between emotion models and artificial intelligence. In *SAB2008 Workshop on The Role of Emotion in Adaptive Behavior and Cognitive Robotics*, Osaka, 2008.

[11] J. Bates. The nature of character in interactive worlds and the oz project. Technical report cmu-cs-92-200, Carnegie Mellon University, 1992.

[12] C. Becker-Asano. *WASABI: affect simulation for agents with believable interactivity*, volume 319 of *Dissertationen zur künstlichen Intelligenz*. IOS Press, 2008. http://books.google.com/books?id=8ABvlwHBCQIC.

[13] C. Becker-Asano and I. Wachsmuth. Wasabi as a case study of how misattribution of emotion can be modelled computationally. In *A Blueprint for Affective Computing: a Sourcebook and Manual*, pages 179–193. Oxford University Press, 2010.

[14] N. Bee, B. Falk, and E. André. Simplified facial animation control utilizing novel input devices: A comparative study. In *International Conference on Intelligent User Interfaces (IUI '09)*, pages 197–206, 2009.

[15] N. Bee, S. Franke, and E. André. Relations between facial display, eye gaze and head tilt: Dominance perception variations of virtual agents. In *Proceedings of 2009 International Conference on Affective Computing & Intelligent Interaction (ACII 2009)*, pages 628–634, 2009.

[16] N. Bee, C. Pollock, E. André, and M. Walker. Bossy or wimpy: Expressing social dominance by combining gaze and linguistic behaviors. In J. Allbeck, N. Badler, T. Bickmore, C. Pelachaud, and A. Safonova, editors, *Intelligent Virtual Agents*, volume 6356 of *Lecture Notes in Computer Science*, pages 265–271. Springer Berlin / Heidelberg, 2010.

[17] K. L. Bellman. Emotions: Meaningful mappings between the individual and its world. In *Emotions in Humans and Artifacts*, pages 149–188. Cambridge, MA: MIT Press, 2002.

[18] K.-I. Benta, A. Rarău, and M. Cremene. Ontology based affective context representation. In *Proceedings of the 2007 Euro American conference on Telematics and information systems*, EATIS '07, pages 46:1–46:9, New York, NY, USA, 2007. ACM.

[19] G. Bertrand, F. Nothdurft, S. Walter, A. Scheck, H. Kessler, and W. Minker. Towards investigating effective affective dialogue strategies. In N. C. C. Chair), K. Choukri, B. Maegaard, J. Mariani, J. Odijk, S. Piperidis, M. Rosner, and D. Tapias, edi-

tors, *Proceedings of the Seventh conference on International Language Resources and Evaluation (LREC'10)*. European Language Resources Association (ELRA), 2010.

[20] C. Biehn. Facial expression repertoire (fer), 2005. `http://research.animationsinstitut.de/`.

[21] G. Boeree. Hans eysenck (1916 – 1997) (and other temperament theorists). http://webspace.ship.edu/cgboer/eysenck.html, 1998.

[22] M. Bradley and P. Lang. Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, 25:49–59, 1994.

[23] H. G. Brown, M. S. Poole, L. Deng, and P. Forducey. Towards a sociability theory of computer anxiety: An interpersonal circumplex perspective. In *HICSS '05: Proceedings of the Proceedings of the 38th Annual Hawaii International Conference on System Sciences (HICSS'05) - Track 6*, page 151.1, USA, 2005. IEEE Computer Society.

[24] J. Cao, H. Wang, P. Hu, and J. Miao. Pad model based facial expression analysis. In G. Bebis, R. Boyle, B. Parvin, D. Koracin, P. Remagnino, F. Porikli, J. Peters, J. Klosowski, L. Arns, Y. Chun, T.-M. Rhyne, and L. Monroe, editors, *Advances in Visual Computing*, volume 5359 of *Lecture Notes in Computer Science*, pages 450–459. Springer Berlin / Heidelberg, 2008.

[25] P. H.-M. Chang, Y.-H. Chien, E. C.-C. Kao, and V.-W. Soo. *A knowledge-based scenario framework to support intelligent planning characters*, pages 134–145. Lecture Notes in Computer Science. Springer-Verlag, London, UK, 2005.

[26] H. Chen, F. Perich, T. Finin, and A. Joshi. Soupa: Standard ontology for ubiquitous and pervasive applications. In *International Conference on Mobile and Ubiquitous Systems: Networking and Services*, pages 258–267, Boston, MA, 2004.

[27] G. L. Clore and A. Ortony. Cognition in emotion: Always, sometimes, or never? In I. R. D. L. . L. Nadel, editor, *Cognitive Neuroscience of Emotion*. Series in Affective Science, 2000.

[28] J. Cloud-Buckner, M. Sellick, B. Sainathuni, B. Yang, and J. Gallimore. Expression of personality through avatars: Analysis of effects of gender and race on perceptions of personality. In *Proceedings of the 13th International Conference on Human-Computer Interaction. Part III*, pages 248–256, Berlin, Heidelberg, 2009. Springer-Verlag.

[29] T. Cochrane. 8 dimensions for the emotions. *Social Science Information. Special issue "The language of emotion: conceptual and cultural issues"*, 48:379–420, 2009.

[30] M. Courgeon, S. Buisine, and J.-C. Martin. Impact of expressive wrinkles on perception of a virtual character's facial expressions of emotions. *Proceedings of the 9th International Conference on Intelligent Virtual Agents*, pages 201–214, 2009.

[31] M. Courgeon, C. Clavel, and J.-C. Martin. Appraising emotional events during a real-time interactive game. In *Proceedings of the International Workshop on Affective-Aware Virtual Agents and Social Robots*, AFFINE '09, pages 7:1–7:5, New York, NY, USA, 2009. ACM.

[32] R. Cowie, E. DouglasCowie, S. Savvidou, E. McMahon, M. Sawey, and M. Schröder. Feeltrace: An instrument for recording perceived emotion in real time. In *Proceedings of the ISCA Workshop on Speech and Emotion*, pages 19–24, 2000.

[33] C. Darwin. *The Expression of Emotions in Man and Animals.* London: Murray, 1873.

[34] B. De Carolis, V. Carofiglio, and C. Pelachaud. From discourse plans to believable behaviour generation. In *Proceedings of the International National Language Generation Conference, New York*, 2002.

[35] F. de Rosis, C. Pelachaud, I. Poggi, V. Carofiglio, and B. D. Carolis. From greta's mind to her face: modelling the dynamics of affective states in a conversational embodied agent. *International Journal of Human-Computer Studies*, 59(1-2):81–118, 2003.

[36] A. K. Dey, G. D. Abowd, and D. Salber. A conceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications. *Human-Computer Interaction*, 16:97–166, December 2001.

[37] J. Dias. Fearnot!: Creating emotional autonomous synthetic characters for empathic interactions. Master's thesis, Universidade Técnica de Lisboa, Instituto Superior Técnico, 2005.

[38] J. Dias and A. Paiva. Feeling and reasoning: a computational model for emotional agents. In *Proceedings of 12th Portuguese Conference on Artificial Intelligence, EPIA*, pages 127–140, 2005.

[39] P. Doyle. Believability through context using "knowledge in the world" to create intelligent characters. In *Proceedings of the First International Joint Conference on*

Autonomous Agents and Multiagent Systems: part 1, AAMAS '02, pages 342–349, New York, NY, USA, 2002. ACM.

[40] L. Edelstein. *The Writer's Guide to Character Traits*. Writers Digest Books, 2 edition, 2009.

[41] A. Egges, S. Kshirsagar, and N. Magnenat-Thalmann. Generic personality and emotion simulation for conversational agents: Research articles. *Comput. Animat. Virtual Worlds*, 15(1):1–13, 2004.

[42] P. Ekman. *Emotion in the Human Face*. Cambridge University Press, 1982.

[43] P. Ekman. Moods, emotions, traits. In P. E. . R. Davidson, editor, *The nature of emotion*, pages 56–58. New York: Oxford University Press, 1994.

[44] P. Ekman. Basic emotions. In T. Dalgleish and M. Power, editors, *Handbook of Cognition and Emotion*, chapter 3. Sussex, U.K.: John Wiley & Sons, Ltd., 1999.

[45] P. Ekman. Facial expressions. In T. Dalgleish and M. Power, editors, *Handbook of Cognition and Emotion*, chapter 16. New York: John Wiley & Sons Ltd, 1999.

[46] P. Ekman. Darwin's contributions to our understanding of emotional expressions. *Philosophical Transactions of the Royal Society Biological Sciences*, 364(1535):3449–3451, 2009.

