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Report on the *empathy in emotions* work

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I. Introduction

The aim of this report is to summarize the work achieved between November 2008 until July 2009. I hope this report will help who would develop a work in a similar field. The research has been focused on the modelisation of empathy as a computation process that overlay the other computational models of emotions. The term "overlay " is used because the process of empathy uses also as an input the output of another computation of the emotions. Another possibility would be to see actually the empathy as an extension of such model.

II. Introduction to Human-Machine Interaction, Emotions and Empathy

A. *Survey on Emotions in Human-Robot Interaction, on why and how we manage with emotions in human-machine interaction.*

Abstract

As robots will get more and more involved in our lives, they will have to well integrate our world and our environment. In that direction, improving human-robot interactions is a need. Emotions are totally part of our process to make decisions, interact and evolve in our environment. Those are studied in many different fields such as computer vision, human-machine interfaces, artificial intelligence or cognitive psychology. That's why this paper aims to state the different relations between emotions and human-robot interactions. Emotions can be used to improve communications from the robot to the user, as for example entertainment interfaces. Emotions can be also analyzed to improve the interfaces and anticipate the behavior of a user (so the product can adapt to such a behavior). Emotions can be tried to be simulated also to improve the decision making process of a robot, helping it to evolve in its environment. Through these techniques, which are not always designed for HRI, we might find many ways to integrate emotions in a human-robot interface that can recognize, feel, and express emotions.

1. Introduction

Whatever the shape communication takes, it is the basis of any interaction between humans and robots. In a human-to-human communication it has been stated that only 7% of a message delivery is made by words, 38% by intonation and sound of voice, and 55% by facial expression and body language [1]. Emotions can be found in each of those means of communication. Emotions influence our perception, our way to make decisions, our reactions, and our learning process [2]. They are at the heart of our interaction with our environment. Therefore, this concept is essential in the human-robot interaction.

Including emotions in a human-robot interaction system can be made following three different directions, though those could be mixed too. Firstly, the emotions can be purely expressed, not simulated but just expressed, as an output of a given computation. The interest is to improve the communication delivering a certain message. Secondly, the emotions can be also read and analyzed from the user, to be used as an input of a computation. This is generally used to improve human-machine interfaces those would adapt a behavior depending on the human reaction. Thirdly, the emotions can be simulated by a system. The simulation would allow a system to feel some kind of emotions that it would reason, react, take decisions depending on those emotions. Such systems have a more complete interaction with their environment and users, and enhanced abilities in decision making.

This paper is organized following those three axes, starting with the expression of emotions, then with the interpretation of emotions, and ending with the affective programming. I will give for each point details and examples of works. This survey will not discuss on the nature of the emotions, neither on their origin or the interest of them, which are debates for other fields than computer science, but only on their use and interest in human-robot interaction (and sometimes extended to human-machine interaction).

2. Works on Emotions

2.1 Expression of the emotions

When we think about expression of the emotions, we might first think about facial expressions. Indeed it's the easiest way to read someone's emotion through his/her facial expression. We might often say "you look happy" or "you look sad". Nowadays many systems are able to express emotions through facial configuration. We can cite for example the iCat made by Phillips, Doldori made at KAIST in the Robotics Research laboratory in the Electrical Engineering department, Kismet from the MIT Media laboratory. Many other robot faces with diverse appearances exist too (such as Einstein's face adapted on KAIST's Hubo). Most of the works on those systems express the main emotions corresponding to fear, happiness, anger, disgust, sorrow and surprise [3]. Those faces configurations are set by positions of facial units for or orientation of gaze, position of eye lips, eyebrows, lips and mouth, and orientation of the head by the neck.

Emotions can also be expressed through language and speech. Modifying speech parameters, such as fundamental frequency level, pitch, tone, timing, voice quality, and articulation [4], the emotions expressed in a speech can be totally different. Each of those parameters can be also defined in smaller parameters (average, range...). Three main speech generations are purposed: the formant synthesis which is a rule based synthesis, and sounds quite unnatural (sounds robot-like) but offers many customizable parameters (interesting for emotions generation); the diphone concatenation (human speech diphones recording are concatenated) which should be more realistic but cannot offer a voice quality control; and the unit selection or recorded sequences in large databases, which seems the most natural solution but can be really inappropriate when the right sequence (corresponding to the right parameters) cannot be found in the database [5].

