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Abstract

This paper presents a *Dynamic Emotion Representation (DER) model*, its implementation and an instance of a full humanoid emotional model built with it. The DER model has been implemented to enable users to create their own DER. The instance of the DER model described in this paper represents three types of emotions, primary, secondary emotions and mood. The design of this DER is discussed with reference to emotion theories and to the needs of a facial animation system in which it is integrated. The DER is used in our Emotionally Expressive Facial Animation System (EE-FAS) to produce emotional expressions, to select facial signals corresponding communicative functions in relation to the emotional state of the agent and also in relation to the comparison between the emotional state and the intended meanings expressed through communicative functions.

1 Introduction

We developed an Emotionally Expressive Facial Animation System (EE-FAS, pronounced e-face) producing animations from a stream of text and XML tags. The tags carry information about communicative functions and emotional stimuli. The use of communicative functions has the advantage of being flexible because they inform about the meaning that should be communicated through the face and not *how* it should be communicated (Pelachaud and Bilvi, 2003). This flexibility enables us to define animation scripts that can produce different animations in relation to the characteristics of the agent such as its body, its current emotional states, its gender and its age (Pelachaud and Bilvi, 2003).

Facial expressions and emotions are linked in some undetermined loose fashion (Izard, 1997; Ekman, 1999b; Smith and Scott, 1997) but intuitively people look for emotional signs in facial expressions (Collier, 1885; Ekman and Friesen, 1972; Smith and Scott, 1997). This is one reason to integrate an emotion model into a facial animation system: to select different communicative signals in relation to the emotional state of an agent producing emotionally expressive animations. In EE-FAS, signals corresponding to communicative functions are selected directly in relation to the emotional state, but they are also selected due to the difference between the intended communicative functions and the emotional state. By knowing the emotional state of an agent (through the emotion model) and the meaning that this agent wants to communicate (through communicative functions) it is possible to produce different facial expressions depending on whether the emotional state matches the intended meaning. For instance, if an agent wants to display a polite smile, EE-FAS produces a different smile depending on whether the character is currently in a positive or negative emotional state. As far as we know, EE-FAS is the only facial animation system applying this technique.

To reach this objective, an emotion model is needed to represent the emotional state of the agent. Many emotion models already exist and they are used within facial animation systems, (Albrecht et al., 2005; Kurlander et al., 1996; Raouzaiou et al., 2003; Latta et al., 2002; Kshirsagar and Magnenat-Thalmann, 2002; Egges et al., 2004; The Duy Bui, 2004) as well as for influencing action selection within autonomous agents architectures (Delgado-Mata and Ruth S. Aylett, 2002; Cañamero, 2003; Reilly, 1996; Gratch and Marsella, 2004; The Duy Bui, 2004; Velásquez, 1997; André et al., 1999; Paiva et al., 2004).

We propose that the term of *emotion model* should be defined as containing two separated parts:

- a mechanism or mechanisms eliciting emotions from external and internal stimuli, including potentially the agent's own goals, beliefs and standards; and
- the emotion representations keeping track of the emotional states and their changes.

This paper presents a framework to build Dynamic Emotion Representations (DER). If so many emotion representations already exist, why would someone build a new one? To answer this question let us first explain the term *Dynamic Emotion Representation*. As already mention, the *emotion representation* should be emphasised in contrast with *emotion elicitation mechanisms*, and this work focuses on the *representation*. The term *dynamic* is used to point out that emotions are ongoing, durative, constantly changing states. Emotions interact together and influence each other. These characteristics are not the focus of most emotion models or emotion representations.

In this paper, section 2 discusses the foundations for the design of a Dynamic Emotion Representation, and its implementation is explained in section 3. The DER responses to successive emotional stimuli in three different mood contexts is also analysed in section 3. Finally a generic DER model is presented in section 4 and conclusions are presented in section 5.

2 Design Foundations for an DER

This section presents a Dynamic Emotion Representation (DER) that is used within an Emotionally Expressive Facial Animation System (EE-FAS). This Dynamic Emotion Representation is based on both different theories of emotions and on technical needs for the EE-FAS. The first subsection presents an overview of the different types of emotions described in emotion theories and the second subsection discusses the technical needs in a facial animation system that could be fulfilled by a DER.

2.1 Emotion Types in Emotions Theories

Primary Emotions are innate, produced by reactive mechanisms mapping external stimulus patterns to pre-organised behaviours, enabling fast, species-typical reactions to environmental changes (Damasio, 1994; Sloman, 2003).

Secondary Emotions are learned associations between recognised stimulus patterns generated by primary emotions and analysed situations where these patterns occurred (Damasio, 1994). The processes involved in learning and analysis of situations are named deliberative mechanisms by Sloman (2001). Deliberative mechanisms are cognitive processes taking into consideration goals, belief, standards and expectations, enabling reasoning about situations, plan making, and understanding of action consequences (Sloman, 2001). They are also responsible for creating hypotheses and abstract concepts (Sloman, 2001). If deliberative mechanisms are more adaptive to new situations than reactive mechanisms due to the analysis of situations and plan making, they are also slower due the involvement of memories and cognitive processes.

Tertiary Emotions might not be directly generated by meta-management mechanisms but are consequences of these processes. Meta-management mechanisms enable the cognitive awareness of internal processes or states and provide the possibility to reason about these internal states and processes (Sloman, 2001). Sloman argues that the interaction and competition for resource control between declarative and meta-management mechanisms could result in complex internal states typical of human emotions (Sloman, 2003).

