iCat: an Affective Game Buddy Based on Anticipatory Mechanisms
(Short Paper)

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ABSTRACT
In this paper, we study the role of emotions and expressive behaviour in socially interactive characters employed in educational games. More specifically, on how we can use such emotional behaviour to help users to better understand the game state. An emotion model for these characters, which is mainly influenced by the current state of the game and is based on the emotivector anticipatory mechanism, was developed. We implemented the model in a social robot named iCat, using chess as the game scenario. The results of a preliminary evaluation suggested that the emotional behaviour embedded in the character indeed helped the users to have a better perception of the game.

Categories and Subject Descriptors
D.3.3 [**Artficial Intelligence**]: Robotics – *Commercial robots and applications.*

General Terms
Experimentation, Theory.

Keywords
Autonomous Agents, Synthetic Characters, Social Robots, Emotion, Anticipation, Educational Games.

1. INTRODUCTION
As the co-existence between humans and machines increases, many researchers are attempting to create believable socially interactive characters, robotic or virtual, that can collaborate with humans in a variety of domains and tasks. One of the application domains where these characters have been employed is education. In this domain, the characters cooperate with users behaving as assistants and companions, giving clues or feedback to the learning situation [10, 16]. The incorporation of emotions in these characters positively affects the way that users perceive the experience, as they lead to more natural and meaningful interactions [3].

Emotional expression has been considered one of the primary means to achieve believability in synthetic characters, as it helps to know that characters really care about what happens in the world [2]. This assumes special importance when characters are immersed in learning scenarios, where the interaction must be motivating and appealing under the risk of losing the user's engagement [19]. Even though, many times the emotional behaviour plays a secondary role, being just confined to a couple of predefined animations played in the end of the interaction that vary depending on the user success or failure to complete the task. Moreover, in most of the scenarios, the character's emotive responses strongly depend on the learning situation itself and cannot be detached from it, which means that they could not be employed in different games or learning situations.

The work presented in this paper addresses the challenge of creating the emotional state and consequent behaviour of a character immersed in an interactive game scenario. The main question is the following: how can the character's emotional behaviour help users to better perceive the state of the game they are playing? Our hypothesis is that if the character's emotional behaviour reflects what is happening in the game, users will be able to better perceive the game state and eventually their performance in the game will increase.

This paper is organized as follows. In the next section, we provide a brief literature review of robotic characters that use emotions to engage people who interact with them. The third section contains the overall architecture that we developed. Finally, we describe a preliminary experiment conducted to evaluate the effect of the developed model in the user's perception of a chess game.

2. RELATED WORK
Emotion plays a key role on routine tasks such as learning, communication, and even rational decision-making [7]. Even so, the incorporation of emotion in machines has been left aside for a long time. Only in the past decade, significant studies on this field started to appear, inspired by Picard's book "Affective Computing" [18].

Characters with a robotic/physical embodiment that follow the human social rules of interaction are named social robots [5]. Endowing these robots with emotions can be very useful for a variety of reasons: (1) to facilitate human-robot interaction; (2) to provide feedback to the user, such as indicating the robot's internal state, goals and intentions; (3) to act as a control mechanism, driving behaviour and reflecting how the robot is affected by different factors over time [9]. A study using the robot Kismet [4] demonstrates that endowing robots with social skills and emotions has benefits far beyond the interface value for the person who interacts with him.

Although many researchers bring up the idea of social robots as companions that interact with humans as supportive peers or

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tutors [5, 12], there are few practical applications on this domain, contrasting with the large number of software embodied agents designed for this purpose [8, 10]. This might happen because the whole social robots area is still in an early stage of development. Yet, some efforts are being done, such as the foundation of the Institute for Personal Robots in Education and the work of Kanda et al. from Osaka University with Robovie [11].

3. GAME, EMOTION AND ANIMATION

We will now present the architecture for our affective game buddy. We implemented this architecture in a scenario composed by a social robot, the iCat [6], which acts as the opponent of a user in a chess game.

The architecture is primarily conceived for a two-player turn-based game. In turn-based games, the flow is a sequence of well defined turns or rounds (*e.g.* chess) and each player has a period of analysis and thinking before committing to an action. Before the game actually starts, the character introduces itself and the game. Then, it invites the user to play. The user can take the time she wants to think before actually playing her turn. After the user's turn is over, it is the character's turn. Here, there is a preliminary phase to appraise the changes in the game, followed by the adjustment of the emotional state as a consequence of those changes. Finally, the character expresses its emotional state and plays its turn. This loop continues until one of the players wins the game.

The architecture is separated in three different modules: game, emotion and animation. This division allows the architecture to be used in other game scenarios and even different character embodiments.

The **game module** comprises the interactive game played by both the user and the character [17]. In other words, this module perceives the game events and selects the actions of the character in the game. The game module works as the main input for the emotion module, as the character's affective state is determined by the dynamics of the game score. After each user's turn, the game state is evaluated and the value is sent to the emotion module. This value is the result of a heuristic evaluation of the game state, which represents the advantage/disadvantage of the character's position in the game. If the character is in a better situation than its opponent, the evaluation should be positive, otherwise, it should be negative.

