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Affective Game Engines: Motivation and Requirements

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ABSTRACT

The tremendous advances in gaming technologies over the past decade have focused primarily on the physical realism of the game environment and game characters, and the complexity and performance of game simulations and networking. However, current games are still lacking in the affective realism of the game characters, and the social complexity and realism of their interactions. To achieve the next leap in the level of engagement and effectiveness, particularly in the arena of serious games, gaming research needs to focus on enhancing the social and affective complexity and realism of the game characters, their interaction, and the game narrative as a whole. To achieve these goals, games and game development tools will need to provide functionality to support the recognition of user and game character emotions, real-time adaptation and appropriate responses to these emotions, and more realistic expression of emotions in game characters and user avatars. To support these functionalities, the games will need to construct affective models of the players, and include computational models of emotion within the game characters. In this paper, we discuss these functionalities, and suggest a set of requirements for an affective game engine, capable of supporting the development of more affectively realistic, engaging, and effective games. The discussion is organized around the functional requirements and the computational tasks necessary to support them. We emphasize the importance of selecting appropriate semantic primitives, and discuss how existing methods and techniques in affective computing and computational affective modeling contribute to the development of affective game engines and game development tools.

Keywords

Affective Game Engines, Affective Gaming, Game Design, Affective Computing, Affective Modeling, Emotion

1. INTRODUCTION

Gaming platforms and game development engines have in many ways surpassed the prohibitively expensive virtual reality environments [1]. However, while the visual realism, and simulation complexity and performance have grown tremendously over the past 10 years, the affective and social realism of game characters, and the game plots and narrative, remain at relatively simple levels. Both the complexity and realism of the social interactions, and the realism of affective expression by the game characters, remain limited. As games begin to proliferate into serious gaming applications (e.g., coaching, training and therapeutic games), and into more diverse demographic groups, there will be increasing demands for more complex social interactions among the game characters and the player, for more affective realism of the game characters and the player avatars, for more engaging real-time gameplay and game character adaptations to the player's state, and for a larger repertoire of emotions in the game characters in general. All these capabilities will require an explicit focus on *emotion*: its recognition and expression, as well as its generation and effects.

Emotions play a key role in the user experience, both in entertainment games, and in serious games developed for education, training, assessment, therapy or rehabilitation. The gaming community has recently recognized the importance of emotion in the development of more engaging games [2, 3], and the area of *affective gaming* is receiving increasing attention. The current focus of affective gaming research is on the sensing and recognition of the players' emotions, and tailoring the game responses to these emotions [4, 5]. Progress is being made in emotion recognition in games, primarily in the recognition of arousal (a component of emotion), and several games have been developed in laboratories exploring the possibility of adapting the gameplay to the player's state; e.g., changing the difficulty of the levels or the reward structure if the player becomes too frustrated or bored [2, 6]. A significant effort is also being devoted to generating 'affective behaviors' in the game characters, to enhance their realism and believability [7]. Less emphasized is the modeling of emotions, their generation and their effects, in the game characters themselves, and in user models representing the players.

Gilleade and colleagues captured the objectives of affective gaming in a succinct statement, describing a progression of functionalities an affective game should support: "Assist me, Challenge me, Emote me" [2]; the last goal representing the type of enhanced engagement, perhaps even the induction of specific emotions, possible with affect-focused and affect-adaptive games.

In this paper we suggest that advancing the state-of-the-art in gaming to effectively cover the "assist me, challenge me, emote me" spectrum will require game development tools that directly support enhanced affective realism and complexity, by facilitating the recognition of players' emotions, adaptation of the gameplay and game character behavior to the players' emotions, and generation of socially appropriate and affectively realistic game character behavior and expression.

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Below we outline some of the computational requirements for these functionalities, and suggest a set of requirements for an affective game engine capable of facilitating the development of more affectively realistic, engaging and effective games. We discuss how the emerging area of affective computing, computational affective modeling, and established methods in AI can facilitate the development of affective game engines. We emphasize the importance of selecting appropriate semantic primitives and representational structures.