Basic Emotions are discussed by Ortony and Turner (1990), who explain the meanings of the term *basic*: as *psychologically primitive* and as *biologically primitive.* The *psychological* point of view of *basic emotions* aims to build a set of "psychologically irreducible" emotions, which means that these emotions would be building blocks for other emotions, and that they could not be composed of other emotions (Ortony and Turner, 1990). *Biologically*, *basic emotions* are innate and serve survival functions kept through evolution. One consequence of this argument is that *basic emotions* should be found across human cultures and across species of higher animals. The most common method to study *basic emotions* is the observation of facial expressions (Darwin, 1979; Plutchik, 1980; Izard, 1977; Tomkins, 1980; Ekman, 1999a). The main arguments in favour of the existence of basic emotions are studies carried out by Ekman (1992) and Izard (1971), showing that facial expressions of basic emotions are universally recognised.

Discreet and multi-dimensional emotion representations are the main methods used to describe emotional spaces. The most common discreet representation is the six basic emotions as just described but other models can be based on a different set of basic emotions (Ekman, 1992; Izard, 1971). Multi-dimensional spaces are also used to represent emotional states, such as Plutchik (1980) who suggests the "emotional wheel" described by two dimensions *activation* and *evaluation*, and Russell (1997) who proposes the dimensions *pleasure* and *arousal*. Thayer (1996) also describes an emotional space using two dimensions, *energy* and *tension*, but this space represents a particular type of emotion which is mood.

In summary, Primary, Secondary and Tertiary emotions form an emotion hierarchy which is the basis of the structure for DER models. The concepts of Basic Emotions and of discrete *vs.* multi-dimensional representations are fundamental to many emotion theories. Therefore, we expect the DER model to be able to represent them. The DER is intended to be useful for representing and testing many theories of emotions.

2.2 Design: Technical Needs and Emotion Theories

The introduction of a Dynamic Emotion Representation into a facial animation system supports the production of emotional facial expressions. It also provides consistency in the selection of facial signals corresponding to communicative functions. A DER does this by representing lasting emotional contexts.

2.2.1 Emotional Expressions

Two main types of facial expressions are distinguished: those produced as emotional events or episodes (Darwin, 1979; Tomkins, 1980; Ekman, 1992; Izard, 1971) and those produced by communicative functions (Chovil, 1997; Poggi and Pelachaud, 2000). The first type can be related to the six universally recognised facial expressions, which are themselves related to the six basic emotions(Ekman, 1992; Izard, 1971). Bavelas and Chovil (1997) emphasise that expressions produced from emotional episodes might be different from the facial expressions produced as emotional communicative functions, e.g. *personal reaction*. The facial animation system should be able to produce both types of expressions.

2.2.2 Emotional Expressions and Primary Emotions

The definition of *basic emotions*, in the biologically primitive sense, and the definition of primary emotions are closely related. Evidence for both types are based on the exhibition of pre-organised behaviours. From this perspective, emotional facial expressions, such as the six universally recognised facial expressions, can be seen as behaviours triggered by primary emotions. As presented by Izard (1997, page 64) and interpreted by Ginsburg (1997, page 351), expressions of emotions could be triggered at the beginning of an emotional episode, or at the "emotion activation".

With this view, a system that produces emotional facial expressions, as originating from primary emotions, would have to detect emotion activations. In the framework of the DER model, a module needs to detect and represent the activation of particular emotions, e.g. this module needs to keep track of new incoming emotional stimuli. This module is said to represent *primary emotions*. By default, the behaviour activations correspond to the six basic emotions: Angry, Happy, Surprised, Disgusted, Sad and Afraid. However, other primary emotions can be chosen by a user of the DER model.

2.2.3 Short-to-Medium Term Emotional Context

The DER aims to stand as an emotional context and a consistency mechanism to select facial signals corresponding to communicative functions. The module defining the primary emotions is not used as an emotional context. Its function is to represent emotion activations, not emotional states.

A second module is designed to maintain emotional states. By default these emotional states again correspond to the six basic emotions. The primary emotion module detects stimuli, when activated these increase the activation level of the second module.

Due to the longer life time of this emotional state, this module is called the *secondary emotion module*. By default, it is composed of six dimensions: anger, happiness, surprise, disgust, sadness and fear.

2.2.4 Medium-to-Long Term Emotional Context

Looking at theories of emotions, a more lasting emotional context is mood; it is generally differentiated from other emotions due to this characteristic. As suggested by Picard (1997), mood could influence the effects of emotional stimuli on other emotions. For instance, "A bad mood can make it easier for negative-valenced emotion to be activated, while a good mood makes this more difficult" (Picard, 1997, page 155). For this reason, a third module is designed to represent mood states.

Mood can be represented on one dimension good/bad as described by Reilly (1996), Picard (1997), and Kshirsagar and Magnenat-Thalmann (2002). However, in our default system, mood is represented by two dimensions, *calm/tense* and *energy/tiredness* — a model based on the theory of mood described by Thayer (1996). Using these two dimensions Thayer proposes four mood states: *Energetic-calm* (high energy and low tension) is the optimum mood; *Energetic-tense* (high energy and high tension) is a mood that enables people to be active and to do what has to be done; *Tired-calm* (low energy and low tension) is a relaxing state such as before sleep but a person in this state is also very sensitive to tension; and *Tired-tense*, (low energy and high tension) is the worst state when the energy is insufficient to do what has to be done.