Emotions can finally be transmitted through posture and body language such as robotic pets do like the aibo by Sony, pleo by Ugobe or other agents like Embodied Conversational Agents (ECA) like Greta by the University of Paris 8. Effective body language can be often designed by capturing the human (or animal) postures that express emotions. These postures are then applies to the agent (robot or not) and selected as a validate posture or not by a statistical evaluation [6].

2.2. Interpretation of the emotions

On the same way, emotions can be read and interpreted from the facial expression. It is the reversed methodology than their expression detailed previously. The features analyzed (by computer vision

techniques) are based on the localization of specific points and areas of the face and their movements. The methods offered are diverse. It can be the recognition using direction of specific facial muscles (and different ways are used to classify the features extracted and recognize specific emotions). Emotions can be also described in a dictionary to convert the motions associated (mouth, eyes and eyebrows). For mouth, eyes, and eyebrows detection, parametric models are also used. Another popular method focuses on the recognition of the Actions Units described by Ekman and Friesen [7], using different features such as lips, nasolabial furrow and wrinkles [8].

Recognition of emotion through speech goes by the analyze of the following features: pitch, the fundamental frequency of the acoustic signal delimited by the vocal cords vibration, intensity, speech rate (number of words in an definite time), pitch contour (variations of pitch) and phonetic features . Out of these features, statistics has been computed for already known emotions, unknown emotions being classified depending on the references obtained. Many different classifiers are used (such as Kernel Regression, Maximum Likelihood Bayes, K-nearest Neighbors, Fisher Linear classifier. With those classifications, approval and disapproval emotions only have been identified. Using Hidden Markov Model, a system recognized up to six basic emotions [9]. Through the speech, timing (pause and speed), text (content of the speech), can be also analyzed to identify emotions. By the linguistic analysis of the text, emotion labels, duration and intensity of emotions can be detected [10].

The source of information that can be the body language on human communication is sure fact [11]. However, the main emotional gesture recognition systems are nowadays focused on hand gesture recognition more than the body language. On the other hand, the analysis of hand gestures (by pattern, statistics and classifiers...) can be used to reinforce the facial expressions detection [12].

2.3. Programming the emotions

Affective programming is a totally different concept since it is not part of an input or of an output, but it is part of the computing. In such case, the emotion is used in a cognitive system for decision making. Those decisions can wear diverse shapes depending on environmental conditions and research aims [2].

Emotions can be used in a motivational system for supervised learning. Motivated learning is reinforced, like we human usually learn a lot better what we are motivated into. A system like this has also other needs (background process) to assume and have to manage a constant load (energy or memory availability). An overload creates a state of exhaustion that blocks the activity of the system. In that case emotions are used to manage the social activity of the system to optimize a learning process [13].

Some models like the OCC model [15], explains the emotion process, from the stimuli to the appraisal and the expression of the emotions. The OCC model covers 22 emotions, is often used as a model for programming emotions [16].

Emotions are often used as an interaction with an environment (response to some input) that can be influenced by parameters (as any interaction system). Instead of a cognitive way, some system [14] use a neuroscientific way to generate various emotions. This way implies the use of reinforcers that will allow a blending of emotions (and transitions between emotions) without having predefined static emotions, contrary to the previous system.

Many other models are inspired by animals to simulate emotions, those are called ethological models [17]. They are mainly used for entertainment to improve the quality of an interaction between human and robots [18].

Models and techniques are diverse but all are aiming to simulate a real emotional system, which weights its decisions output (usually emotional expression) depending on emotions (and their related appraisal system). Realizing it many techniques are used such as Kohonen maps or other neural networks.

3. Conclusion

Emotions are at the heart of the human-robot interaction through many forms. They can be expressed through facial expression, body gestures, or sound output. They can be as well interpreted through the same mean, and even more details including speech content analysis and hand gestures. All this work can be applied to improve the communication between human and robots. Some fields still need the research to be deepened, such as body/hand language expression and interpretation, speech and text analysis. But even more, all those are limited on the panel of emotions on which they work, and this panel should be enlarged.

In another hand researchers are trying to simulate the whole emotional process, not only to enhance the communication between human and robot, but even more to improve their interaction. Many emotions could this way be expressed, learning techniques would gain, and decisions taken would be more accurate. In a long term view, this approach offers the most perspectives in the human-robot interaction, on the way for a robot not to be considered as an object anymore, but more likely as a “living” being.