[47] P. Ekman and W. Friesen. *Unmasking the Face*. New Jersey: Prentice-Hall, 1975.

[48] P. Ekman, W. Friesen, and J. Hager. *The Facial Action Coding System*. Weidenfeld & Nicolson, London, UK, 2nd edition, 2002.

[49] C. Elliott. I picked up catapia and other stories: a multimodal approach to expressivity for "emotionally intelligent" agents. In *Proceedings of the first international conference on Autonomous agents*, AGENTS '97, pages 451–457, New York, NY, USA, 1997. ACM.

[50] C. Elliott. Hunting for the holy grail with "emotionally intelligent" virtual actors. *SIGART Bull.*, 9(1):20–28, 1998.

[51] H. J. Eysenck and S. B. G. Eysenck. *Manual of the Eysenck Personality Questionnaire*. London: Hodder and Stoughton, 1975.

[52] S. Eysenck. Citation classic. the measurement of psychoticism: a study of factor stability and reliability. *CC/SOC BEHAV SCI*, 1(35):12, 1986.

[53] M. Fabri, D. J. Moore, and D. J. Hobbs. Designing avatars for social interactions. In L. Canamero and R. A. (eds.), editors, *Animating Expressive Characters for Social Interaction, Advances in Consciousness Research Series*. Benjamins Publishing, 2008.

[54] G. Faigin. *The Artist's Complete Guide to Facial Expressions*. Watson-Guptill, New York, 1990.

[55] C. Felbaum. *Wordnet, an Electronic Lexical Database for English*. Cambridge: MIT Press, 1998.

[56] E. Figa and P. Tarau. The vista architecture: experiencing stories through virtual storytelling agents. *SIGGROUP Bull.*, 23(2):27–28, 2002.

[57] S. C. for Biomedical Informatics Research. The protégé ontology editor and knowledge acquisition system. Latest version available at http://protege.stanford.edu/download/download.html. Last reviewed: 28/02/2011.

[58] R. Forchheimer and I. S. Pandzic. *MPEG-4 facial animation The Standard, Implementation and Applications*. John Wiley and Sons, West Sussex, UK, 1996.

[59] N. H. Frijda. *The Emotions*. Cambridge ; New York : Cambridge University Press; Paris: Editions de la Maison des sciences de l'homme, 1986.

[60] N. H. Frijda. The laws of emotion. In . N. S. Jennifer M. Jenkins, Keith Oatley, editor, *Human Emotions: A Reader*, pages 271–287. Malden, MA: Blackwell Publishers, 1998.

[61] A. Gangemi, N. Guarino, C. Masolo, A. Oltramari, and L. Schneider. Sweetening ontologies with dolce. In *Proceedings of the 13th International Conference on Knowledge Engineering and Knowledge Management. Ontologies and the Semantic Web*, EKAW '02, pages 166–181, London, UK, 2002. Springer-Verlag.

[62] A. N. Garvin. Experiential retailing: extraordinary store environments and purchase behavior. Master's thesis, Eastern Michigan University, 2009.

[63] P. Gebhard. ALMA: a layered model of affect. In *AAMAS '05: Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems*, pages 29–36, NY, USA, 2005. ACM.

[64] P. Gebhard. *Emotionalisierung interaktiver Virtueller Charaktere*. PhD thesis, Universität des Saarlandes, 2007.

[65] P. Gebhard and K. H. Kipp. Are computer-generated emotions and moods plausible to humans?. In *IVA*, volume 4133 of *Lecture Notes in Computer Science*, pages 343–356. Springer, 2006.

[66] S. D. Gosling, P. J. Rentfrow, and W. B. S. Jr. A very brief measure of the big-five personality domains. *Journal of Research in Personality*, 37(6):504–528, 2003.

[67] K. Grammer and E. Oberzaucher. The reconstruction of facial expressions in embodied systems: New approaches to an old problem. *ZiF Mitteilungen*, 2:14–31, 2006.

[68] W. O. W. Group. Owl 2 web ontology language. document overview. w3c recommendation 27 october 2009. Latest version available at http://www.w3.org/TR/owl2-overview/. Last reviewed: 09/19/2010.

[69] M. Grüninger and M. Fox. Methodology for the design and evaluation of ontologies. In *IJCAI'95, Workshop on Basic Ontological Issues in Knowledge Sharing*, 1995.

[70] M. Gutiérrez, A. García-Rojas, D. Thalmann, F. Vexo, L. Moccozet, N. Magnenat-Thalmann, M. Mortara, and M. Spagnuolo. An ontology of virtual humans: Incorporating semantics into human shapes. *Vis. Comput.*, 23(3):207–218, 2007.

[71] D. Heckmann, T. Schwartz, B. Brandherm, M. Schmitz, and M. von Wilamowitz-Moellendorff. Gumo: The general user model ontology. *User Modeling 2005*, pages 428–432, 2005.

[72] L. Hewlett-Packard Development Company. Jena: A Semantic Web Framework for Java, 2008. version 2.5.6. `http://jena.sourceforge.net/`.

[73] J. R. Hobbs and F. Pan. Time ontology in owl. Latest version available at http://www.w3.org/TR/owl-time/. Last reviewed: 25/06/2011.

[74] W. K. Hofstee, B. de Raad, and L. R. Goldberg. Integration of the big five and circumplex approaches to trait structure. *Journal of Personality and Social Psychology*, 63(1):146–163, 1992.

[75] D. C. Howe. Rita.wordnet. http://www.rednoise.org/rita/wordnet/documentation/index.htm. Last reviewed: 08052011.

[76] S. Inversions. `http://www.facegen.com/modeller.htm`.

[77] K. Isbister and C. Nass. Consistency of personality in interactive characters: verbal cues, non-verbal cues, and user characteristics. *Int. J. Hum.-Comput. Stud.*, 53(2):251–267, 2000.

[78] S. Kaiser and T. Wehrle. *Facial expressions in social interactions: Beyond basic emotions*, volume Advances in Consciousness Research (Vol.74): Animating Expressive Characters for Social Interactions, chapter 4, pages 53–69. Amsterdam : John Benjamins Publishing Company, 2008.

[79] Z. Kasap and N. Magnenat-Thalmann. Intelligent virtual humans with autonomy and personality: State-of-the-art. *Intelligent Decision Technologies*, 1(1-2):3–15, 2007.

[80] Z. Kasap, M. B. Moussa, P. Chaudhuri, and N. Magnenat-Thalmann. Making them remember - emotional virtual characters with memory. *IEEE Computer Graphics and Applications*, 29(2):20–29, 2009.

[81] D. Keltner. Facial expression, personality, and psychopathology. In P. Ekman and E. L. Rosenberg, editors, *What the face reveals: basic and applied studies of spontaneous expression using the facial action coding system(FACS)*, chapter 25, pages 548–550. Oxford University Press, 1997.

[82] H. Kessler, A. Festini, H. C. Traue, S. Filipic, M. Weber, and H. Hoffmann. Simplex - simulation of personal emotion experience. In K. V. (Ed.), editor, *Affective Computing: Emotion Modelling, Synthesis and Recognition*. I-Tech Education and Publishing, Vienna, 2008.

[83] E. Krahmer, S. van Buuren, Z. Ruttkay, and W. Wesselink. Audio-visual personality cues for embodied agents: An experimental evaluation. In *Proc. of the AAMAS03 Ws on "Embodied Conversational Characters as Individuals"*, 2003.

[84] R. Krummenacher, H. Lausen, and T. Strang. Analyzing the modeling of context with ontologies. In *International Workshop on Context-Awareness for Self-Managing Systems*, pages 11–22, 2007.

[85] S. Kshirsagar and N. Magnenat-Thalmann. A multilayer personality model. In *SMARTGRAPH '02: Proceedings of the 2nd international symposium on Smart graphics*, pages 107–115, NY, USA, 2002. ACM.

[86] B. Lance and S. Marsella. Glances, glares, and glowering: how should a virtual human express emotion through gaze? *Autonomous Agents and Multi-Agent Systems*, 20(1):50–69, 2010.

[87] D. Lenat. Cyc: A large-scale investment in knowledge infrastructure. *Communications of the ACM*, 38(11):33–38, 1995.

[88] Y. li Tian, T. Kanade, and J. F. Cohn. Recognizing action units for facial expression analysis. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 23:97–115, 2001.

[89] J. M. López, R. Gil, R. García, I. Cearreta, and N. Garay. Towards an ontology for describing emotions. In *Proceedings of the 1st world summit on The Knowledge Society: Emerging Technologies and Information Systems for the Knowledge Society*, WSKS '08, pages 96–104, Berlin, Heidelberg, 2008. Springer-Verlag.