Why could Thayer's model be more interesting than using one dimension good/bad? The main reason is that his model is a more plausible model of mood in natural systems. The dimension good/bad is generally evaluated by the difference between positive and negative emotional stimuli, and this method has two problems: in first place, mood is "cognitively impenetrable", as argued by Sizer (2000), therefore it can not be the result of positive or negative cognitive evaluations of events. Secondly, mood is described by Thayer (1996) and Sizer (2000) as an overview of a person's mental and physical state, not simply an overview of the emotional state. This view could also be supported by Sloman's theory of emotions if the definition of mood as a "cognitive functional architecture" given by Sizer (2000) and the definition of *meta-management mechanisms* given by Sloman (2001) are compared. Sizer (2000) defines mood as mechanism-organising — categorising memorised information and representing the general state of a person. Sloman (2001, page 7) defines meta-management mechanisms as enabling "self-observation or self-monitoring of a wide variety of internal states, along with categorisation and evaluation of those states, linked to high level mechanisms for learning and for controlling future processes."

Thayer's model represents variables not normally considered emotional. The terms *energy* and *tension* are not clearly defined by Thayer (1996); they are described as a representation of the general mental and physical states of a person. The term *energy* includes mental energy and physical energy, such as the extent to which a person is awake, their blood sugar level, or their health. The energy level follows a daily biological pattern (Thayer, 1996). Tension level varies accordingly to the pressure of the environment, such as threats, task accomplishments and maybe reproduction instinct.

The use of a more plausible model might not be a good design decision, so why not use a simpler model? By relating Thayer's model to existing work on computational emotion models, such as those described by Delgado-Mata and Ruth S. Aylett (2002), Cañamero (2003), and Velásquez (1997), links can be built between drives, such as hunger or thirst, and energy and tension. For instance, hunger is related to the level of energy provided by food and the need for food produces some pressure on the system to fulfil this need, which can be interpreted as tension. Representing mood on the bases of Thayer's model would be closer to mood theories of natural systems and could also be integrated with existing autonomous virtual agent systems.

One issue is how to reconcile Thayer's model with the suggestion of Picard (1997) to use mood state, as positive and negative, to influence the effects of emotional stimuli. Thayer's model does not represent directly a dimension good/bad or positive/negative but using his description of the four mood states two new dimensions appear:

- Pleasure/displeasure represented by the extremes: *energy-calm* (high energy and low tension), and *tired-tense* (low energy and high tension).
- Sleep/arousal represented by the extremes: *energy-tense* (high energy and high tension), and *tired-calm* (low energy and low tension).

These two dimensions are used by Russell (1997) to describe emotional states.

So a positive or negative value of mood can be computed as the difference between the level of energy and the level of tension. If the tension is superior to the energy the mood is qualified as negative or bad, in the reverse case the mood is qualified as positive or good.

3 The DER Architecture

3.1 Overview of a DER

As discussed previously, three types of representation are needed, one to represent the emotion activations, a second one to represent short-to-medium term emotional context, and a third one to represent medium-to-long term emotional context. For each one of these three representations a module is designed, *Primary Emotion Module*, *Secondary Emotion Module*, and *Mood module*. Figure 1 shows a graphical representation of the Dynamic Emotion Representation (DER) containing these three modules.

Each one of these modules has a particular role in the facial animation system, the *primary emotion module* aims to produce emotional facial expressions,

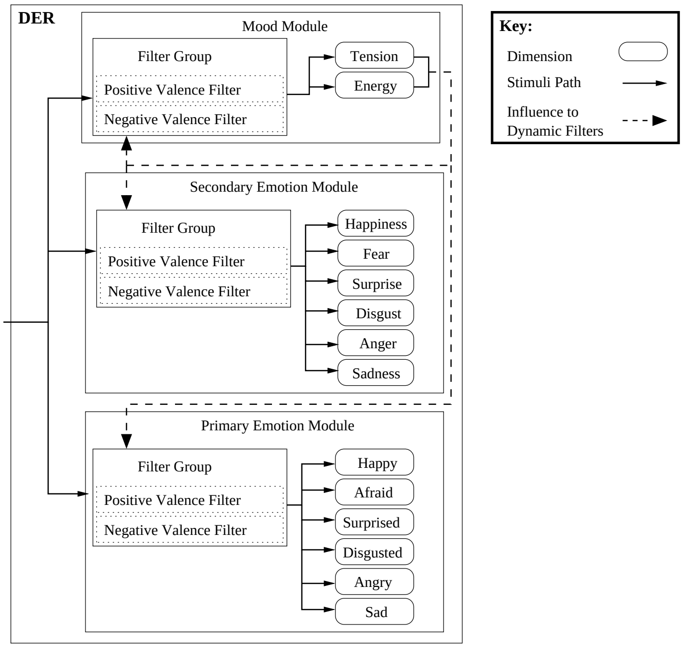


Figure 1: Graphical representation of an instance of the Dynamic Emotion Representation Model, based on three types of emotions: primary and secondary emotions and mood.

the *secondary emotion module* is used to select facial signals corresponding to communicative functions, and the *mood module* gives a lasting emotional context in which *emotional impulses* have different effects on the representation.

An *emotional impulse*, which is a particular type of *emotional stimulus* defined later in this section, is the input of the DER. *Emotional impulses* are generally produced by the mechanisms eliciting emotions, such as mechanisms based on the Ortony Clore Collins (OCC) model (Ortony et al., 1988).

Figure 1 shows that each module in the DER is composed of a group of two *dynamic filters* and a list of *dimensions*. One of these *dynamic filters* modifies *emotional impulses* having a negative *valence* and the other one modifies *emotional impulses* having a positive *valence*. These filters qualify as *dynamic* because their parameters are changing over time in relation to the state of particular elements in the DER. The *dynamic filters* in Figure 1 are influenced by the positive/negative value of the mood, as suggested by Picard (1997). These filters modify the *peak intensity* of incoming *emotional impulse* to simulate a variable emotional perception. Dimensions are representing states changing over time due to the incoming *emotional impulse*.