2. AFFECTIVE GAME ENGINES

Progress in gaming has been greatly aided by the emergence of game engines: development tools that facilitate the creation of games by providing realistic graphics and real-time simulation environments. Game engines exist for many game genres (e.g., FPS vs. serious games for training), and vary in complexity and cost (from the free Crystal Space, engines such as Unity (around USD200) to the popular Unreal engine (~USD300,000)) [8]. However, to date, no engine has emerged that focuses explicitly on facilitating the development of affectively realistic game characters and avatars, and suitable for the development of affect-adaptive games.

What types of capabilities would such an affective game engine need to have? To support the development of *affect-adaptive games*, the affective game engine would need to: (1) facilitate recognition of a broad range of player's emotions, in real-time, and within varied gaming contexts (e.g., from the Wii to iPhones); and (2) generate effective adaptations to these emotions, including changes in gameplay reward structure, and realistic portrayal of appropriate emotions by the game characters. To enable this type of emotion recognition and adaptation, the game engine would need to support the dynamic construction of an *affective user model* [9, 10]; that is, a model of the user that contains information not only about his/her current level, skills, knowledge state, and game history, but also about the emotions typically experienced, their characteristic expression and behavioral manifestations, their triggers, and typical transitions among them.

To support the development of *socially complex and affectively realistic games,* the game engine would need to support the development of game characters capable of recognizing emotions in other game characters, and dynamically generating appropriate and affectively-realistic behavior. For example, one can imagine a next-generation of Sims where the characters have sufficient affective complexity to react with pride, jealousy or embarrassment to some social situation, and realistically display the associated affective manifestations, which involve multiple modalities (facial expressions, head movement, hand gestures, gaze). To accomplish such level of realism, the game characters would need to incorporate a *computational model of emotion.* Such an emotion model would need to *dynamically generate emotions,* in real-time, in response to evolving gameplay (including the behavior of the player and the other game characters). The model would also need to *model the effects of these emotions* on the character's decision-making and behavior, the latter including both affective expression, such as changes in facial expressions, gestures and quality of movement, as well as specific emotion-dependent behavioral choices (e.g., run or hide when fearful, approach when happy or helpful; attack when aggressive). The game engine would also need to support for the development of affectively-realistic player avatars, capable of displaying the player's affective state in a manner consistent with the player's expectations and needs.

Two areas of research and practice are relevant for implementing the affective game engine functionalities outlined above: *artificial intelligence (AI),* and the emerging area of *affective computing* [11, 12]. Although commercial game companies are increasingly mentioning AI their marketing slogans, the use of AI methods in games remains limited, and the techniques used typically do not represent state-of-the-art in academic AI. Schaeffer [13] points out that state-of-the-art in gaming AI, reflected by rule-based programming, finite state automata, and the A* algorithm, lags behind academic AI. He further points out the potential of AI to contribute to more engaging and effective games, by incorporating learning and high-level development tools. To enable the development of the affective game engine functionalities outlined above, additional AI techniques would be necessary, most importantly: symbolic computational methods for emotion modeling in game characters, symbolic representational methods and classification algorithms for emotion recognition and the development of affective user models, techniques from adaptive interface research and intelligent tutoring systems for affect-adaptive gameplay, and research from embodied conversational agents and relational agents [14] for enhancing the social realism and effectiveness of game characters.

AI has much to contribute to the development of affective game engines. However, the primary contributions would come from *affective computing* [12]. While recognized as a critical relevant discipline by affective gaming researchers [2], affective computing remains largely unexplored in gaming applications. Affective computing consists of three core areas: *emotion sensing and recognition by machines*; *computational models of emotion*; and *emotion expression by synthetic agents and robots.* The methods and techniques developed in these areas are directly applicable to the development of affective game engines, and to affective game design in general. While some of the affective computing methods for the sensing, recognition and expression of emotion are being explored in affective gaming [4, 5]), the area of affective user modeling and computational models of affect has been largely ignored [12]. Below we therefore emphasize the importance of affective modeling, as a basis for more realistic behavior of game characters, and as a means of developing more realistic and complete affective models of the players, to enable real-time affect-adaptive gameplay, and to enable the game system to induce a wide range of desired emotions in the players.