In our implementation scenario, the chess game, the game module is composed by two main parts: a user interface and a chess engine [17]. The interface is a physical electronic board from DGT Projects which is connected to a computer via USB interface. The chess engine contains an internal board representation and a set of search techniques and methods that evaluate a position and return a move (which the engine considers as the "best one", given the evaluation) for the character to play. The chess engine implementation is based on Tom Kerrigan's work [23].

The **emotion module** receives evaluations from the game module, processes them and updates the character's affective state. This update takes effect in the two components of the affective state: emotional reactions and mood. These two components were inspired on Scherer' work [21], which separates the affective states in five categories: emotion, mood, interpersonal stances, attitudes and personality traits. We only have the first two categories, emotion (that we called emotional reactions) and mood. We decided not to include the remaining categories because we did not have enough information from the character's outside world to properly represent those states.

Emotional reactions are the immediate emotions experienced by the character after the user's turn in the game. According to Scherer [21], emotions are relatively brief episodes of response to the evaluation of an external or internal event as being of major significance. Although they have a short duration, they are quite explicit. Emotional reactions can be associated with previous expectations, particularly in games, where we unintentionally build an idea of our opponent's performance. For instance, the more we think we know our opponent, the more we get surprised with her failure if we consider she is a great player.

To endow our agent with this kind of behaviour, we used the emotivector *anticipatory* mechanism. An anticipatory system is a system containing a predictive model of itself and/or of its environment that allows it to change state at an instant in accord with the model's predictions pertaining to a later instant [20]. The emotivector is an anticipatory mechanism that generates an affective signal resulting from the mismatch between the expected and the sensed values of the sensor to which it is coupled to [14]. In our architecture, the emotivector is coupled to the evaluation values received from the game module. Thus, when a new value is received, the emotivector performs the following actions: (1) using the history of evaluation values, the next expected value is computed (using moving averages prediction algorithm [15]); (2) by confronting the expectation computed in the previous step with the actual sensed value (i.e., the new evaluation value), the emotivector selects one of nine different sensations for that percept. For example, after three moves in the chess game, if the iCat has already captured an opponent's piece (and the opponent has captured none), the emotivector might be expecting a rewarding sensation on the user's next move. If the user actually plays a bad move (e.g., by putting her queen in a very dangerous position), the elicited sensation will be a "stronger reward", which means "this move was better than I was expecting". On the other hand, if iCat is expecting a reward, and the opponent captures one of its pieces, the elicited sensation will be a "weaker reward", which means "this move was worse than I was expecting". The emotivector nine sensation model is described in [14].

Mood is a less specific affective state, often less intense and thus less likely to be triggered by a particular stimulus or event [21]. Moods generally have either a positive or negative valence effect [22]. Valence refers to the emotional value associated with a stimulus. Mood works like a background affective state, when other emotions (in this case, the emotional reactions) are not occurring. In our approach, we represent mood as a valence variable V that ranges between a minimum and a maximum value. The magnitude of V represents the mood intensity. Positive values are associated to good scores in the game, whereas negative are related to bad scores

The game module's evaluation values are also the main stimuli for the valence variable. However, to do so, some pre-processing is required, as it may not be desirable a linear correspondence between the evaluation and the valence values (in evaluation functions many times the boundary values only happen at the end of the game). Thus, we introduce an intermediate function F(x), which filters the values received from the game module before they "become" a valence value. For instance, in the chess game, the heuristic function returns values close to zero almost the entire game. A logarithmic function was employed, so that valence can reflect slight changes in the game score.

Although mood is defined as a lasting affective state, it does not last forever. Over the time, in the absence of new stimuli, valence decays towards zero (neutral valence). When a new stimulus is received (i.e., when the user makes a move), the valence gradually increases/decreases until it reaches the desired value (according to our affective model, mood should not change abruptly). Figure 1 shows a possible evolution of valence in a chess game. When the game begins, the valence is neutral, which means that none of the players has any advantage or disadvantage. At instant t_0 the user plays her first move, and iCat acquired a little advantage in the game, which gradually raises its valence to a positive value, reaching such value at instant t_1. Notice that at t_0 an emotional reaction was also generated by the emotivector, which means that the mood will be overridden by the reaction. Then, for a certain period of time, the valence remains with the same value, since no other moves are played by the user. At the instant t_2, the valence starts decaying at the predefined decay rate, due to the absence of new stimuli. But at the instant t_3 the user plays a new move, which again brings more advantage to the iCat. In this case, instead of keeping on with the decay, the valence raises towards the new value.

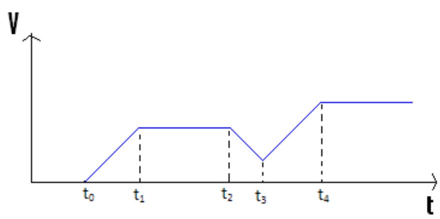

Figure 1. Example of the valence evolution. One of the axes of the graphic represents time (t) and the other comprises the valence values (V).