3.2 Dimensions and Emotional Stimuli in the DER

This sub-section gives a definition of *emotional stimulus*, explains the interaction between emotional stimuli and dimension intensities, and also gives the description of a dimension in the DER.

3.2.1 Definition of Emotional Stimulus

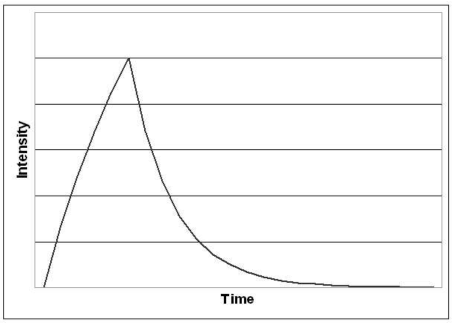


Figure 2: Emotional Stimulus. Sustain duration is zero in this example.

The following definition of *emotional stimulus* can be considered to be the definition of an interface between mechanisms eliciting emotions and emotion representations. The DER model uses the description of an emotional stimulus given by Picard (1997), which is represented graphically by figure 2.

In the DER model, an *emotional stimulus* is described by its *attack*, its *sustain* and its *decay duration*, its *peak intensity*, and a list of other characteristics such as *name*, and *valence*. The *valence* of an emotional stimulus could be negative (-1), positive (1), or neutral (0).

Emotional stimuli arriving in the DER have an *attack*, a *sustain*, and a *decay* duration of 0s. They can therfore considered to be *emotional impulse*. They are only characterised by a *valence*, a *name*, and a *peak intensity*.

3.2.2 Dimension Intensity and Emotional Stimuli

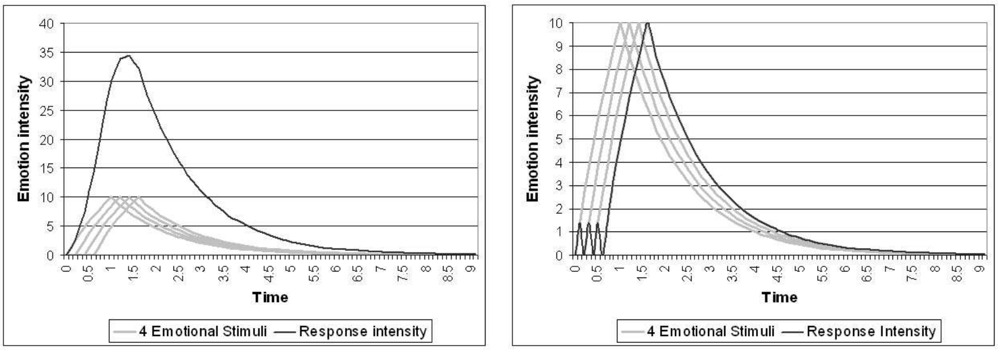
The emotional stimuli previously described modify the intensity of the associated dimensions. Picard (1997) suggests that emotional stimuli should be additive and that the intensity response to successive emotional stimuli would be such as the graphic on figure 3(a).

The DER model also proposes, in addition to the operation *sum* described by Picard (1997), an operation called *replace* with which the intensity of an emotion is equal to the intensity of the last arrived emotional stimulus. This type of intensity response is shown on Figure 3(b). The reason for defining this operation will become clear later.

3.2.3 Description of a Dimension in the DER

A *dimension* in the DER transforms an incoming *emotional impulse* into an *emotional stimulus* by changing its duration: attack, sustain and decay durations. The definition of these duration characteristics is typical of the emotion represented by the dimension. For instance the decay of the emotion *sadness* is slower that the decay of the emotion *surprise*, therefore the parameters of the filters are different.

A *dimension* is composed of a groups *dynamic filters* and a variable intensity. *Dynamic filters* are used to modify the characteristics of emotional impulses and



(a) Operation *sum* used to compute the intensity of emotions, as suggested by Picard (1997).

(b) Operation *replace* used to compute the intensity of emotions. This operation is defined by the DER model in addition to the *sum* operation defined by Picard (1997).

Figure 3: Two operations to compute the response intensity of an emotion after the arrival of four emotional stimuli.

control their effects on dimension intensity. Each filter is applied to one type of emotional stimulus discriminated by one of its characteristics such as its name. Each filter modifies one characteristic of the emotional impulse, such as its peak intensity.

For each dimension, in the DER, three filters are associated with one type of emotional impulse modifying its attack, sustain, and decay duration. These modifications depend on the type of emotional stimulus and on the emotion represented by the dimension.

In addition to these three filters, a fourth one modifies the peak intensity of the emotional impulse in relation to the intensities of this dimension and other dimensions. For instance, this method is used to change the effects of emotional stimuli *happiness* on the dimension *happiness* depending on the intensity of the dimension *anger*.

3.3 Description of the Three modules of the DER

3.3.1 Primary Emotion Module

The *Primary Emotion Module* is by default composed of six dimensions representing the activations of six behaviours: Happy, Angry, Sad, Disgusted, Surprised, and Afraid.

In this module, the computation of a dimension's intensity is carried out by using the *replace* operation shown on figure 3(b).

Each dimension, in the secondary emotion module, has a group of dynamic filters modifying the emotional impulse's characteristics. One of these filters set the sustain duration of the emotional impulse to 1s. This is meant to represent emotion activations for 1s, each time an emotional impulse arrives. Each dimension has a *threshold of activation* and if the peak intensity of the emotional impulse is inferior to this threshold its peak intensity is reduced to zero, otherwise it is not changed.