3. EMOTION RESEARCH

Emotion research in the affective sciences over the past 20 years has produced data, conceptual and computational models, and methods and techniques that are directly relevant to affective gaming and affective game design, including the development of affective game engines. The emerging findings inform sensing and recognition of user emotions by machines, computational affective modeling, and the generation of expressive affective behaviors in synthetic agents and robots.

3.1 Definitions

When searching for a definition of emotions, it is interesting to note that many definitions describe instead characteristics of affective processing (e.g., fast, undifferentiated processing), or the roles and functions of emotions. The latter are usefully divided into those involved in interpersonal, social behavior (e.g., communication of intent, coordination of group behavior, attachment), and those involved in intrapsychic regulation, adaptive behavior, and motivation (e.g., goal management, coordination of multiple systems necessary for action, selection of best adaptive behaviors). Nevertheless, emotion researchers do agree on a high-level definition of emotions, as the "evaluative judgments of the environment, the self and other social agents, in light of the agent's goals and beliefs" and the associated distinct modes of neural functioning reflected across multiple modalities (e.g., cognitive, physiological) and coordinating multiple subsystems (cognitive, behavioral), to achieve the agent's goals.

3.2 Multiple Modalities

A key characteristic of emotions is their multi-modal nature, which has direct implications for both sensing and recognition of player emotion, and behavioral expression of emotions by game characters. The most visible is the *behavioral / expressive modality*; e.g., facial expressions, speech, gestures, posture, and behavioral choices. Closely related is the *somatic / physiological modality:* the neurophysiological substrate making behavior and cognition possible (e.g., neuroendocrine system manifestations, such as blood pressure and heart rate). The *cognitive / interpretive modality* is most directly associated with the evaluation-based definition of emotions above, and emphasized in the current cognitive appraisal theories of emotion generation. Finally, the *experiential/subjective modality* reflects the individual's conscious experience of emotions.

3.3 Multiplicity of Affective Factors

The term 'emotion' can often be used rather loosely, to denote a wide variety of affective factors, each with different implications for sensing and recognition, modeling and expression. *Emotions* proper represent short states (lasting seconds to minutes), reflecting a particular affective assessment of the state of self or the world, and associated behavioral tendencies and cognitive biases. Emotions can be further differentiated into *basic* and *complex* (often referred to as *social),* based on their cognitive complexity, the universality of triggering stimuli and behavioral manifestations, and the degree to which an explicit representation of the agent's 'self' is required (Ekman and Davidson 1994; Lewis 1993). *Basic emotions* typically include fear, anger, joy, sadness, disgust, and surprise. *Complex emotions* such as guilt, pride, and shame have a much larger cognitive component and associated idiosyncracies in both their triggering elicitors and their behavioral manifestations, which makes both their detection and their expression more challenging. *Moods* reflect less-focused and longer lasting states (hours to days to months). Finally, *affective personality traits* represent more or less permanent affective tendencies (e.g., extraversion vs. introversion, aggressiveness, positive vs. affective emotionality).

3.5 Emotion Generation and Emotion Effects

While multiple modalities play a role in *emotion generation* (Izard, 1993), most existing theories (and computational models) emphasize the role of cognition, both conscious and unconscious, in emotion generation: the 'cognitive appraisal' theories of emotion [15]. A key component of appraisal theories is a set of domain-independent appraisal dimensions which capture aspects of the current situation, such as novelty, urgency, likelihood, goal relevance and goal congruence, responsible agent and the agent's ability to cope [16, 17]. If the values of the dimensions can be determined, the resulting vector can be readily mapped onto the associated emotion space, which provides a highly-differentiated set of possible emotions.

Less understood are the processes mediating the *effects of the triggered emotions.* The visible manifestations of specific emotions are certainly well documented, at least for the basic emotions; that is, the associated facial expressions, gestures, posture, nature of movement, speech content and tone characteristics. Some effects on cognition are also known; e.g., fear reduces attentional capacity and biases attention toward threat detection [18, 19]. However, the mechanisms mediating these observed effects have not yet been identified, although several theories have been proposed, including *spreading activation* [20, 21], and *parameter-based models*. Proposed independently by a number of researchers (e.g., [22-25], parameter-based models suggest that affective factors act as parameters inducing patterns of variations in cognitive processes that characterize different emotions in terms of systemic changes in biases, processing speeds and capacities.