[90] C. Mackay, T. Cox, G. Burrows, and T. Lazzerini. An inventory for the measurement of self-reported stress and arousal. *The British Journal of Social and Clinical Psychology*, 17(3):283–284, 1978.

[91] N. Magnenat-Thalmann and Z. Kasap. Modelling socially intelligent virtual humans. In *VRCAI '09: Proceedings of the 8th International Conference on Virtual Reality Continuum and its Applications in Industry.* ACM, 2009. http://www.vrcai2009.com/socially_intelligentVH.pdf.

[92] L. Malatesta, A. Raouzaiou, K. Karpouzis, and S. Kollias. Towards modeling embodied conversational agent character profiles using appraisal theory predictions in expression synthesis. *Applied Intelligence*, 30(1):58–64, 2009.

[93] M. Mancini and C. Pelachaud. Implementing distinctive behavior for conversational agents. *Gesture-Based Human-Computer Interaction and Simulation, Lecture Notes in Computer Science*, 5085/2009:163–174, 2009.

[94] S. Marsella and J. Gratch. Ema: A computational model of appraisal dynamics. In *European Meeting on Cybernetics and Systems Research*, 2006. http://www.ict.usc.edu/ marsella/publications/N_Emcsr_Marsella.pdf.

[95] S. Marsella and J. Gratch. Ema: A process model of appraisal dynamics. *Journal of Cognitive Systems Research*, 10(1):70–90, 2009.

[96] G. Matthews, D. Jones, and A. Chamberlain. Refining the measurement of mood: the uwist mood adjetive checklist. *British Journal of Psychology*, 81:17–42, 1990.

[97] R. McCrae and O. John. An introduction to the five-factor model and its applications. *Journal of Personality*, 60(1):175–215, 1992.

[98] R. R. McCrae. The five-factor model of personality traits: consensus and controversy. In . G. M. P. J. Corr, editor, *Cambridge Handbook of Personality Psychology*, chapter 9, pages 148–161. Oxford: Oxford University Press, 2009.

[99] R. R. McCrae and P. T. Costa. Validation of a five-factor model of personality across instruments and observers. *Journal of Personality and Social Psychology*, 52(1):81–90, 1987.

[100] D. L. McGuinness and F. van Harmelen. Owl web ontology language. overview. w3c recommendation 10 february 2004. Latest version available at http://www.w3.org/TR/2004/REC-owl-features-20040210/#s1.2. Last reviewed: 09/19/2010.

[101] M. McRorie, I. Sneddon, E. de Sevin, E. Bevacqua, and C. Pelachaud. A model of personality and emotional traits. In Z. Ruttkay, M. Kipp, A. Nijholt, and H. Vilhj'almsson, editors, *Intelligent Virtual Agents*, volume 5773 of *Lecture Notes in Computer Science*, pages 27–33. Springer Berlin / Heidelberg, 2009.

[102] A. Mehrabian. *Nonverbal Communication*. Chicago, IL: Aldine-Atherton, 1972.

[103] A. Mehrabian. Incorporating emotions and personality in artificial intelligence software, 1995. http://www.kaaj.com/psych/ai.html. Last access: 20101111.

[104] A. Mehrabian. Analysis of the big-five personality factors in terms of the pad temperament model. *Australian Journal of Psychology*, 48(2):86–92, 1996.

[105] A. Mehrabian. Pleasure-arousal-dominance: A general framework for describing and measuring individual differences in temperament. *Current Psychology*, 14(4):261–292, 1996.

[106] A. Mehrabian and J. A. Russell. *An Approach to Environmental Psychology*. Cambridge, MIT Press, 1974.

[107] G. Miller. Wordnet: A lexical database for english. *Communications of the ACM*, 38(11), 1995.

[108] M. Mitrasinovic. *Total landscape, theme parks, public space*. Ashgate Publishing Limited, 2006.

[109] D. Moffat and N. H. Frijda. Where there's a will there's an agent. In M. J. Wooldridge and N. R. Jennings, editors, *Intelligent Agents: ECAI-94. Workshop on Agent Theories, Architectures, and Languages*, pages 245–260. Springer, Berlin, 1995.

[110] M. Mosmondor, T. Kosutic, and I. S. Pandzic. Livemail: personalized avatars for mobile entertainment. In *Proceedings of the 3rd international conference on Mobile systems, applications, and services*, MobiSys '05, pages 15–23, New York, NY, USA, 2005. ACM.

[111] M. B. Moussa and N. Magnenat-Thalmann. Applying affect recognition in serious games: The playmancer project. *Lecture Notes in Computer Science. Motion in Games*, 5884/2009:53–62, 2009.

[112] A. Nakasone and M. Ishizuka. Storytelling ontology model using rst. In *IAT '06: Proceedings of the IEEE/WIC/ACM international conference on Intelligent Agent Technology*, pages 163–169, Washington, DC, USA, 2006. IEEE Computer Society.

[113] M. Neff, Y. Wang, R. Abbott, and M. Walker. Evaluating the effect of gesture and language on personality perception in conversational agents. In J. Allbeck, N. Badler, T. Bickmore, C. Pelachaud, and A. Safonova, editors, *Intelligent Virtual Agents*, volume 6356 of *Lecture Notes in Computer Science*, pages 222–235. Springer Berlin / Heidelberg, 2010.

[114] A. Newell. *Unified Theories of Cognition*. Cambridge, MA: Harvard University Press, 1990.

[115] I. Niles and A. Pease. Towards a standard upper ontology. In *Proceedings of the international conference on Formal Ontology in Information Systems - Volume 2001*, FOIS '01, pages 2–9, New York, NY, USA, 2001. ACM.

[116] Z. Obrenovic, N. Garay, J. López, I. Fajardo, and I. Cearreta. An ontology for description of emotional cues. In J. Tao, T. Tan, and R. Picard, editors, *Affective Computing and Intelligent Interaction*, volume 3784 of *Lecture Notes in Computer Science*, pages 505–512. Springer Berlin / Heidelberg, 2005.

[117] Z. Obrenovic, D. Starcevic, and V. Devedzic. Using ontologies in design of multimodal user interfaces. *Human-Computer Interaction - INTERACT '03*, pages 535–542, 2003.

[118] M. Ochs, N. Sabouret, and V. Corruble. Simulation of the dynamics of nonplayer character's emotions and social relations in games. *IEEE Transactions on Computational Intelligence and AI in Games*, 1(4):281–297, 2009.

[119] A. Ortony. On making believable emotional agents believable. In *Emotions in Humans and Artifacts*, pages 189–211. Cambridge, MA: MIT Press, 2002.

[120] A. Ortony, G. Clore, and A. Collins. *The Cognitive Structure of Emotions*. Cambridge University Press, 1988.

[121] A. Paiva, J. Dias, D. Sobral, R. Aylett, P. Sobreperez, S. Woods, C. Zoll, and L. Hall. Caring for agents and agents that care: Building empathic relations with synthetic

agents. *Autonomous Agents and Multiagent Systems, International Joint Conference on*, 1:194–201, 2004.

[122] S. Pasquariello and C. Pelachaud. Greta: A simple facial animation engine. *6th Online World Conference on Soft Computing in Industrial Applications, Session on Soft Computing for Intelligent 3D Agents*, 2001.

[123] R. W. Picard. *Affective Computing*. MIT Press, 1997.

[124] S. M. Platt and N. Badler. Animating facial expressions. *Computer Graphics*, 15(3):245–252, 1981.

[125] R. Plutchik. *Emotions: A Psychoevolutionary Synthesis*. Harper & Row, New York, 1980.

[126] M. Poznanski and P. Thagard. Changing personalities: towards realistic virtual characters. *Journal of Experimental & Theoretical Artificial Intelligence*, 17(3):221–241, 2005.

[127] B. D. Raad. Structural models of personality. In . G. M. P. J. Corr, editor, *Cambridge Handbook of Personality Psychology*, chapter 8, pages 127–147. Oxford: Oxford University Press, 2009.

[128] B. D. Raad and D. P. Barelds. A new taxonomy of dutch personality traits based on a comprehensive and unrestricted list of descriptors. *Journal of Personality and Social Psychology*, 94(2):347–364, 2008.

[129] M. Radovan and L. Pretorius. Facial animation in a nutshell: past, present and future. In *SAICSIT '06 Proceedings of the 2006 annual research conference of the South African institute of computer scientists and information technologists on IT research in developing countries*, 2006.

[130] A. S. Rao and M. P. Georgeff. Modeling rational agents within a bdiarchitecture. In J. Allen, R. Fikes, and E. H. Sandewall, editors, *Proceedings of the 2nd International Conference on Principles of Knowledge Representation and Reasoning (KR'91)*, pages 473–484, 1991.