The threshold of activation is dynamic and changes in relation to other dimension intensities; in fact this threshold is a dynamic filter. For instance, this mechanism is used in the default system to make it more difficult for *happiness* emotional impulse to activate the corresponding behaviour *Happy* when the intensity of the dimension *anger*, in the *secondary emotion module*, is relatively high.

3.3.2 Secondary Emotion Module

In the default version of the secondary emotion module, six dimensions are defined: happiness, sadness, fear, anger, disgust, surprise. These dimensions are referred to *secondary emotions* and differ from the *primary emotions* described previously by the fact that they are not a representation of emotion activations but of emotional states. The intensity of emotional stimuli are summed to compute the dimension intensity, as shown on Figure 3(a).

For each dimension, a group of dynamic filters is used to control the influence of each type of emotional stimulus on this particular dimension. As explained earlier, some of these filters are dedicated to transform the emotional impulses into emotional stimulus. The characteristics of this transformation depend on the type of emotional impulse and the emotion represented by this dimension.

Other filters modify the peak intensity of the emotional impulse in relation to the type of the emotional stimulus, the type of emotion represented by the dimension and the intensity of the other dimensions within this module. For instance, in the dimension *happiness*, the filter controlling the peak intensity of *happiness* impulse is influenced by the intensity of the dimension *anger*. This configuration limits the effect that *happiness* impulses have on the dimension *happiness* when the intensity of the dimension *anger* is relatively high. In the dimension *happiness*, other filters are defined, such as a filter to control the effect of *anger* impulse on this dimension. Whereas *happiness* stimuli increase the intensity of the dimension *happiness*, the *anger* stimuli reduce it.

3.3.3 Mood Module

As introduced earlier, the representation of the mood is based on a model described by Thayer (1996). This model suggests the representation of mood using two dimensions, *tension* and *energy*.

As suggested by Picard (1997), positive or negative mood value is used to influence dynamic filters of a module which modifies the effects of *emotional impulse* on the dimensions of that module. This positive/negative value of mood is computed as the nearest distance between the pair (tension,energy) and the line where tension=energy. If the tension exceeds the energy the mood is negative. If the tension is less than the energy the mood is positive. The computed distance represents how positive or negative the mood is.

3.4 Examples of Emotion Variations Within the DER

3.4.1 Traces on the graphs

Figure 4 shows four graphs, where the bottom one represents the input emotional impulse of the DER and the three other represent the responses of the DER

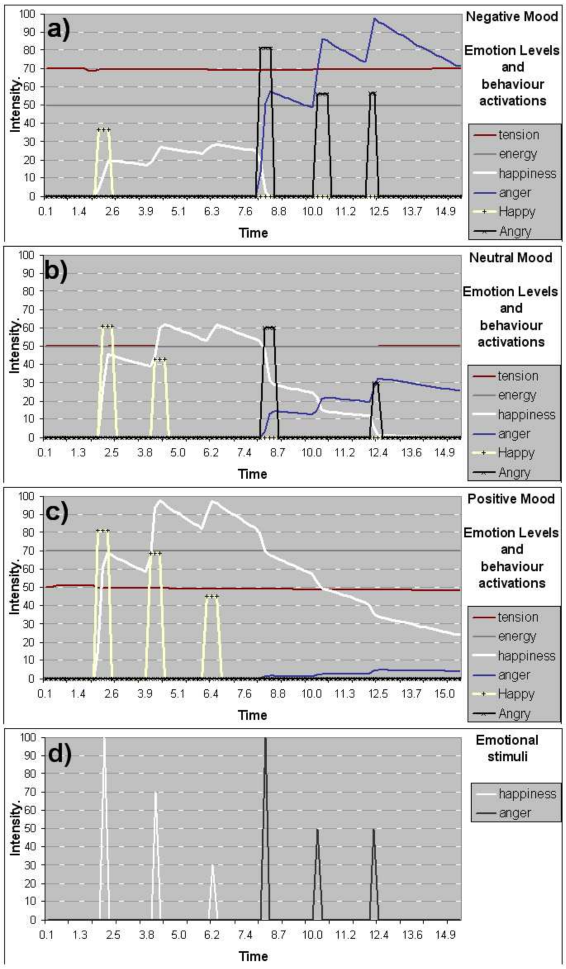


Figure 4: Response of the DER to 6 emotional impulses in three different mood states.

to these emotional impulse within three mood contexts, from top to bottom: negative mood marked *a*, Neutral Mood marked *b*, and positive mood marked *c*.

On the graph representing the Emotional Impulses (EI's),Figure 4 (d), three *happiness* EI's with different intensities arrive at 2 second intervals. Following that, three *anger* EI's arrive at 2 second intervals.

On the graphs representing the responses of the DER, *Angry* and *Happy* primary emotions, as well as *happiness* and *anger* secondary emotions are represented. The two almost straight lines on these graphs show the tension and energy levels from which the positive, neutral or negative mood value is computed.

3.4.2 Mood State Influences

Mood state modifies the peak intensity of incoming Emotion impulses (EI's), but its effect is not linear, reducing the high intensity values and amplifying the small intensity values. In the positive mood state (in contrast to the neutral state), the high intensity of positive EI's, such as the intensity of *happiness* EI's, is less reduced and the low intensity of positive EI's are more amplified. All intensities of negative EI's, such *Anger* EI's, are reduced. With negative mood state the effects on positive and negative EI intensities are reversed.

The intensity of the secondary emotion *happiness*, resulting from the effect of *happiness* EI's, is higher in the context of positive mood (Figure 4(c)) than in any other contexts due to the effect of the mood on the *happiness* EI intensities.