4. EMOTION RECOGNITION AND EXPRESSION IN GAMING

Much progress has been made in machine recognition of emotion over the past 5 years. Multi-modal approaches (facial expression, speech and physiological signals) are beginning to approach the accuracy rates of human observers [26, 27]. Significant advances are being made in recognizing spontaneous emotion expressions, under more realistic circumstances (i.e., in real-life vs. controlled laboratory settings) [28], and attempts are being made to recognize more complex emotions, such as embarrassment [29].

However, not all of these promising results readily translate to the gaming context. Gaming presents a specific set of constraints and challenges for the recognition and expression of emotions. Broad game categories (e.g., entertainment vs. serious gaming), game genres (e.g., FPS vs. slower-tempo strategy games vs. games emphasizing social interaction, such as Sims), and delivery modes ranging from the Wii to iPhones, have different requirements for both the types of emotions that may need to be sensed and expressed, and the most appropriate channels and sensors for doing so. Below we briefly discuss emotion recognition and expression, and their relevance for the development of affective games, emphasizing the significance of their multimodal nature, and their temporal dimension.

4.1 Emotion Signatures Across Multiple Modalities and Time

The *multi-modal nature of emotions,* and their evolution over time, both facilitate and constrain recognition of emotions in players, and generation of expressive affective behavior in game characters. Many emotions have characteristic multi-feature, multi-modal 'signatures' that serve as basis for both recognition

and expression; e.g., fear is characterized by raising of the eyebrows (facial expression), fast tempo and higher pitch (speech), threat bias in attention and perception (cognition), a range of physiological responses reflecting increased arousal and mobilizing the energy required for fast reactions, and of course characteristic behavior (flee vs. freeze). Identifying unique emotion signatures that provide the highly diagnostic signals necessary for recognition is a key challenge in machine emotion recognition. Once identified, the constituent features guide the selection of appropriate (non-intrusive) sensors, and the classification algorithms required to map the raw data onto a recognized emotion.

The identification of the most diagnostic emotion features also guides the selection of best expressive channels to convey a particular emotion to the player, via game character behavior. In expression however, multiple modalities also present a challenge, by requiring that expression be coordinated and synchronized across multiple channels to ensure character realism. For example, expression of anger must involve consistent signals in speech, movement and gesture quality, facial expression, body posture and specific action selection, evolving, and decaying, at appropriate rates.

The *temporal dimension of emotions* also facilitates recognition, and presents challenges for expression. Temporal affective data increase recognition accuracy. In some channels (e.g., facial expressions), recognition is much higher for video clips than for still photographs. In many modalities, the temporal dimension is an essential component (e.g., speech, movement, behavior monitoring, physiological data). In affective expression, the temporal dimension presents a challenge by requiring realistic evolution of the affective state, and transitions among states. This requires data about affective dynamics, and their manifestations in the dynamic qualities of facial expressions, speech and movement, as the emotion intensity ramps up and decays. Particularly challenging are the depictions of mixed affective states (e.g., sadness and joy, fear and anger) and transitions among states, which may need to be gradual for some situations but dramatic for others. For some modalities, these dynamics are well-documented (e.g., the *facial action units* vocabulary of facial expressions (Ekman and Friesen, 1978) that defines the onset and offset patterns [29]), but in general, these dynamics are determined empirically and require significant tuning of the recognition and modeling algorithms.

4.2 Semantic Primitives for Emotion Recognition and Expression

The sensing and recognition of emotions, and the expression of their myriad of manifestations in game characters, thus require fundamental knowledge of emotions and their characteristic multi-modal, temporal signatures. Extensive literature in emotion research serves as the core resource for this information (e.g., [30]).