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B. A Survey on the Different Computational Models of Emotions with an introduction to empathy

Abstract

The synthesis of emotions receives a great interest in many domains. When the concept of emotions is included in a human-machine interaction, the interactivity is a lot improved: it is more entertaining for the user and the machine shows better adaptation to a social environment. In decision making and learning process also, the inclusion of emotions as a new parameter opens a way to a new heuristic process and agent's behaviors. Emotion models have been broadly studied in the past years and many models and implementations are now available. The next step in the study of emotions is also the understanding of their meaning as a mean of communication. In order to achieve such communication we need to be able to project our self in another state of mind and emotions, this is called empathy. We conducted a survey on the computational models of emotions and the new ideas brought through the concept of empathy in order to find new domains of contribution.

1. Introduction

According to Albert Mehrabian [16], 55% of a message in the face-to-face communication is expressed by the body language, 38% by the tone and 7% only by the words. Even if this rule has to be understood under the initial conditions of his experiments [16], we can still understand that the emotions take an important part in the communication, especially in the non-verbal communication.

Many systems require research on the emotions, such as robotized agents, dialogues agents and also the Embodied Conversational Agents (which are usually virtual 3D agents used as attendants for virtual sales or expositions like houses). But these kinds of interactions are nowadays interesting also to the space industry to analyze and assist people especially for long missions [11].

In a previous survey [23], we have compared different uses of emotions in the human-robot interaction field. We have described there the three sub-domains of utilization of the emotions: the expression of emotions, the analysis of the emotions and the synthesis of the emotions. The conclusions of the survey have shown some directions for contributions towards the expression and analysis of the emotions. We are now focusing on the synthesis of the emotions which leads to the process of the emotional information.

In the human decision making process, emotions play an important role especially on the social relationships. It is a noble goal for human-robot interaction to give a heart to a robot, to allow a machine to feel emotions and interact with things in the world depending on those emotions. Interacting with emotions, a machine can integrate in a social environment a lot more efficiently, because people will start to like it (with the affective meaning of "like"). Therefore we need to simulate the emotions process, synthesize the emotions to provide the result in an artificial being.

The computing of emotions is a broad research area and a lot of research has been yet made. We made here a survey on the different systems that aim to synthesize the emotional process, the different computational models of emotions.

Because emotions are on the basis of communication, we need also to explore the role of emotions in this communication. Every communication implies a protocol, a way that allows a message to transit from an agent A to an agent B. Empathy allows the understanding of emotions. Also, by empathy, new emotions are learnt and understood by an agent, which may be able to reproduce the emotions according to similar conditions. Empathy can be therefore seen as a process of emotions, that influences future expressions of emotions and behavior.

This work aims to present and compare those models and their purpose of application in order to show the different ways on which a research contribution can be done.

The rest of the document will be organized as follows. Section 2 presents the related works on the fields of psychology and Section 3 shows the computer science solutions for emotion synthesis. Section 4 introduces the notion of empathy. Section 5 explains how we validate our work and we will conclude on the survey in Section 6.

2. Theoretical Models of Emotions

An emotional system is first based on a theoretical model that describes how emotions are processed by humans or animals. Several different models have been used already for the computation of emotions. Those models can be either psychological or physiological [5]. Some models are based on animal behaviors (ethological basis for computing emotions) and others on human behaviors. The theoretical models are usually issued by research in psychology e.g. Paul Ekman's basic emotions [8]. I will additionally give a particular attention to the Ortony, Clore and Collins (OCC) model [19] which has been often preferred to as the referent emotional model over all others.

Paul Ekman described the fundamental emotions [8], basic emotions called sometimes the Big Six. The emotions that should be recognized by any human being are biologically universal. These emotions are: happiness, sadness, anger, fear, surprise and disgust. Although Ekman has extended them to fifteen [9], many research work stick to those six emotions, and sometimes even more limited for those who need to overlap with the OCC model [27].

2.1. Ortony, Clore and Collins

We can have a look a little bit deeper in the OCC model because of its wide use. Many researchers inspired their models from the OCC model but apply also some variation depending on their purpose of application (determining the emotions they need to express). The OCC model is a cognitive model that allows the expression of 22 emotions depending on categories that are the reactions to consequences of events, actions of agents, and aspect of objects. The model based on given knowledge (goals, standards,

attitudes) computes also intensity variables such as attractiveness of an object, worthiness of an action, or desirability of an event. The OCC model is described in Figure 1 [1].