[131] A. Raouzaiou, N. Tsapatsoulis, K. Karpouzis, and S. Kollias. Parameterized facial expression synthesis based on MPEG-4. *EURASIP J. Appl. Signal Process.*, 2002(1):1021–1038, 2002.

[132] M. R. Raphalalani. Basic emotions in Tshivenda: a cognitive semantic analysis. Master's thesis, Stellenbosch University, 2006.

[133] J. Russell. Core affect and the psychological construction of emotion. *Psychological Review*, 110(1):145–172, 2003.

[134] J. A. Russell. A circumplex model of affect. *Journal of Personality and Social Psychology*, 39(6):1161–1178, 1980.

[135] J. A. Russell. Measures of emotion. In R. Plutchik and H. Kellerman, editors, *Emotion: Theory, Research, and Experience. The Measurement of Emotions*, volume 4, chapter 4, pages 83–111. New York: Academic Press, 1989.

[136] J. A. Russell and A. Mehrabian. Evidence for a three-factor theory of emotions. *Journal of Research in Personality*, 11(3):273–294, 1977.

[137] M. Sagar. Facial performance capture and expressive translation for king kong. In *ACM SIGGRAPH 2006 Sketches*, SIGGRAPH '06, New York, NY, USA, 2006. ACM.

[138] R. Schapp. Enhancing video game characters with emotion, mood and personality. Master's thesis, Delft University of Technology, 2009.

[139] J. Scheffczyk, C. F. Baker, and S. Narayanan. Ontology-based reasoning about lexical resources. *Ontologies and Lexical Resources for Natural Language Processing*, pages 1–8, 2006.

[140] K. R. Scherer. *Appraisal considered as a process of multi-level sequential checking*, pages 92–120. Oxford University Press, New York and Oxford, k. r. scherer, a. schorr, & t. johnstone (eds.) edition, 2001.

[141] T. Strang and C. Linnhoff-Popien. A context modeling survey. In *UbiComp 1st International Workshop on Advanced Context Modelling, Reasoning and Management*, pages 31–41, 2004.

[142] I. Swartjes and M. Theune. The virtual storyteller: story generation by simulation. *Twentieth Belgian-Netherlands Conference on Artificial Intelligence, BNAIC*, 2008.

[143] B. Szekely and J. Betz. Jastor: Typesafe, ontology driven rdf access from java. Latest version available at http://jastor.sourceforge.net/. Last reviewed: 25/06/2011.

[144] M. Tekalp and J. Ostermann. Face and 2-D mesh animation in MPEG-4. *Signal Processing: Image Communication*, 15(4-5):387–421, 2000.

[145] R. E. Thayer. Factor analytic and reliability studies on the activation-deactivation adjective check list. *Psychological Reports*, 42:747–756, 1978.

[146] Y. Tong, W. Liao, and Q. Ji. Inferring facial action units with causal relations. In *Proceedings of the 2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'06)*, 2006.

[147] J. D. Velásquez. Modeling emotions and other motivations in synthetic agents. In *Proceedings of AAAI97*, 1997.

[148] V. Vinayagamoorthy, M. Gillies, A. Steed, E. Tanguy, X. Pan, C. Loscos, and M. Slater. Building expression into virtual characters. *Eurographics. State of the Art Reports (STARs)*, 2006.

[149] X. H. Wang, D. Q. Zhang, T. Gu, and H. K. Pung. Ontology based context modeling and reasoning using owl. In *Proceedings of the Second IEEE Annual Conference on Pervasive Computing and Communications Workshops*, PERCOMW '04, pages 18–, Washington, DC, USA, 2004. IEEE Computer Society.

[150] D. Watson. *Mood and Temperament*. The Guilford Press, 2000.

[151] D. Watson and L. A. Clark. On traits and temperament: general and specific factors of emotional experience and their relation to the five-factor model. *J Pers*, 60(2):441–476, 1992.

[152] D. Watson and L. A. Clark. The panas-x: Manual for the positive and negative affect schedule - expanded form. Available from http://www.psychology.uiowa.edu/Faculty/Watson/PANAS-X.pdf, 1994.

[153] C. Whissell. The dictionary of affect in language. In R. Plutchik and H. Kellerman, editors, *EMOTION. Theory, Research, and Experience. Volume 4: The Measurement of Emotions*, chapter 5, pages 113–131. New York: Academic Press, 1989.

[154] J. S. Wiggins. A psychological taxonomy of trait-descriptive terms: The interpersonal domain. *Journal of Personality and Social Psychology*, 37(3):395–412, 1979.

[155] J. S. Wiggins, P. D. Trapnell, and N. Phillips. Psychometric and geometric characteristics of the revised interpersonal adjective scales (ias-r). *Multivariate Behavioral Research*, pages 517–530, 1988.

[156] V. Zammitto, S. DiPaola, and A. Arya. A methodology for incorporating personality modeling in believable game characters. *4th Intl Conf on Games Research and Development (CyberGames)*, 2008.

[157] M. A. Zevon and A. Tellegen. The structure of mood change: An idiographic/nomothetic analysis. *Journal of Personality and Social Psychology*, 43(1):111–122, 1982.

Appendix A

Ontology Rules

The following rules are specified for emotion elicitation in JENA format. Thus this is the way they were defined in our application. The format is:

name-of-the-rule: $a_1 \wedge a_2 \wedge ... \wedge a_n \Longrightarrow c_1 \wedge c_2 \wedge ... \wedge c_n$,

where a_i and c_i are predicates of the form: *subject, relation, object*.

A *subject* is in most of the cases a variable that is taken from the database. To use it in the rule it is preceded by a question mark (?). For instance, the variable ?character refers to the character to whom the rules are applied.

A *relation* is the link between the subject and the object. It is taken from the ontology itself through an URI that indicates where it has defined. In our case the URIs that has been defined are:

- **personalityOntology**: http://dmi.uib.es/ ugiv/ontologies/personalityEmotion
- **event**: http://dmi.uib.es/ ugiv/ontologies/event
- **rdf-syntax**: ¡http://www.w3.org/1999/02/22-rdf-syntax-ns (this is the definition of RDF concepts according to the standard)

An *object* can be a variable taken from the database (preceded by "?") or a defined type in the ontology (preceded by the URI).

Table A.1 presents the rules used to elicit emotions according to the Satisfaction of the Event and the AgentAdmiration for agents with role "ByOther" and "OnOther".

Rule: **NotSatisfactionByMeEmotions**

If the event is *NotSatisfactory* and the role is *ByMe*, then the rules are:

<**EventRelation**><hasSatisfactionValue><**EventSatisfactionScale**>∧
?eventSatScale <**rdf-syntax**#type><**personalityOntology**#NotSatisfactory>∧
?character <**personalityOntology**#hasEventSatisfaction> ?eventRelation ∧
?character <**event**#hasRole> ?agentRole ∧
?agentRole <**rdf-syntax**#type> <**event**#ByMe>
$\Longrightarrow$
?agentRole <**personalityEmotion**#hasNegativeSelfEmotion><**personalityEmotion**#Shame>∧
?agentRole <**personalityEmotion**#hasNegativeSelfEmotion><**personalityEmotion**#Remorse>

Rule: **SatisfactionByMeEmotions**

If the event is *Satisfactory* and the role is *ByMe*, then the rules are:

?eventRelation <**personalityEmotion**#hasSatisfactionValue> ?eventSatScale ∧
?eventSatScale <**rdf-syntax**#type> <**personalityEmotion**#Satisfactory>∧
?character <**personalityEmotion**#hasEventSatisfaction> ?eventRelation ∧
?character <**event**#hasRole> ?agentRole ∧
?agentRole <**rdf-syntax**#type><**event**#ByMe>
$\Longrightarrow$
?agentRole <**personalityEmotion**#hasPositiveSelfEmotion><**personalityEmotion**#Pride>∧
?agentRole <**personalityEmotion**#hasPositiveSelfEmotion><**personalityEmotion**#Gratification>

Rule: **IndifferentByMeEmotions**

If the event does not have a level of satisfaction (i.e. it is *Indifferent*) and the role is *ByMe*, then the rules are:

?eventRelation <**personalityEmotion**#hasSatisfactionValue> ?eventSatScale ∧
?eventSatScale <**rdf-syntax**#type> <**personalityEmotion**#IndifferentE> ∧
?character <**personalityEmotion**#hasEventSatisfaction> ?eventRelation ∧
?character <**event**#hasRole> ?agentRole ∧
?agentRole <**rdf-syntax**#type> <**event**#ByMe>
$\Longrightarrow$
?agentRole <**personalityEmotion**#hasSelfEmotion><**personalityEmotion**#Neutral>