The arrival of an EI activates a behaviour if the intensity is higher than a certain threshold. In the context of positive mood (Figure 4(c)) all the *happiness* EI's activate the behaviour *Happy* due to the effect of mood on positive EI intensity. In the context of neutral mood, Figure 4(b), *happiness* EI's with low intensity , such as the third one, do not activate the behaviour. In the context of negative mood (Figure 4(a)), the second *happiness* EI does not activate the behaviour due to the reduction of its intensity by the effect of the mood state.

3.4.3 Secondary Emotion Influences

The behaviour activation thresholds are variable. They are influenced by the intensity of opposite secondary emotions. For instance, the intensity value of the secondary emotion *happiness* increases the activation threshold of the behaviour *Angry*. This is the reason why no *Angry* behaviour is activated in the context of positive mood (4(c)). In the context of neutral mood (4(b)), the second *anger* EI does not activate the *angry* behaviour, where the third *anger* EI activates the behaviour because the intensity of *happiness* is lower, therefore the behaviour activation threshold is lower too.

An EI increases the intensity of its corresponding secondary emotion and decreases the intensity of opposite secondary emotions. For instance the *anger* EI increases the intensity of the secondary emotion *anger* and decreases the intensity of the secondary emotion *happiness*. These effects are not constant, they are related to the intensity of the secondary emotions. For instance, with care it is possible to see in Figure 4 (b), that the third *anger* EI increases the intensity of the secondary emotion *anger* more than the second *anger* EI, and this is due to the lower level of the secondary emotion *happiness* when the third *anger* EI arrives. For the same reason, the effect of the third *angry* EI on the secondary emotion *happiness* is more important than the effect of the second one. It should be emphasised that the *anger* EI's have the same intensity and that the mood state is stable between the two stimuli; the only difference is the intensity level of the secondary emotions.

4 A Generic Dynamic Emotion Representations Model

Many theories of emotions exist, therefore we made some decisions for the design of the DER. To overcome this problem, and to let people experiment with different emotion theories, we decided to implement a DER model with which users can build their own DER. This model can be configured through an XML file. A fragment of this file can be seen in A.

4.1 Description of the Main Components of the DER Model

The DER model is composed of any number of modules. Each module is composed of a dynamic filters group and a list of dimensions, as show on Figure 1. The only characteristic of a module is its *name*. In the XML fragment, the filter groups of a module has the tags `emotional_perception` in the XML fragment.

Each dimension is composed of a list of dynamic filters. The characteristics of a dimension are its *name*, its *valence* and the *name of the operation* used to compute its intensity, such as *sum* or *replace* shown Figure 3.

The definition of dynamic filters, used to control the effects of emotional impulses on dimensions and to control the interaction between dimensions is more complex so it is described separately in the next sub-section.

4.2 Dynamic Filters

In the DER model, *dynamic filters* are used to control the influence of emotional stimuli on dimensions. The DER model defines *dynamic filters* as functions which have parameters varying over time and which are used to modify values of emotional impulse parameters.

A *dynamic filter* is composed of a *function* with its list of parameters and a series of *influences* that modify the *function* parameters. The aim of the function is to take the value of one emotional impulse parameter as an input and provide a corresponding value. The definition of influences also requires a function that takes the intensity of a dimension, or the value of an emotional impulse parameter, as an input and provides a corresponding value that will be used to modify a parameter of the dynamic filter function. To design a DER model that can be configurable by users a *generic function* type is defined with the following parameters:

- *name:* is a name describing the function.
- *type:* is the type of mathematical function used to define the function, linear or sigmoid.
- *input_type:* gives the type of object taken as input by the function, stimulus or dimension
- *selective_para:* indicates the name of an object characteristic that is used to select which object should be taken as input. The characteristics for an emotional stimulus could be *name*, *valence*, *decay duration* and so on; for a dimension it is its *name*.
- *selective_value:* indicates the value of the characteristic specified by *selective_para* used to select the object that should be taken as input.
- *input_para:* indicates the name of the object characteristic that should be used as input, such as *peak intensity* or *sustain duration*.

Depending on the mathematical type of the function, a list of parameters should be defined. For instance, in the case of a sigmoid function four parameters are defined: *gain*, *down/up shift*, *right/left shift*, and *slope steepness*.

In the case of the function of a dynamic filter, the function parameters can be modified by *influences*. An *influence* modifies one parameter of the dynamic filter function and is defined with the following parameters:

- *influenced_parameter:* indicating which parameter of the dynamic filter function should be modified, such as *right/left shift* for a sigmoid function.
- *operation:* specifies which operation should be used to modify this function parameter. In the current implementation two operations are possible *addition* and *replace*.
- *influencing_factor:* indicating by which factor the influencing source should modify the function parameter.

As well as these parameters, a list of *influencing sources* and an operation to combine the values of the *influencing sources* need to be defined. An *influencing source* is defined by *generic functions* as described previously.

An example of a dynamic filter can be seen in A.

5 Conclusion

This paper presents the foundations and the implementation of a Dynamic Emotion Representation (DER).

The design of the DER is inspired by emotion theories and guided by the needs of the facial animation system in which it is integrated. The *primary emotion module* represents emotion activation and it is used to produce emotional expressions. The *secondary emotion module*, representing a short-to-medium term emotional context, also influences the selection of facial signals corresponding to communicative functions. The *mood module* is used as a medium-to-long term emotional context and influence the effects of emotional stimuli on the representations.