A critical factor in both recognition and expression of emotion is the identification of a set of *semantic primitives* for each expressive channel, whose distinct configurations characterize the different emotions [31]. An appropriate set of such primitives greatly facilitates both recognition and expression, by providing a unifying vocabulary of features. The most established example of such a vocabulary is the Facial Action Coding System (FACS) developed by Ekman and Friesen (1978). FACS describes in detail features such as shape of the lips and eyebrows, narrowing of the eyes, and raising of cheeks, to completely define a broad range of facial expressions. Specific configurations of these expressions than characterize different emotions; e.g., lips turned upward, raising of lower eyelid and narrowing of lids are associated with happiness. FACS has been successfully used to model facial expressions in synthetic characters [32]. Semantic primitives for other modalities are also being developed, including speech (patterns of pitch and tonal variations used to identify basic emotions [32], and posture ('basic posture units' identified by Mota & Picard [33], used to identify boredom and engagement).

The semantic primitives then guide the selection of the best sensors, and ideally correspond to the features used in the classification algorithms mediating emotion recognition. The primitives also facilitate affective expression generation, by helping define the syntax and semantics of markup languages used to specify the expressive features of emotions, across different channels (face, body movement, speech)

4.3 Channel and Sensor Selection

Affective gaming presents a unique set of constraints on recognition, by requiring non-intrusive sensors and precluding methods that require fixed player positions. For example, sensors that detect arousal, a key component of emotions, such as finger-tip caps to detect galvanic skin response or heart-rate monitors, are not optimal for gaming, nor are facial recognition systems that require the player to remain in a fixed position. Instead, gaming requires sensors that are unobtrusive, or that can be readily incorporated into existing game controls; e.g., gamepad pressure to detect arousal [4]. Number of sensor systems can be explored, including a camera for tracking facial expressions (e.g., IBM blue-eyes), physiological sensors such as a wireless heart rate monitor (e.g., POLAR s610i [34]), and sensor-instrumented chairs for detecting body posture (e.g., Tekscan Body Pressure Measurement System [35]). Products are also emerging that offer helmet-embedded sensors combining multiple channels (EEG, facial electromyogram, blink rate, heart rate, head motion and skin temperature) to recognize game-relevant player states, such as engagement vs. boredom (e.g., emotiv.com, emsense.com, neurosky.com). The advent of movement-oriented controls, such as those in the Wii, promises to provide a rich set of affective sensors based on movement quality and haptic sensors.

4.4 Feature Selection and Classification Algorithms for Emotion Recognition

To recognize user emotion, the sensed data must be aggregated into useful features, often directly corresponding to the semantic primitives associated with a particular channel (e.g. FACS codes for facial expressions). These then represent input for a classification algorithm that assigns them to one of the emotions. A discussion of the wide variety of feature selection and classification algorithms is beyond the scope of this paper. Excellent reviews can be found in [26-28].

5. COMPUTATIONAL EMOTION MODELING IN GAMING

The past 15 years have witnessed a rapid growth in computational models of emotion and affective architectures. Researchers in cognitive science, artificial intelligence and

human computer interaction (HCI) are developing models of emotion for theoretical research regarding the nature of emotion, as well as a range of applied purposes: to create more believable and effective synthetic characters and robots, and to enhance HCI [6, 36, 37]. Computational models of emotion are relevant for game development from two distinct perspectives. *First,* affective computational models enable the game characters to dynamically generate appropriate affective behavior in real time, in response to evolving situations within the game, and to player behavior. Such adaptive character behavior is more believable than 'scripted' behavior, and the resulting realism contributes to an increased sense of engagement. These models also enable the characters to consistently and realistically portray specific emotions when the game objective is to induce a particular emotion in the player, as is the case in psychotherapeutic games. *Second*, computational affective modeling methods are also relevant for the creation of more detailed, mechanism-based affective models of the players.

The complexity of models required to generate affective behavior in game characters varies with the complexity of the game plot, the characters, the available behavior repertoire of the player within the game, and of course the game objectives (e.g., entertainment vs. education vs. therapy). For many games, simple models are adequate, where a small set of gameplay or player behavior features is mapped onto a limited set of game characters' emotions, which are then depicted in terms of simple manipulations of character features (e.g., player fails to find a treasure and the avatar shows a 'sad face', player loses to a game character and the character gloats). Such simple models are termed 'black-box' models, since they make no attempt to represent the underlying affective mechanisms. Data available from the affective sciences provide the basis for defining the necessary mappings (triggers-to-emotions, emotions-to-effects). However, as the complexity of the games increases, resulting in more involved plots and narratives, and associated increase in the sophistication of the game characters and richness of player interactions, the need for more sophisticated affective modeling arises. This may in some cases require 'process-models', using explicit representations of some of the affective mechanisms, and allowing a greater degree of generality and complexity.