Rule: **SatisfactionOnMeEmotionsGoal**

If the event is *Satisfactory*, it means the realization of a goal, and the role is *OnMe*, then the rules are:

?eventRelation <**personalityEmotion**#hasEvent> ?event ∧
?eventRelation <**personalityEmotion**#hasSatisfactionValue> ?satScale ∧
?satScale <**rdf-syntax**#type> <**personalityEmotion**#Satisfactory>∧
?character <**personalityEmotion**#hasEventSatisfaction> ?eventRelation ∧
?character <**event**#hasRole> ?agentRole ∧
?agentRole <**rdf-syntax**#type> <**event**#OnMe>∧
?character <**personalityEmotion**#hasGoal>?event
$\Longrightarrow$
?agentRole <**personalityEmotion**#hasPositiveSelfEmotion><**personalityEmotion**#Satisfaction>∧
?agentRole <**personalityEmotion**#hasPositiveSelfEmotion> <**personalityEmotion**#Relief>

Rule: **SatisfactionOnMeEmotions**

If the event is *Satisfactory* and the role is *OnMe*, then the rules are:

?eventRelation <**personalityEmotion**#hasEvent> ?event ∧
?eventRelation <**personalityEmotion**#hasSatisfactionValue> ?satScale ∧
?satScale <**rdf-syntax**#type><**personalityEmotion**#Satisfactory>∧
?character <**personalityEmotion**#hasEventSatisfaction> ?eventRelation ∧
?character <**event**#hasRole> ?agentRole ∧
?agentRole <**rdf-syntax**#type> <**event**#OnMe>
⟹
?agentRole <**personalityEmotion**#hasPositiveSelfEmotion> <**personalityEmotion**#Joy>

Rule: **NotSatisfactionOnMeEmotionsGoal**

If the event is *NotSatisfactory*, it is related to a goal, and the role is *OnMe*, then the rules are:

?eventRelation <**personalityEmotion**#hasEvent> ?event ∧
?eventRelation <**personalityEmotion**#hasSatisfactionValue> ?satScale ∧
?satScale <**rdf-syntax**#type> <**personalityEmotion**#NotSatisfactory>∧
?character <**personalityEmotion**#hasEventSatisfaction > ?eventRelation ∧
?character <**event**#hasRole> ?agentRole ∧
?agentRole <**rdf-syntax**#type> <**event**#OnMe>∧
?character <**personalityEmotion**#hasGoal> ?event
⟹
?agentRole <**personalityEmotion**#hasNegativeSelfEmotion> <**personalityEmotion**#Disappointment>∧
?agentRole <**personalityEmotion**#hasNegativeSelfEmotion> <**personalityEmotion**#Fear>

Rule: **NotSatisfactionOnMeEmotions**

If the event is *NotSatisfactory* and the role is *OnMe*, then the rules are:

?eventRelation <**personalityEmotion**#hasEvent> ?event ∧
?eventRelation <**personalityEmotion**#hasSatisfactionValue> ?satScale ∧
?satScale <**rdf-syntax**#type> <**personalityEmotion**#NotSatisfactory>∧
?character <**personalityEmotion**#hasEventSatisfaction> ?eventRelation ∧
?character <**event**#hasRole> ?agentRole ∧
?agentRole <**rdf-syntax**#type> <**event**#OnMe>
⟹
?agentRole <**personalityEmotion**#hasNegativeSelfEmotion> <**personalityEmotion**#Sadness>

Rule: **PositiveAdmirationByOtherEmotions**

The agent who has the role *ByOther* is positively admired by the agent who evaluates the event. Then the rules are:

?agent <**personalityEmotion**#feels> ?admirationScale ∧
?admirationScale <**personalityEmotion**#feelsFor> ?otherAgent ∧
?admirationScale <**rdf-syntax**#type> <**personalityEmotion**#Positive>∧
?otherAgentRole <**event**#hasEmotionalAgent> ?otherAgent ∧
?otherAgentRole <**rdf-syntax**#type><**ontologies**/event#ByOther>
⟹
?otherAgentRole <**personalityEmotion**#hasPositiveOtherEmotion> <**personalityEmotion**#Admiration>∧
?otherAgentRole <**personalityEmotion**#hasNegativeOtherEmotion><**personalityEmotion**#Reproach>

Rule: **NegativeAdmirationByOtherEmotions**

The agent who has the role *ByOther* is negatively admired by the agent who evaluates the event. Then the rules are:

?agent <**personalityEmotion**#feels> ?admirationScale ∧
?admirationScale <**personalityEmotion**#feelsFor> ?otherAgent ∧
?admirationScale <**rdf-syntax**#type> <**personalityEmotion**#Negative>∧
?otherAgentRole <**event**#hasEmotionalAgent> ?otherAgent ∧
?otherAgentRole <**rdf-syntax**#type> <**event**#ByOther>
⟹
?otherAgentRole <**personalityEmotion**#hasPositiveOtherEmotion> <**personalityEmotion**#Gratitude>∧
?otherAgentRole <**personalityEmotion**#hasNegativeOtherEmotion> <**personalityEmotion**#Anger>

Rule: **PositiveAdmirationOnOtherEmotions**

The agent who has the role *OnOther* is positively admired by the agent who evaluates the event. Then the rules are:

?agent <**personalityEmotion**#feels> ?admirationScale ∧
?admirationScale <**personalityEmotion**#feelsFor> ?otherAgent ∧
?admirationScale <**rdf-syntax**#type> <**personalityEmotion**#Positive> ∧
?otherAgentRole <**event**#hasEmotionalAgent> ?otherAgent ∧
?otherAgentRole <**rdf-syntax**#type> <**event**#OnOther>
⟹
?otherAgentRole <**personalityEmotion**#hasPositiveOtherEmotion> <**personalityEmotion**#Joy> ∧
?otherAgentRole <**personalityEmotion**#hasNegativeOtherEmotion> <**personalityEmotion**#Pity>

Rule: **NegativeAdmirationOnOtherEmotions**

The agent who has the role *OnOther* is negatively admired by the agent who evaluates the event. Then the rules are:

?agent <**personalityEmotion**#feels> ?admirationScale ∧
?admirationScale <**personalityEmotion**#feelsFor> ?otherAgent ∧
?admirationScale <**rdf-syntax**#type> <**personalityEmotion**#Negative> ∧
?otherAgentRole <**event**#hasEmotionalAgent> ?otherAgent ∧
?otherAgentRole <**rdf-syntax**#type> <**event**#OnOther>
⟹
?otherAgentRole <**personalityEmotion**#hasPositiveOtherEmotion> <**personalityEmotion**#Gloating> ∧
?otherAgentRole <**personalityEmotion**#hasNegativeOtherEmotion> <**personalityEmotion**#Resentment>

Rule: **EmotiveScaleSGEmotions**

These are the emotions elicited due to a *StronglyGood* event. Then the rules are:

?emotiveScale <**rdf-syntax**#type> <**personalityEmotion**#StronglyGood>
⟹
?emotiveScale <**personalityEmotion**#hasPositiveEmotion> <**personalityEmotion**#Love>∧
?emotiveScale <**personalityEmotion**#hasEmotion><**personalityEmotion**#Love>

Rule: **EmotiveScaleGEmotions**

These are the emotions elicited due to a *Good* event. Then the rules are:

?emotiveScale <**rdf-syntax**#type> <**personalityEmotion**#Good>
⟹
?emotiveScale <**personalityEmotion**#hasPositiveEmotion> <**personalityEmotion**#Liking>∧
?emotiveScale <**personalityEmotion**#hasEmotion><**personalityEmotion**#Liking>

Rule: **EmotiveScaleIEmotions**

These are the emotions elicited due to a *Indifferent* event. Then the rules are:

?emotiveScale <**rdf-syntax**#type> <**personalityEmotion**#Indifferent>
⟹

?emotiveScale <**personalityEmotion**#hasEmotion><**personalityEmotion**#Neutral>
Rule: **EmotiveScaleBEmotions** These are the emotions elicited due to a *Bad* event. Then the rules are:
?emotiveScale <**rdf-syntax**#type> <**personalityEmotion**#Bad> $\Longrightarrow$?emotiveScale <**personalityEmotion**#hasNegativeEmotion> <**personalityEmotion**#Disliking>$\wedge$?emotiveScale <**personalityEmotion**#hasEmotion><**personalityEmotion**#Disliking>
Rule: **EmotiveScaleSBEmotions** These are the emotions elicited due to a *StronglyBad* event. Then the rules are:
?emotiveScale <**rdf-syntax**#type> <**personalityEmotion**#StronglyBad> $\Longrightarrow$?emotiveScale <**personalityEmotion**#hasNegativeEmotion> <**personalityEmotion**#Hate>$\wedge$?emotiveScale <**personalityEmotion**#hasNegativeEmotion> <**personalityEmotion**#Fear>$\wedge$?emotiveScale <**personalityEmotion**#hasEmotion><**personalityEmotion**#Hate>$\wedge$?emotiveScale <**personalityEmotion**#hasEmotion><**personalityEmotion**#Fear>
Rule: **IsGoal** Allows to know if the event is a Goal. Then the rules are:
?agent <**personalityEmotion**#hasGoal> ?event $\Longrightarrow$?event <**personalityEmotion**#isGoalOf> ?agent

Table A.1: JENA Rules for the elicitation of emotions

Appendix B

Mapping from FAPs to AUs

B.1 Mapping

Table B.1 presents the mapping done from Facial Animation Parameters (FAPs) into Action Units (AUs), based on the movements performed and the muscles involved.