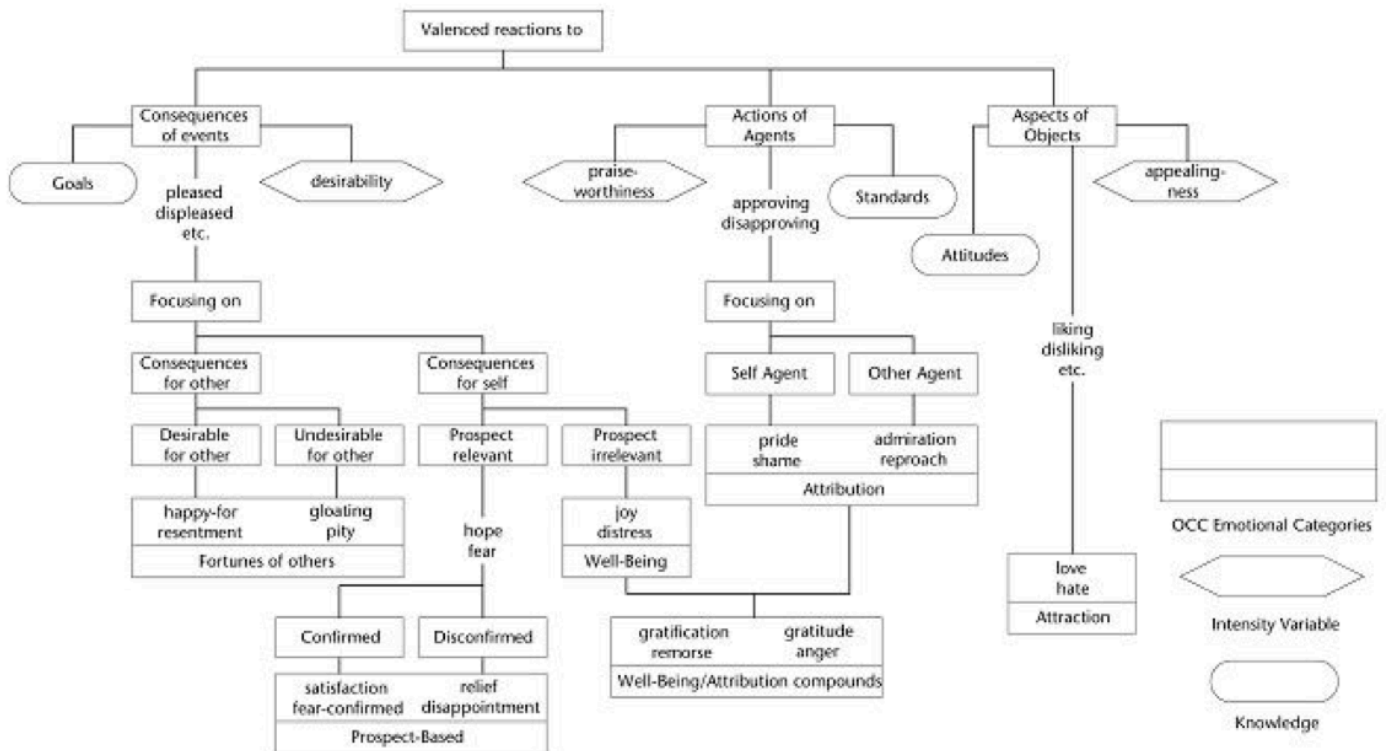


Figure 1: The OCC model.

Implementing the OCC model can be accomplished by following five steps [1]:

1. Classify the consequence of an event, the action of an agent, or the aspect of an object. Depending on the knowledge basis of the model, this step allows the system to know on which category to reason.
2. Evaluate the intensity of the variable of reaction of the category chosen (desirability, attractiveness...).
3. Interact depending on the intensity on a certain category (e.g. it can be just counting the positive or negative values given by a set of rules).
4. Find for the resulting emotion an expressional emotion (determined by the needs of the system. Figure 2 shows a possible table of correspondence of Paul Ekman's basic emotions to the OCC resulting emotions [27]).
5. Express the emotion (it can be done for the system by making a decision).