A number of computational emotion models have been developed for both research and applied purposes. These models typically focus on the basic emotions (e.g., joy, fear, anger, sadness), and use a variety of methods for implementing emotion generation via appraisal [38-41], or, less frequently, emotion effects via parametric modeling [42]. Most appraisal models are based on either the OCC model [43], or the explicit appraisal dimension theories developed by [17, 44] (e.g., *novelty, valence, goal relevance and congruence, responsible agent, coping potential).* Typically, symbolic AI methods are used to implement the stimulus-to-emotion mapping, whether this is done via an intervening set of appraisal dimensions, or directly from the domain stimuli to the emotions. In general, the complexity of this process lies in analyzing the domain stimuli (e.g., features of a game situation, behavior of game characters, player behavior) and extracting the appraisal dimension values. This may require representation of complex mental structures, including the game characters' and players' goals, plans, beliefs and values, their current assessment of the evolving game situation, and expectations of future developments, as well as complex causal representation of the gameplay dynamics. Rules, semantic nets and Bayesian belief nets are some of the frequently used formalisms implementing this mapping.

6. AFFECTIVE USER MODELING

Affective user models are representational structures that store information about the player's affective profile. This includes information about specific emotions experienced, their triggers (e.g., gameplay situations and interactions), and their expressive and behavioral manifestations (defined in terms relevant for the available sensors and monitoring). Affective user models play a critical role in affect-adaptive gaming, supporting both emotion recognition, and the use of appropriate affect-adaptive strategy by the game system.

Since affective behavior can be highly idiosyncratic, affective models necessarily involve a learning component, so that the player's behavior can be tracked over time, to identify characteristic affective patterns extracted from player state and gameplay interaction; e.g., Player A may express frustration by more forceful manipulation of the game controls, whereas Player B may exhibit increasing delays between game inputs. Significant existing research in intelligent tutoring systems provides the knowledge and methods supporting affective user modeling (e.g., [34, 35, 45, 46], including sensors and classification algorithms for identifying specific emotions that are relevant for both intelligent tutoring and gaming (e.g., frustration, interest, boredom, engagement) with reasonable rates of accuracy (70-80%). The algorithms used to associate specific user manifestations (e.g., increased heart rate, frown, speech quality) or user-system interaction patterns (e.g., type of input), with specific emotions range from simple correlations and multiple regression models [45, 47], to machine learning algorithms, both symbolic and connectionist, and include tree induction algorithms and artificial neural nets [35]. Many of these algorithms are available in the Waikato Environment for Knowledge Analysis [47].

The information contained in the model can be represented in a variety of structures. A useful representation is an augmented state transition diagram or a hidden Markov model (Picard, 1997) that explicitly indicates the known states of the user (e.g., happy, sad, frustrated, bored, excited), the situations and events that trigger these transitions (e.g., in gaming context, loss or gain of points or game resources; appearance or disappearance of a particular game character, etc.), and the player's behavior (or other monitored characteristic) that indicate each emotion. The requirements section below discusses the structures, development, and use of affective user models in more detail.

7. AFFECTIVE GAME ENGINE REQUIREMENTS

Based on the discussion and analysis above, a number of specific requirements emerge for an affective game engine. We begin with a discussion of the central knowledge-base, containing basic information about emotions in general, the affective profiles of both the player and the game characters, and representations of the currently active affective states, for both the player and the game characters (section 7.1). The knowledge and data represented in this centralized information repository would be shared by the modules implementing the four core functionalities of an affective game engine: *emotion recognition* in the player, *emotion expression* by game characters and player

avatars, *representation of the player's emotions* via dynamic affective user models, and *modeling of emotions within the game characters*. The remainder of the section then discusses the two emotion modeling modules in more detail (7.2-7.3). Due to space limitations, we do not discuss the requirements for the Emotion Recognition or the Emotion Expression modules, which are discussed in a related report ([48] that also discusses the ability of existing game engines to meet these requirements.