Table B.1: Mapping of Facial Animation Parameters (FAPs) into Action Units (AUs)

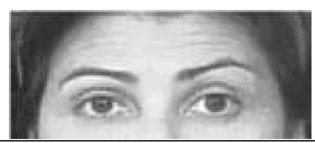
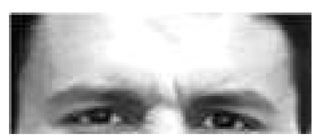
AU	**Description**	**Facial Muscle**	**FAP**	**Description**	**Picture**
1	Inner Brow Raiser	Frontalis, pars medialis	31 + 32 +	raise_l_i_eyebrow raise_r_i_eyebrow	
2	Outer Brow Raiser	Frontalis, pars lateralis	35 + 36 +	raise_l_o_eyebrow raise_r_o_eyebrow	
4	Brow Lowerer - Frown	Depressor Glabellae, Corrugator, Depressor supercilii	31 - 32 - 33 - 34 - 35 - 36 - 37 - 38 -	raise_l_i_eyebrow raise_r_i_eyebrow raise_l_m_eyebrow raise_i_m_eyebrow raise_l_o_eyebrow raise_r_o_eyebrow squeeze_l_eyebrow squeeze_r_eyebrow	
5	Upper Lid Raiser [1]	Levator palpebrae, superioris	19 - 20 -	close_t_l_eyelid close_t_r_eyelid	

Table B.1 – Continue

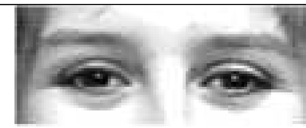
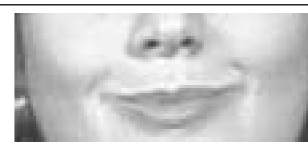
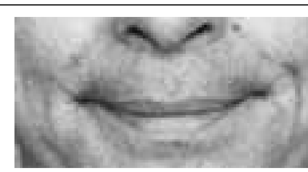
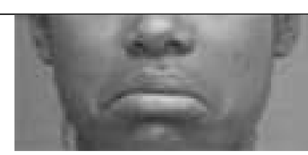
AU	**Description**	**Facial Muscles**	**FAP**	**Description**	**Picture**
6	Cheek Raiser	Orbicularis oculi, pars orbitalis	41 + 42 + 21 + 22 +	lift_l_cheek lift_r_cheek close_b_l_eyelid close_b_r_eyelid	
7	Lid Tightnener	Orbicularis oculi, pars palebralis	19 + 20 + 21 + 22 +	close_t_l_eyelid close_t_r_eyelid close_b_l_eyelid close_b_r_eyelid	
9	Nose Wrinkler	Levator labii superioris alaquae nasi	4 - 61 + 62 +	lower_t_midlip stretch_l_nose stretch_r_nose	
10	Upper Lip Raiser	Levator labii superioris	4 - 61 + 62 + 63 +	lower_t_midlip stretch_l_nose stretch_r_nose raise_nose	
11	Nasolabial Deepener	Zygomaticus minor	6 + 7 + 61 + 62 +	stretch_l_cornerlip stretch_r_cornerlip stretch_l_nose stretch_r_nose	
12	Lip Corner Puller	Zygomaticus major	6 + 7 + 12 + 13 +	stretch_l_cornerlip stretch_r_cornerlip raise_l_cornerlip raise_r_cornerlip	
13	Cheek Puffer	Levator anguli oris (a.k.a. Caninus)	39 + 40 +	Puff_l_cheek Puff_r_cheek	
14	Dimpler	Buccinnator	6 - 7 - 53 - 54 -	stretch_l_cornerlip stretch_r_cornerlip stretch_l_cornerlip_o stretch_r_cornerlip_o	
15	Lip Corner Depressor	Triangularis	12 - 13 -	Raise_l_cornerlip Raise_r_cornerlip	

Table B.1 – Continue

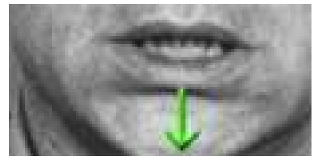
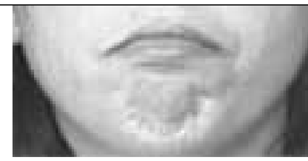
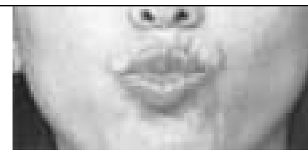
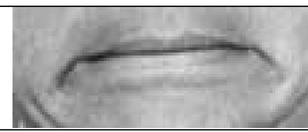
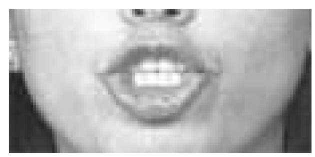
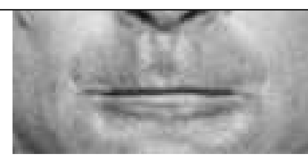
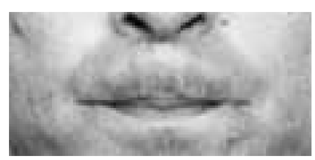
AU	Description	Facial Muscles	FAP	Description	Picture
16	Lower Lip Depressor [1]	Depressor labii inferioris	5 - 10 - 11 - 57 - 58 -	Raise_b_midlip Raise_b_midlip_lm Raise_b_midlip_rm Raise_b_midlip_lm_o Raise_b_midlip_rm_o	
17	Chin Raiser	Mentalis	18 + 10 + 11 +	Depress_chin raise_b_midlip_lm raise_b_midlip_rm	
18	Lip Puckerer	Incisive labii superiori Incisive labii inferioris	16 + 17 +	Push_b_lip Push_t_lip	
20	Lip Stretcher	Risorius Platysma	6 + 7 + 53 + 54 +	Stretch_l_cornerlip Stretch_r_cornerlip Stretch_l_cornerlip_o Stretch_r_cornerlip_o	
22	Lip Funneler	Orbicularis oris	4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 -	Lower_t_midlip Raise_b_midlip Stretch_l_cornerlip Stretch_r_cornerlip_o Lower_t_lip_lm Lower_t_lip_rm Raise_b_lip_lm Raise_b_lip_rm	
23	Lip Tightener	Orbicularis oris	5 + 6 - 7 -	raise_b_midlip Stretch_l_cornerlip Stretch_r_cornerlip_o	
24	Lip Pressor	Orbicularis oris	4 + 5 + 8 + 9 + 10 + 11 +	Lower_t_midlip Raise_b_midlip Lower_t_lip_lm Lower_t_lip_rm Raise_b_lip_lm Raise_b_lip_rm	
25	Lip Part	Depressor labii inferioris OR Relaxation of mentalis OR Orbicularis oris	5 - 10 - 11 -	Raise_b_midlip Raise_b_lip_lm Raise_b_lip_rm	