The DER is integrated within an Emotionally Expressive Facial Animation System (EE-FAS), enabling the production of subtle differences in facial expressions in relation to the agent's emotional state. Facial signals corresponding to communicative functions are selected in relation to the emotional state of the agent but also in relation to the difference between the emotional state and the intended communicative functions. The DER provides for more varied emotional behaviour than most AI emotional models because the agent's history determines its full emotional state and response, yet it also creates plausible, human-like emotional behaviour.

This paper also presents a generic model of DER enabling us to build different types of DER. This model has been implemented and uses XML files to configure its structure and to define the interactions between its components.

The architecture used to implement the EE-FAS is modular and based on middle-ware called Psyclone (Thòrisson, 2004; Thòrisson et al., 2004). Psyclone enables the exchange of messages between modules and between applications. By implementing the DER model with a Psyclone interface, we hope to encourage the research community to use the DER model within different applications, through the use of a Psyclone interface, and to create their own instances of this model.

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A XML fragment for the configuration of a DER


```
<dimensional_module name="mood">
  + <emotional_perception>
  + <dimension name="tension" valence="-1" stimulus_operation="add">
  + <dimension name="energy" valence="-1" stimulus_operation="add">
</dimensional_module>
<dimensional_module name="secondary emotions">
  + <emotional_perception>
  - <dimension name="happiness" valence="1" stimulus_operation="add">
    - <filters>
      - <dynamic_filter>
        - <function name="Happ. Stim."
                    type="sigmoid"
                    input_type="stimulus"
                    selective_para="name" selective_value="happiness"
                    input_para="peak intensity">
            <gain>100</gain>
            <down_up_shift>0</down_up_shift>
            <right_left_shift>60</right_left_shift>
            <slope_steepness>20</slope_steepness>
        </function>
        - <influence>
          <influenced_parameter>right_left_shift</influenced_parameter>
          <operation>addition</operation>
          <inflencing_factor>1</inflencing_factor>
          - <influencing_source type="dimension" operation="abosulte maximum">
            + <function name="anger influence" type="sigmoid"
                        input_type="dimension" selective_para="name"
                        selective_value="anger" input_para="intensity">
            + <function name="Sadn. influence" type="sigmoid"
                        input_type="dimension" selective_para="name"
                        selective_value="sadness" input_para="intensity">
            + <function name="fear influence" type="sigmoid"
                        input_type="dimension" selective_para="name"
                        selective_value="fear" input_para="intensity">
            </influencing_source>
         </influence>
      </dynamic_filter>
    - <dynamic_filter>
      + <function name="Anger Stim." type="sigmoid"
                  input_type="stimulus" selective_para="name"
                  selective_value="anger" input_para="peak intensity">
      </dynamic_filter>
    - <dynamic_filter>
      + <function name="Sadn Stim." type="sigmoid"
                  input_type="stimulus" selective_para="name"
                  selective_value="sadness" input_para="peak intensity">
      </dynamic_filter>
    - <dynamic_filter>
      + <function name="Fear Stim."  type="sigmoid"
                  filter_what="stimulus" selective_para="name"
                  selective_value="fear" input_para="peak intensity">
      </dynamic_filter>
  </filters>
</dimension>
  + <dimension name="anger" valence="-1" stimulus_operation="add">
  + <dimension name="sadness" valence="-1" stimulus_operation="add">
  + <dimension name="surprise" valence="0" stimulus_operation="add">
  + <dimension name="fear" valence="-1" stimulus_operation="add">
  + <dimension name="disgust" valence="-1" stimulus_operation="add">
</dimensional_module>
<dimensional_module name="Primary Emotions">
  + <emotional_perception>
  + <dimension name="Happy" valence="0" stimulus_operation="replace">
  + <dimension name="Angry" valence="-1" stimulus_operation="replace">
  + <dimension name="Sad" valence="-1" stimulus_operation="replace">
  + <dimension  name="Surprised" valence="0" stimulus_operation="replace">
  + <dimension name="Afraid" valence="-1" stimulus_operation="replace">
  + <dimension name="Disgusted" valence="-1" stimulus_operation="replace">
```

```
</dimensional_module>
```

References

Albrecht, I., M. Schröder, J. Haber, and H.-P. Seidel (2005). Mixed feelings: Expression of non-basic emotions in a muscle-based talking head. *Special issue of Journal of Virtual Reality on Language, Speech & Gesture 8*, 201–212.

André, E., M. Klesen, P. Gebhard, S. Allen, and T. Rist (1999, October). Integrating models of personality and emotions into lifelike character. In *Proceeding of the Workshop on Affect in Interaction – Towards a new Generation of Interfaces in conjunction with the 3rd i3 Annual Conference*, Siena, Italy, pp. 136–149.

Bavelas, J. B. and N. Chovil (1997). Faces in dialogue. See Russel and Fernández-Dols (1997), pp. 334–346.

Cañamero, D. (2003). *Designing Emotions for Activity Selection in Autonomous Agents*, pp. 115–148. The MIT Press.

Chovil, N. (1997). Facing others: A social communicative perspective on facial displays. See Russel and Fernández-Dols (1997), pp. 321–333.

Collier, G. (1885). *Emotional expression.* Lawrence Erlbaum Associates.

Damasio, A. R. (1994). *Descartes' error emotion, reason, and the human brain.* Putnam.

Darwin, C. (1979). *Expression of the Emotions in Man and Animals.* J Friedmann. ISBN:0904014398.

Delgado-Mata, C. and M. P.-C. Ruth S. Aylett, Rocio Ruiz-Rodarte (2002). Emotional ruins:communicating emotions inside a virtual environment for cultural heritage. In *Proceedings of Creative Digital Culture.*

Egges, A., S. Kshirsagar, and N. Magnenat-Thalmann (2004, january). Generic Personality and Emotion Simulation for Conversational Agents. *Computer Animation and Virtual Worlds 15*, 1–13.