7.1 Shared Emotion Knowledge-Base

A core central element of an affective game engine would be a shared knowledge-base containing generic information about emotions (their generation, influences, expression), and a representation of both the player's and the game characters' possible, and current, affective states, and their individual triggers and manifestations.

Exactly which affective states would be necessary would depend on the game. The affective complexity of existing games is relatively simple, compared to the affective complexity of other expressive media (drama, film), not to mention the complexity of human social interaction. For existing games, representation of basic emotions, plus the 'standard' HCI-relevant states of boredom, engagement, surprise, would be adequate. However, as affective gaming advances, more complex social emotions would also need to be represented, depending of course on the specific game's characteristics and objectives.

Whichever affective factors (specific states, traits, attitudes, etc.) were selected for inclusion in a particular game, their representations would need to be shared by the multiple functionalities implemented within the affective engine; e.g., the Affective Player Modeling module would use this information to recognize the player's emotions; the Affective Expression module would use the information to express both the avatar's and the game characters' emotions in a consistent manner.

The game engine should therefore provide the representational structures necessary to encode this knowledge, and the dynamic user and game character data, as they emerge during gameplay. The most natural means of representing these factors is in terms of individual *emotion schemas*, organized into an inheritance hierarchy. Given the often idiosyncratic characteristics of affective triggers and expressions, a hierarchical organization is particularly appropriate, as it allows an efficient representation of both the commonalities shared among different players and game characters (e.g., more points lead to happiness, smiling indicates joy), and any individual and idiosyncratic triggers of emotions, their manifestations, and their effects on decision-making and behavior, following standard object-oriented class hierarchy design.

Exactly which slots the emotion schemas would need would depend on the level of detail required, and game features requiring specific functionalities (e.g., if the player had an avatar within the game, which needed to express the player's emotions, the player's manifestations of each emotion need to be represented), and the theoretical perspective (dimensional vs. discrete emotion model). Minimally, a *generic affective schema*, containing fundamental knowledge about emotions and other affective factors would need the following slots: a type (e.g., emotion, mood, trait, attitude), name (joy, anger), intensity (data and algorithm for intensity calculation), decay functions (reduction in intensity over time), triggering conditions, manifestations across distinct modalities and associated channels (e.g., joy is associated with smiling, sadness is associated with slow movement), and likely behavioral choices.

Instances of these generic schemas, representing specific emotions and affective factors comprising the affective profiles of players or game characters, would then include additional idiosyncratic information about triggers, affective dynamics (intensity and decay calculations), expressive manifestations, and player or character behavioral choices.

Dynamic instantiations if these affective schemas, generated during gameplay and representing affective states currently experienced by the player and the game characters, would contain intensity and its expected decay pattern and duration (e.g., moods last longer than emotions), specific game events triggering the emotion, and the current manifestations within the available channels, and decisions and behavioral choices influenced influenced by the emotion. The information in these schemas would be accessed or modified by the different modules comprising the affective game engine, and significant dependencies would exist among these modules, e.g., in terms of shared semantic primitives.

7.2 Affective User Models of Players

The affective user model plays a central role within the game. It facilitates *recognition of the player's emotion*, by providing individual player data about the manifestations of specific emotions. It also *facilitates realistic expression of players' emotions* via an avatar within the game. The Affective User Modeling module *dynamically constructs and maintains an affective model of the player*, and updates it as new data emerge (e.g., when additional triggers or manifestations of particular emotions are identified).