Table B.1 – Continue

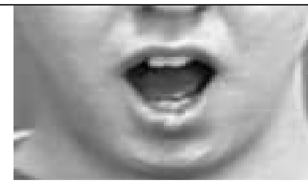
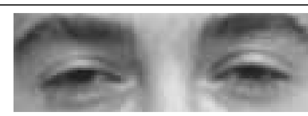
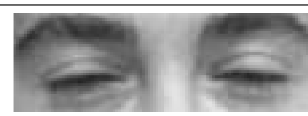
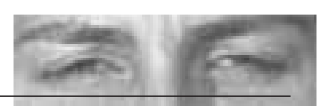
AU	**Description**	**Facial Muscles**	**FAP**	**Description**	**Picture**
26	Jaw Drops	Masseter, relaxed Temporalis, Internal Pterygoid	3 +	Open_jaw	
27	Mouth Stretch	Pterygoids, digastric	5 - 10 - 11 - 52 - 57 - 58 -	Raise_b_midlip Raise_b_lip_lm Raise_b_lip_rm Raise_b_midlip_o Raise_b_lip_lm_o Raise_b_lip_rm_o	
28	Lip Suck	Orbicularis oris	16 - 17 -	Push_b_lip Push_t_lip	
AD 29	Jaw Thrust [4]	Orbicularis oris	14 + 17 -	Thrust_jaw Push_t_lip	
AD 30	Jaw Sideways		15	Shift_jaw	
AD 38	Nostril Dilator	Nasalis Pars Alaris	61 62	Stretch_l_nose Stretch_r_nose	
AD 39	Nostril Compressor	Nasalis Pars Transversa Depressor Septi Nasi	61 62	Stretch_l_nose Stretch_r_nose	
43b (f. 41)	Lid droop	Relaxation of Levator palpebrae superioris	19 + 20 +	Close_t_l_eyelid Close_t_r_eyelid	
43d (f. 42)	Slit	Orbicularis oculi	19 + 20 + 21 + 22 +	Close_t_l_eyelid Close_t_r_eyelid Close_b_l_eyelid Close_b_r_eyelid	
43 (f. 42)	Eyes closed	Relaxation of Levator palpebrae superioris; Orbicularis oculi, pars palpebralis,	19 + 20 + 21 + 22 +	Close_t_l_eyelid Close_t_r_eyelid Close_b_l_eyelid Close_b_r_eyelid	
44 (f. 42)	Squint	Orbicularis oculi, Pars palpebralis	19 + 20 + 21 +	Close_t_l_eyelid Close_t_r_eyelid Close_b_l_eyelid	

Table B.1 – Continue

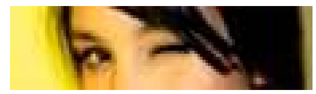
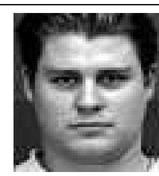
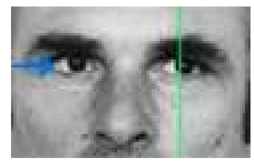
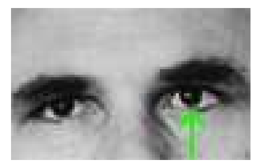
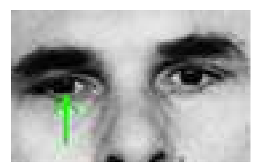
AU	Description	Facial Muscles	FAP	Description	Picture
			22 + 31 - 32 -	Close_b_r_eyelid Raise_l_i_eyebrow Raise_r_i_eyebrow	
45 (f. 42) Occurs in a moment	Blink	Relaxation of, Levator palpebrae superioris; Orbicularis oculi, pars palpebralis	19 20 21 22	Close_t_l_eyelid Close_t_r_eyelid Close_b_l_eyelid Close_b_r_eyelid	
46 (f. 42) Only one eye	Wink	Relaxation of, Levator palpebrae superioris; Orbicularis oculi, pars palpebralis	19 or 20 21 or 22	Close_t_l_eyelid Close_t_r_eyelid Close_b_l_eyelid Close_b_r_eyelid	
51	Head turn left		49	Head_yaw	
52	Head turn right		49	Head_yaw	
53	Head up		48	Head_pitch	
54	Head down		48	Head_pitch	
55	Head tilt left		48	Head_roll	

Table B.1 – Continue

AU	**Description**	**Facial Muscles**	**FAP**	**Description**	**Picture**
56	Head tilt right		48	Head_roll	
61	Eyes turn left		23	Yaw_l_eyeball	
62	Eyes turn right		23	Yaw_l_eyeball	
63	Eyes up		25 26	Pitch_l_eyeball Pitch_r_eyeball	
64	Eyes down		25 26	Pitch_l_eyeball Pitch_r_eyeball	

[1]This mapping is valid with FAPs with negative intensities - upper movement

[2]Images for AUs: 1, 2, 4, 5, 6, 7, 9, 10, 11, 13, 15, 17, 18, 22, 25, 26, 27, 43b, 43d, 43, 44, 51, 52, 53, 54, 55, 56 were taken from: http://www.cs.cmu.edu/ face/facs.htm

[3]Images for AUs: 12, 14, 16, 20, 23, 24, 28, 29, 46, 61, 62, 63, 64 were taken from: http://micromovimiento.com/?p=933#more-933

[4]AD instead of AU stands for *Action Descriptor*

B.2 Opposite AUs

As result of the observation of the facial movements and the AUs involved, we concluded that the AUs shown in white and gray cells in Tables B.2, B.3, B.4 and B.5 cannot be present at the same time in a facial expression. It will help us to discern which FAPs, and in which direction, they should be activated.

For instance, Table B.2 indicates that the AUs 12 and 15 are opposed because they share a set of muscles which move in different directions. These muscles are given by the FAPs, which are present in both AUs. Thus FAP12 and FAP13 are moving upwards in the movement described by AU12, but they are moving downwards in the movement described by AU15.

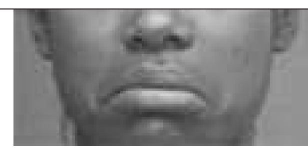
AU	Description	Facial Muscles	FAP	Description	Picture
12	Lip Corner Puller	Zygomaticus major	6 + 7 + 12 + 13 +	Stretch_l_cornerlip Stretch_r_cornerlip Raise_l_cornerlip Raise_r_cornerlip	
15	Lip Corner Depressor	Triangularis	12 - 13 -	Raise_l_cornerlip Raise_r_cornerlip	

Table B.2: PAD space octant's description

Table B.3 shows a set of AUs - 16, 25 and 26, which are opposed to AU17. As can be seen in the table, AUs 16 and 25 describe a movement that involves FAPs 10 and 11 with and downward direction, while AU17 has a correspondence with these FAPs but with upward direction. Regarding AU26, although it does not share similar FAPs with AU17, the movement described by the former it is opposed to the one described by the latter.

Table B.4 shows two sets of AUs that are also opposed. On one hand, AUs 23 and 24 describe movements that involve a closure of the mouth, although they do not involve the same set of FAPs. On the other hand, AUs 25, 26 and 27 describe movements that imply openness of the mouth. Here we can see that AU24 is related to FAPs (5, 10 and 11) which are oriented upwards, while AU25 and AU27 are related to this set of FAPs but downwards. Although AU26 is not related to the former FAPs, it describes a movement that is opposed to the ones described by AUs 23 and 24.

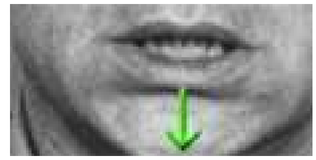
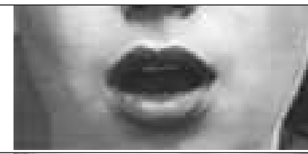
AU	Description	Facial Muscles	FAP	Description	Picture
16	Lower Lip Depressor [1]	Depressor labii inferioris	5 - 10 - 11 - 57 - 58 -	Raise_b_midlip Raise_b_midlip_lm Raise_b_midlip_rm Raise_b_midlip_lm_o Raise_b_midlip_rm_o	
25	Lip Part	Depressor labii inferioris OR Relaxation of mentalis OR Orbicularis oris	5 - 10 - 11 -	Raise_b_midlip Raise_b_lip_lm Raise_b_lip_rm	
26	Jaw Drops	Masseter, relaxed Temporalis, Internal Pterygoid	3 +	Open_jaw	
17	Chin Raiser	Mentalis	18 + 10 + 11 +	Depress_chin Raise_b_midlip_lm Raise_b_midlip_rm	

Table B.3: PAD space octant's description

Finally, Table B.5 presents AUs related with stretching and tightening of lips. AU20 is related to FAPs 6 and 7, which are oriented in a way that stretch the lips. Opposite to that are AUs 22 and 23, which are also related to FAPs 6 and 7, but oriented in a way that squash the lips (tightening or funneling them).

AUs Combinations

Table B.6 shows a set of combinations, collected from different sources that worked with facial expression recognition. It gives us a hint of how AUs can be combined to create different facial expressions.

On the other hand, Table B.7 shows a set of combinations that are not possible in human faces.