Ekman, P. (1992). Facial expressions of emotion: New findings, new questions. *Psychological Science 3*, 34–38.

Ekman, P. (1999a). *Basic Emotions*, Chapter 3. John Wiley & Sons Ltd.

Ekman, P. (1999b). *Facial Expressions*, Chapter 16. John Wiley & Sons Ltd.

Ekman, P. and W. V. Friesen (1972). *The Repertoire of Non Verbal Behaviour-Categories, Origins Usage and Coding Smiotica*, pp. 49–98. Pergamon Press.

Ginsburg, G. P. (1997). Faces: An epilogue and reconceptualization. See Russel and Fernández-Dols (1997), pp. 349–382.

Gratch, J. and S. Marsella (2004). Evaluating the modeling and use of emotion in virtual humans. In *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems*, Volume 1, pp. 320–327. IEEE Computer Society.

Izard, C. E. (1971). *The face of emotion*. Appleton-Century-Crofts.

Izard, C. E. (1977). *Human emotions*. Plenum Press.

Izard, C. E. (1997). Emotions and Facial Expression: A Perspective from Differential Emotions Theory. See Russel and Fernández-Dols (1997), pp. 57–77.

Kshirsagar, S. and N. Magnenat-Thalmann (2002, June). A multilayer personality model. In *Proceedings of 2^{nd} International Symposium on Smart Graphics*, Hawthorne, New York, pp. 107–115. ACM Press.

Kurlander, D., T. Skelly, and D. Salesin (1996). Comic chat. In *SIGGRAPH '96: Proceedings of the 23rd annual conference on Computer graphics and interactive techniques*, New York, NY, USA, pp. 225–236. ACM Press.

Latta, C., N. Alvarado, S. S. Adams, and S. Burbeck (2002). An expressive system for endowing robots or animated characters with affective facial displays. In *The 2002 conference of the British Society for Artificial Intelligence and the Simulation of Behavior*.

Ortony, A., G. L. Clore, and A. Collins (1990/1988). *The cognitive structure of emotions*. Cambridge University Press.

Ortony, A. and T. J. Turner (1990). What's Basic About Basic Emotions? *Psychological Review 97*(3), 315–331.

Paiva, A., J. Dias, D. Sobral, R. Aylett, P. Sobreperez, S. Woods, C. Zoll, and L. Hall (2004). Caring for Agents and Agents that Care: Building Empathic Relations with Synthetic Agents . In *3rd International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2004)*, Volume 1, pp. 194–201. IEEE Computer Society. 19-23 August 2004, New York, NY, USA.

Pelachaud, C. and M. Bilvi (2003). Computational model of believable conversational agents. In M.-P. Huget (Ed.), *Communication in Multiagent Systems*, pp. 300–317. Springer.

Picard, R. W. (1997). *Affective Computing*. The MIT Press, Cambridge, Massachusetts.

Plutchik, R. (1980). A general psychoevolutionary theory of emotion. In R. Plutchik and H. Kellerman (Eds.), *Emotion: Theory, research, and experience*, pp. 3–33. Academic press, inc.

Poggi, I. and C. Pelachaud (2000). Emotional meaning and expression in animated faces. pp. 182–195.

Raouzaiou, A., K. Karpouzis, and S. D. Kollias (2003). Online gaming and emotion representation. In N. N. García, J. M. Martínez, and L. Salgado (Eds.), *VLBV*, Volume 2849 of *Lecture Notes in Computer Science*, pp. 298–305. Springer.

Reilly, W. S. N. (1996). *Believable Social and Emotional Agents.* Ph. D. thesis, School of Computer Science, Carnegie Mellon University, Pittsburgh.

Russel, J. A. and J. M. Fernández-Dols (1997). *The Psychology of Facial Expression.* Cambridge University Press.

Russell, J. A. (1997). Reading emotion from and into faces: Resurrecting a dimensional-contextual perspective. See Russel and Fernández-Dols (1997), pp. 295–320.

Sizer, L. (2000, December). Towards a computational theory of mood. *Brit. J. Phil. Sci. 51*(4), 743–769.

Sloman, A. (2001). Beyond shallow models of emotions. *Cognitive Processing 2*(1), 177–198.

Sloman, A. (2003). *How Many Separately Evolved Emotional Beasties Live within Us?*, pp. 35–114. The MIT Press.

Smith, C. A. and H. S. Scott (1997). A componential approach to the meaning of facial expressions. See Russel and Fernández-Dols (1997), pp. 295–320.

Thayer, R. E. (1996). *The origin of everyday moods.* Oxford University Press.

The Duy Bui (2004). *Creating Emotions And Facial Expressions For Embodied Agents.* Ph. D. thesis, University of Twente.

Thòrisson, K. R. (2004). Communicative machines: Psyclone. http://www.cmlabs.com/psyclone.

Thòrisson, K. R., C. Pennock, T. List, and J. DiPirro (2004). Artificial intelligence in computer graphics: A constructionist approach. *Computer Graphics Quarterly*, 26–30. New York: Association for Computing Machinery.

Tomkins, S. S. (1980). Affect as amplification: some modification in theory. In R. Plutchik and H. Kellerman (Eds.), *Emotion: Theory, research, and experience*, pp. 3–33. Academic press, inc.

Velásquez, J. D. (1997). Modeling emotions and other motivations in synthetic agents. In *AAAI/IAAI*, pp. 10–15.