OCC Emotions		Paul Ekman's Basic Emotions
Happy-for	Love	Happiness
Gloating	Hope	
Joy	Satisfaction	
Pride	Relief	
Admiration	Gratification	
Resentment	Distress	Sadness
Remorse	Shame	
Pity		
Anger	Hate	Anger
Reproach		
Fear	Fear-confirmed	Fear
N/A		Surprise
N/A		Disgust

Table 1: Correspondence between OCC emotions and Paul Ekman's emotion

The Table 1 allows to highlight the OCC model has some imperfections and does not allow the expressions of all kind of emotions.

2.2. Swagerman and Frijda

Swagerman together with Frijda developed a computer model of emotions [29]. This model is based on the attraction by a system to a certain state of the environment. Therefore different goals might be produced to create a state of the environment that would be preferred by the system. Depending on the achievement of the goals, actually on the difficulties in the achievement, the system will produce emotions such as irritation, frustration, anger but also satisfaction. When the main goal is life, such system can even feel fear, and relief of the fear.

Figure 2 describes the model designed by Frijda [30]. We can observe that the role of the urgency, difficulty and seriousness appraisal as a relevant activation signal to trigger a behavior. This approach is strongly related to the notion of goal achievement and here is the novel idea brought by the model. Goals are motivations for emotions, and the distance to a goal (in a multidimensional matter, such as relevance, context, urgency, difficulty) modulates an emotion.

Such system implemented in the Swagerman's *Artificial Concern REalization System ACRES* show extreme mood swings because the model does not include any notion of inertia and the emotional state is just switching from one state to another without transition. Also there is no process of a current

emotional state, no memory of the current state either that would allow a blending of the emotions, or at least the consideration of the current emotion to process the following.

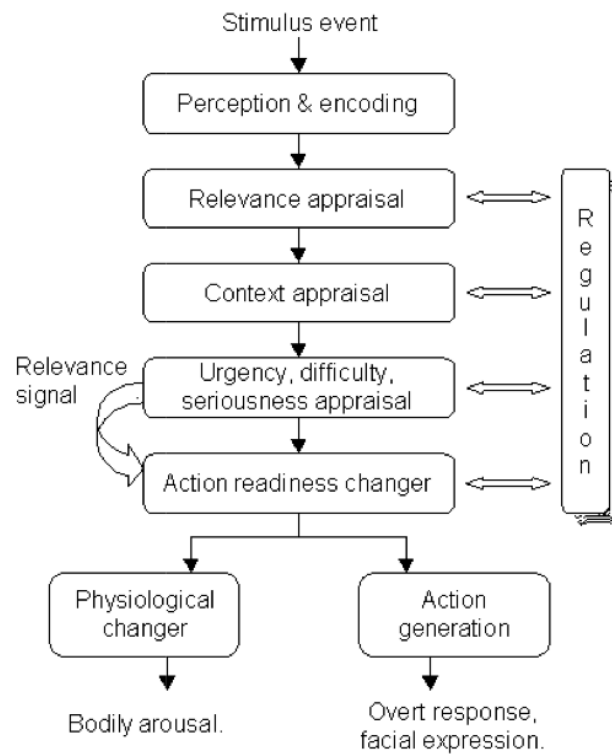


Figure 2: Frijda's model of emotions

2.3. Roseman

Solomon in [4] introduced a theory based on appraisals which are processes that elicits the emotions. The emotions are not raw feelings but the result of processes and judgments. Roseman in [24] extended the theory identifying more accurate appraisals of the emotions. By statistically analysis the appraisals describes by 182 subjects, Roseman suggested the appraisals of unexpectedness, situational state, motivational state, probability, control potential, problem source, and agency causes a large number of emotions.

Depending on a nature of an event, the relation of the event with the agent and with the agent's situation, different emotions can be expressed. The figure 3 shows 17 emotions that are elicited. The polarity of the emotions depends on the consistency of the agent's wishes (whether the event is as wanted, or as improving things, or on the contrary unwanted and making things worse). Surprise seems

to be a particular emotion that is induced by only the unexpectedness character of an event, which could be of any nature. Surprise has basically no polarity and could be positive or not.