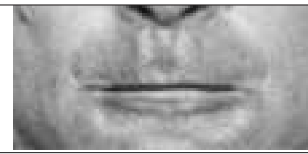
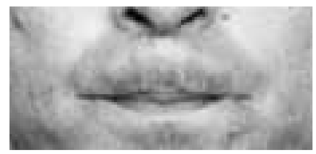
AU	Description	Facial Muscles	FAP	Description	Picture
23	Lip Tightener	Orbicularis oris	5 + 6 - 7 -	raise_b_midlip Stretch_l_cornerlip Stretch_r_cornerlip_o	
24	Lip Pressor	Orbicularis oris	4 + 5 + 8 + 9 + 10 + 11 +	Lower_t_midlip Raise_b_midlip Lower_t_lip_lm Lower_t_lip_rm Raise_b_lip_lm Raise_b_lip_rm	
25	Lip Part	Depressor labii inferioris OR Relaxation of mentalis OR Orbicularis oris	5 - 10 - 11 -	Raise_b_midlip Raise_b_lip_lm Raise_b_lip_rm	
26	Jaw Drops	Masseter, relaxed Temporalis, Internal Pterygoid	3 +	Open_jaw	
27	Mouth Stretch	Pterygoids, digastric	5 - 10 - 11 - 52 - 57 - 58 -	Raise_b_midlip Raise_b_lip_lm Raise_b_lip_rm Raise_b_midlip_o Raise_b_lip_lm_o Raise_b_lip_rm_o	

Table B.4: PAD space octant's description

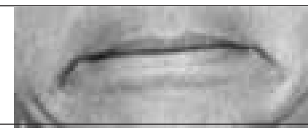
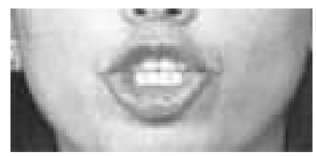
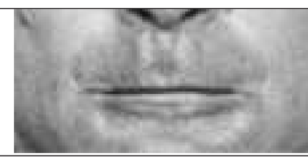
AU	Description	Facial Muscles	FAP	Description	Picture
20	Lip Stretcher	Risorius Platysma	6 + 7 + 53 + 54 +	Stretch_l_cornerlip Stretch_r_cornerlip Stretch_l_cornerlip_o Stretch_r_cornerlip_o	
22	Lip Funneler	Orbicularis oris	4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 -	Lower_t_midlip Raise_b_midlip Stretch_l_cornerlip Stretch_r_cornerlip_o Lower_t_lip_lm Lower_t_lip_rm Raise_b_lip_lm Raise_b_lip_rm	
23	Lip Tightener	Orbicularis oris	5 + 6 - 7 -	Raise_b_midlip Stretch_l_cornerlip Stretch_r_cornerlip_o	

Table B.5: PAD space octant's description

AUs	*Possible Meaning*	**Source**
1 + 2 + 5	Fear / Hot Anger (Novelty Sudden)	[92]
9 + 10 + 15 + 35	Fear (Intrinsic Pleasant/Unpleasant)	[92]
4 + 7	Fear (Expectation/Discrepant) / Hot Anger (Goal attainment/obstructive)	[92]
17 + 23	Fear (Goal attainment/obstructive)	[92]
20 + 26 + 27	Fear (Power)	[92]
4 + 7 + 10 + 17 + 24	Hot Anger (Control and power high)	[92]
9 + 25	For analysis purposes,	Donato et al. cited in [88]
10 + 25	they treated each combination as a new AU	Donato et al. cited in [88]
16 + 25		Donato et al. cited in [88]
20 + 25	Lower Face	Donato et al. cited in [88]
23 + 24		[88]
9 + 17	Lower Face	[88]
9 + 25	Lower Face	[88]
9 + 17 + 23 + 24	Lower Face	[88]
10 + 17	Lower Face	[88]
10 + 25	Lower Face	[88]
15 + 17	Lower Face	[88]
10 + 15 + 17	Lower Face	[88]
12 + 25	Lower Face	[88]
12 + 26	Lower Face	[88]
17 + 23 + 24	Lower Face	[88]
23 + 24	Lower Face	[88]
1 + 6	Upper face	[88]
4 + 5	Upper face	[88]
6 + 7	Upper face	[88]
1 + 2 + 4	Upper face	[88]

Table B.6: AUs combinations

AUs	**Source**
15 + 25	[146]
12 + 15	own observation
16 + 17	comparison using related FAPs
17 + 26	comparison using related FAPs
17 + 25	comparison using related FAPs
23 + 27	[146]
24 + 25	comparison using related FAPs
24 + 26	comparison using related FAPs
24 + 27	comparison using related FAPs
20 + 22	comparison using related FAPs
20 + 23	comparison using related FAPs

Table B.7: AUs that do not happen together

Appendix C

Emotion Values in the Activation-Evaluation Space

Table C.1: Emotion Values in the Activation-Evaluation Space

Emotion	Activation	Evaluation
Adventurous	4.3	5.9
Affectionate	4.7	5.4
Afraid	4.9	3.4
Aggressive	5.9	2.9
Agreeable	4.3	5.2
Amazed	5.9	5.5
Ambivalent	3.2	4.2
Amused	4.9	5.0
Angry	4.2	2.7
Annoyed	4.4	2.5
Antagonistic	5.3	2.5
Anticipatory	3.9	4.7
Anxious	6.0	2.3
Apathetic	3.0	4.3
Ashamed	3.2	2.3
Astonished	5.9	4.7
Attentive	5.3	4.3
Bashful	2.0	2.7
Bewildered	3.1	2.3
Bitter	6.6	4.0
Boastful	3.7	3.0
Bored	2.7	3.2
Calm	2.5	5.5

Table C.1 – Continue

Emotion	Activation	Evaluation
Cautious	3.3	4.9
Cheerful	5.2	5.0
Confused	4.8	3.0
Contemptuous	3.8	2.4
Content	4.8	5.5
Contrary	2.9	3.7
Cooperative	3.1	5.1
Critical	4.9	2.8
Curious	5.2	4.2
Daring	5.3	4.4
Defiant	4.4	2.8
Delighted	4.2	6.4
Demanding	5.3	4.0
Depressed	4.2	3.1
Despairing	4.1	2.0
Disagreeable	5.0	3.7
Disappointed	5.2	2.4
Discouraged	4.2	2.9
Disgusted	5.0	3.2
Disinterested	2.1	2.4
Dissatisfied	4.6	2.7
Distrustful	3.8	2.8
Eager	5.0	5.1
Ecstatic	5.2	5.5
Embarrassed	4.4	3.1
Empty	3.1	3.8
Enthusiastic	5.1	4.8
Envious	5.3	2.0
Furious	5.6	3.7
Gleeful	5.3	4.8
Gloomy	2.4	3.2
Greedy	4.9	3.4
Grouchy	4.4	2.9
Guilty	4.0	1.1
Happy	5.3	5.3
Helpless	3.5	2.8
Hopeful	4.7	5.2
Hopeless	4.0	3.1
Hostile	4.0	1.7
Impatient	3.4	3.2
Impulsive	3.1	4.8
Indecisive	3.4	2.7
Intolerant	3.1	2.7
Irritated	5.5	3.3

Table C.1 – Continue

Emotion	**Activation**	**Evaluation**
Jealous	6.1	3.4
Joyful	5.4	6.1
Loathful	3.5	2.9
Lonely	3.9	3.3
Meek	3.0	4.3
Nervous	5.9	3.1
Obedient	3.1	4.7
Obliging	2.7	3.0
Outraged	4.3	3.2
Panicky	5.4	3.6
Patient	3.3	3.8
Pensive	3.2	5.0
Pleased	5.3	5.1
Possessive	4.7	2.8
Proud	4.3	5.7
Puzzled	2.6	3.8
Quarrelsome	4.6	2.6
Rebellious	5.2	4.0
Rejected	5.0	2.9
Remorseful	3.1	2.2
Resentful	5.1	3.0
Sad	3.8	2.4
Sarcastic	4.8	2.7
Satisfied	4.1	4.9
Scornful	5.4	4.9
Self-controlled	4.4	5.5
Serene	4.3	4.9
Sociable	4.8	5.3
Sorrowful	4.5	3.1
Stubborn	4.9	3.1
Submissive	3.4	3.1
Surprised	6.5	5.2
Suspicious	6.5	5.2
Sympathetic	3.6	3.2
Terrified	6.3	3.4
Trusting	3.4	5.2
Unaffectionate	3.6	2.1
Unfriendly	4.3	1.6
Wondering	3.3	5.2
Worried	3.9	2.9

Appendix D

Publications and contributions

This chapter contains the articles that were presented and published in different conferences and journals, with the objective to present the partial results we were achieving along the realization of this thesis.