Until now, we described how the character's internal affective state is affected by the changes in the game. However, the affective state only makes sense if it is properly displayed to the user in the character's embodiment, which is the main role of the animation module. The **animation module** manipulates the characters' body parts by setting their values in real time or through predefined animations (i.e., scripts containing a temporal sequence of some body parts and their values). The predefined animations are used to display the emotional reactions: each one of the nine sensations resulting from the emotivector is mapped into a different animation (e.g. sad, happy…). On the other hand, mood uses direct manipulation: two different sets of variable parameterizations were defined, each one corresponding to one extreme of the valence space. The mood is reflected in the embodiment as a linear interpolation of those two parameterizations. The animation module also performs other predefined animations that we called idle animations, such as blinking or looking around randomly, to increase the character's overall believability. We also define as idle animations the animations sent by the game module corresponding to the actions taken by the character during the game.

Idle animations can only occur when no emotional reactions are being played, but mood coexists with them. Therefore, we established a priority policy for body part manipulation, as it may happen that some of the parts are used concurrently. The most priority values are the ones set up by the emotional reactions, followed by the mood and finally the idle animations, in the presence of overlapping values.

The animation module communicates with the iCat control software, the OPPR Platform, which handles the robot's facial expressions [6]. We used animations from the library of the OPPR software for the emotional reactions, since these animations were previously submitted to tests ensuring that users perceive those emotional expressions on the iCat's embodiment [1]. We made a correspondence between these animations and each one of the nine emotivector sensations. For example, the "stronger reward" sensation means that we experienced a reward much better than we were expecting, and therefore the correspondent emotion is "excitement". The full mapping is described in [13].

4. EVALUATION

We performed a preliminary experiment in which the iCat acted as the opponent of a human player in a chess match to validate the hypothesis that *if the iCat's emotional behaviour reflects what happens in the game, users' perception of the game increases.* We believe that, if the hypothesis is true, it will also lead the players to improve their chess knowledge and skills. Yet, this issue is not addressed in the context of this paper.

4.1 Experiment

The adopted criteria to assess the success of the perception of the game measure was to compare what the user "thinks" about the game with the value obtained from the chess engine's evaluation function. At a certain moment in the game, if these two variables match each other, we consider that the user could successfully perceive the game state.

A total of 9 participants, both males and females, between 7 and 31 years old took part in the experiment. None of the participants had prior experience interacting with the iCat and all of them already had some prior experience playing chess. We divided the experiment in two different sessions, one in the facilities of a local chess club and the other at the Instituto Superior Técnico (Technical University of Lisbon). The experiment was conducted with three different treatments regarding the iCat's emotional behaviour: (1) in agreement with the developed emotion model (*emotional*); (2) incoherent random emotional behaviour, where emotional reactions to the user's move are randomly chosen between eight possible animations (only the correct one cannot be selected), and valence is also a random value (*random*); (3) without expressing any emotional state (*neutral*).

Figure 2. User playing with the iCat

The experiment was composed by three chess problems, with different levels of difficulty (easy, medium and hard). Participants interacted with the three versions of the iCat's emotional behaviour in a balanced order, each one in one of the exercises. The idle animations were performed by the robot in the three games, apart from the control condition. Figure 2 contains a picture of the experiment. During the experiment, the experimenter asked the users to complete the following assertions: (1) “According to the iCat’s expression, it is…” a) winning; b) loosing; c) neither winning nor loosing; (2) “By your analysis of the game, iCat is…” a) winning; b) loosing; c) neither winning nor loosing.

4.2 Results and Discussion

We performed a Spearman correlation test with a two-tailed test of significance for the samples of each one of the three conditions. We had three variables to correlate: the user’s perception of the game based on the iCat’s expression, the user’s perception of the game based on her own analysis and the “actual” game state, obtained from the evaluation of the chess engine. From the correlation test, two relevant results were found. Firstly, concerning to the relation between the perception based on iCat’s expression and the real value of the game, there is a strong correlation between these variables when applying the test to the values retrieved from the *emotional* condition (0.980 for $p < 0.001$). This result indicates that *users were able to correctly interpret the iCat’s emotional behaviour*, as their opinions regarding iCat’s expressions were consistent with the results of the chess evaluation function. The second and most relevant aspect is that the correlation between the user’s own analysis of the game and the actual game state variables is also higher in the *emotional* condition. The correlation is 0.930 ($p < 0.001$). With the *random* samples, the correlation is 0.485 ($p = 0.010$) and in the neutral condition the value is 0.680 ($p < 0.001$). Since the only aspect that changed among the three sets of values was the iCat’s emotional behaviour, these results suggest that *the user’s perception of the game increases when the iCat’s emotional behaviour is in agreement with the actual state of the game*.

5. CONCLUSION

This paper is a first step towards the development of artificial game-playing agents that help users in turn based games by the means of their affective behaviour. An emotion model for interactive characters, which is mainly influenced by the current state of the game was developed and implemented in the iCat robot, using chess as the game scenario. Although preliminary, the results of the experiment indicated that users’ perception of the game indeed increases when the character’s affective state reflects what happens in the game.

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