		Positive Emotions Motive-Consistent		Negative Emotions Motive-Inconsistent			
		Appetitive	Aversive	Appetitive	Aversive		
Circumstance-Caused	Unexpected	Surprise					
	Uncertain	Hope		Fear		Low Control Potential	
	Certain	Joy	Relief	Sadness	Distress		
Other-Caused	Uncertain	Hope		Frustration	Disgust	High Control Potential	
	Certain	Joy	Relief				
Self-Caused	Uncertain	Liking		Dislike		Low Control Potential	
	Certain					Anger	Contempt
Other-Caused	Uncertain	Liking		Regret		Low Control Potential	
	Certain					Guilt	Shame
	Uncertain	Pride					
Certain							
	Uncertain						
	Certain						
				Non-Characterological	Characterological		

Figure 3: Roseman's structure of emotions

This model is powerful in the way it details the appraisal determinants of emotions, on which criteria can be influenced an emotion. One more time we can insist on the multidimensional nature of emotions elicitation. This model consider the orientation of the event more than does the OCC one: whether the event is caused by circumstances, others, or one's self. A novel approach is also the control potential appraisal, determined by the power of the agent on the event and situation (can the agent do or not something to change the current situation).

Because the theory states that emotions are answers to determined conditions, this model does not clearly specify any process of the current mood and/or memory of the previously felt emotions. This aspect is just stated in the probability appraisal (is it certain or uncertain to happen this way). In addition, no emotional inertia and continuous valence in intensity and time is suggested in the model: for example, it is not a repetitive action in time or a strong action that changes "dislike" to "anger".

2.4. LeDoux

LeDoux's emotional brain defends a Darwinian approach of emotions as process to optimize the survival [14]. He states that emotions are part of a complex neural system which allowed us to survive. The learning process is made through experience and the emotional answers are processed into the brain's neural basis. The brain basically answers to some stimuli (that the brain has detected), which have to be evaluated to evaluate an emotional answer. The amygdala has a major role in the detection of the stimuli. There is actually situation pattern of the brain state that brought first the emotion, like fear in presence of a snake, which is then quickly recognized in the amygdala. The emotion felt then allows the subject to respond in an adaptive manner in the environment.

The brain first react to a new situation and evaluate it, it is the cognitive approach, conscious. But when such a pattern of a situation is recognized again (through the amygdala), the adapted behavior and emotional response will be expressed in anticipation of the cognition.

This approach does not state about the emotions and the explanation of the specific emotions but introduces the idea of a situational pattern that once recognized, is more susceptible to activate emotional states that have been already felt before. Through the example of the snake, LeDoux has shown off also that a baby monkey, natively, does not fear a snake. But the little monkey has learnt to fear snakes through his mother's experience, who were having already the fear of snakes.

This also introduces the emotions as a strong communication process for survival. It implies the notion of emotions recognition and empathy to make this communication efficient.

3. Implementations of the models

Several systems have implemented a computational model of emotions:

The robot head designed in [27] is a typical example of the use of the OCC model in the expression of emotions. Although the project focuses on the mechanical aspects the expression of emotions, they used both OCC models and Paul Ekman's basic emotions to choose the set of emotions they wish to express.

BORIS and OpEd by M.G. Dyer in 1987. BORIS is natural language understanding program and focuses on understanding the emotional states of characters from a text story. It is based on the cognitive appraisal theory of Solomon. BORIS uses a symbolic representation of emotions as five-slot frames: goal situation, expectation, direction, polarity of arousal and strength of the emotion [7]. OpEd is an extended version of BORIS that includes beliefs.

The Artificial Concern Realization System (ACRES), by Fridja and Swagerman in 1987 [29] implements their theory of emotion stimulation. This implies the notions of pleasure and allows the agent to respond emotionally when he is concerned. The system is a dialogue agent that can be annoyed by the user, and also fears of being killed by displaying appropriate messages.

Affective Reasoner started in 1992 by Clark Elliott [10] is a multi agent system based on the OCC model. Each agent has a goal, preferences, principle guiding behavior, and moods. Each agent can influence other agents' emotional state. Moods and personalities affect agents' emotional states. Agents' behaviors are corresponding to specific emotions. The system includes multimedia input and output (text-to-speech, speech recognition, cartoon-style facial expressions). The project helps to improve human-computer interaction, to test appraisal theories of emotion, and to develop more believable characters in computer games.

The OZ project at the Carnegie Mellon University, closed in 2002. The project intended to develop tools for "highly interactive drama" and virtual worlds [11, 12]. Emotions are included as part of agents architecture, using the OCC model to cause emotional actions of the agents by threshold mechanisms. The most advanced demonstration of Oz shows creatures, the Woggles, which have individual personalities, show emotions and social behaviors, and react to their environment taking in account an extra user-controlled Woggle.