An affective model of the player contains information about the player's affective factors relevant for gameplay, whose representation is possible within the affective game engine; that is, the set of emotions and moods represented, traits, attitudes or any other affective factors of interest. The affective user model consists of an instantiated subset of the generic emotion schemas, which represent the player's current state. These schemas include emotion intensities, their duration and decay patterns, and the current triggers and manifestations. In affect-adaptive games, or games where the objective is for the player to experience a certain affective state (e.g., therapeutic games for treatment of phobias), a designated schema would represent this *affective goal state.*

To generate an affective model of the player, the Affective User Modeling module would track the player's behavior within the game, and coordinate with the Emotion Sensing and Recognition module, to identify the specific triggers leading to particular emotions and their manifestations, both within the game (specific game interactions), and in terms of any individual characteristics being monitored (physiological signals, speech patterns, facial expressions). To accomplish this, one or more of the classification algorithms discussed in section 6 would be employed. To facilitate affective player modeling, the affective engine should provide some of these algorithms, as well as the semantic primitives suitable for representing the signals used for emotion recognition.

Training is typically required to tune these algorithms. This may require simple parameter tuning (e.g., modifying weights associated with specific behavioral features being tracked), or it

may require active modification of the features themselves. The engine should therefore also provide support for identifying and selecting the best features to use by the classification algorithms, and a means of tuning the algorithm parameters.

Note that the current state-of-the-art in affective user modeling does not yet support the real-time construction of a completely accurate affective user model, containing all of the information outlined above [10]. We believe that incorporating affective user modeling in games would help advance the state-of-the-art in affective user modeling

7.3 Modeling Game Characters' Emotions

The affective game engine requirements for computational models of game character emotions build upon recent work in affective modeling design by Hudlicka [49]. In an effort to establish more systematic guidelines for affective model development, and to facilitate analysis of existing models, Hudlicka suggests dividing the modeling processes into those responsible for emotion generation, and those responsible for implementing emotion effects, across the multiple modalities. Each of these broad categories of processes are then further divided into underlying computational tasks. For emotion generation, these include defining the stimulus-to-emotion mapping, including the calculation of the appraisal dimension values; specifying the nature of the emotion dynamics, that is, the functions defining the emotion intensity calculation, as well as the ramp-up and decay of the emotion intensity over time; methods for combining multiple emotions, necessary for combining existing emotions with newly derived emotions, and for selecting the most appropriate emotion when multiple emotions are generated. For emotion effects, these tasks include defining the emotion-to-behavior and emotion-to-cognitive process mappings; determining the magnitude of the associated effects on each affected process, as well as the dynamics of these effects; and the integration of the effects of multiple emotions, both in cases where a residual effect of a prior emotion is still in force, and in cases where multiple emotions are generated simultaneously and their effects on cognition an behavior must be integrated.

The affective game engine should support these computations, in a flexible format that would facilitate the tuning necessary to obtain desired performance during gameplay, and accommodate emerging research in the affective sciences, including advances in computational modeling.

8. CONCLUSIONS

This paper outlined an ambitious set of requirements for a game engine capable of supporting the development of *affective games:* games capable of recognizing the players' emotions, adapting the gameplay and game character behavior to these emotions, and able to generate affectively-realistic social interactions among game characters. The requirements outlined above represent an ideal set of requirements, which is currently well beyond the state of the art in affective computing and affective modeling. Much progress must be achieved in affective computing before real-time affect-adaptive gaming can become a reality, including person-independent emotion recognition, advances in recognizing emotions from noisy, incomplete data, such as those typically available in gaming situations, and affective user models capable of reliably determining the often idiosyncratic triggers and manifestations of emotions.

Nevertheless, we believe that the gaming community should begin to consider the development of affective game engines, to facilitate the development of affect-adaptive and affectively-complex and realistic games. Such advancements are necessary if games are to achieve the status of a new, interactive medium [13], and if they are to become effective and engaging teaching and therapeutic tools in the domain of serious gaming. We should not expect a single tool to provide all of the functionalities outlined above. Rather, the proposed requirements would be divided among several constituent tools, analogously to the current division between game engines proper (providing the simulation and animation support), and the definition of the 3D objects populating the game environment.

By providing an outline of the functionalities an affective game engine should support, we hope to contribute to the foundations for the systematic design of affective games, and the tools necessary to build them. In addition, much as games have advanced the state of the art in simulation and physical realism of virtual worlds and characters, there is general agreement among researchers that gaming environments provide contexts for advancing research across a range of areas, including AI, affective computing and modeling, and social computing, by providing real-time, multi-agent environments for studying complex social interactions [34].

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