Cognitive Systems for Cognitive Assistants (CoSy), use emotions as part of the cognition and learning of a robot [26]. This European project aims to give the knowledge to the robot on how and why it performed some task. The research is based on a scenario approach: The Explorer, is concerned with spatial exploration (find a way in a building), the PlayMate will manipulate of 3D structures (copy a given structure), and the Philosopher wants the robot to reason (understand a task, explain a task, describe his process).

The Kismet robot by Cynthia Breazeal [3] is able of multimodal social interactions. She used the OCC model to implement the emotional behavior of Kismet. She implemented emotion drives to activate behaviors based on a threshold approach.

All these applications are inspired by the previously described computational models. They all differ in their purpose of application and thus the way they translate in variables and computer process the input of the psychologically based models. In addition they offer adapted simplifications of the models that made them fit the experiences situation. We can notice that in order to make a contribution, the tools used are certainly important, but the domain of application, the purpose of such system synthesizing emotions is capital, and brings the real contribution.

4. Empathy

The synthesis of the emotions is quite well advanced. The issues in the synthesis tend to concern the set of emotions that can be felt, and those are more or less extended by modifying the current main computational models of emotion, and especially by combining the different approaches proposed in the psychological and medical literature.

4.1. Definition

Another approach would be not to focus on the emotions process itself, but on the utility of emotions. It has been shown in the previous section that emotions make a strong mean of communication. Like any mean of communication, there is a message sent (by the emotions) and the message received. The reception of such message is made through empathy. We will get interested by empathy in this section.

Empathy has been started to be studied quite recently and its definition has not been fixed yet because it is first a psychological concept and it is also related to philosophy. Kohut [28] defines the empathy as *“the capacity to think and feel oneself into the inner life of another person.”* There are two main view of empathy. It can be seen as a cognitive process, allowing taking another’s perspective (inference on another’s feelings, Ickes, 1993), and it can be seen as an affective phenomenon (feeling with or feeling for another, Batson et al. 1997). Both views are of course not incompatible and empathy certainly assumes both roles.

There are no formal models of empathy yet studied and the research in the human-machine interaction is still at the early steps but we can pull out two directions in reasoning from the two points of views we cited:

- The cognitive aspect, by taking another’s perspective is directly relation to the retrieval process (we look for the causes that make another’s precise state of mind).
- The affective aspect, by feeling for and with another is related to the anticipation process, and we join here previously commented LeDoux’s point of view on the role of the amygdale in the emotional process, and why the baby monkey learns the fear of snake through his mother.

We can notice also the work of Mark H. Davis [6] who designed a questionnaire to measure empathy in order to show differences in empathy depending on sex. The questionnaire measures four characteristics of people: fantasy, perspective-taking, empathic concern and personal distress. It will be good to remember this approach in order to validate the empathy simulated by a system.

It will be good in a future work to describe the role of each emotion in a social interaction. By empathy an agent understands a message, and each emotion transmits a specific message. We have no time and space here to describe the message transmitted through each emotion here but R. J. R. Blair describes in his work [2] how a specific empathized emotion brings a very specific message (such as anger which express a rupture in some social law, and requires from the interlocutor to readapt her behavior). By empathizing another’s emotion, an interlocutor understands the message expressed through this emotion.

4.2. Applications

In computer science the investigations on empathy are very recent and only a few works has been led toward that direction.

It is interesting to know that some works aim to make the human user empathize with the artificial system (for example see [20], here is described a system that allows kids to empathize with virtual agent in order to demonstrate the negative effects of bullying).

Another project deserves to be mentioned: Empathy by the Università degli Studi di Bari [25] describes a reprocess of the currently felt emotion to set the mood and smooth the expression a new felt emotion. It consists in adding the current emotional state in the inputs and influences the decision on the new emotion felt. This actually includes the notion of inertia and memory of an emotion, but it is not yet empathy.

We will focus in this part on four works that implement artificial empathy:

Some medical treatments need the patients to be constantly watched using devices for a long term such as cardio meters. The acceptance of the system is vital for the patient, but it is quite constraining to bear them, especially for a long term interaction between the patient and the device. R. Picard [21] offered to embed empathy in such monitoring system through a human-machine interaction as a (simple) dialogue system. The empathetic system has been strongly preferred by the patients, which shows the pertinent interest of the study of empathy in human-machine interaction.

Delay time due to computation usually raises the user's frustration. R. Picard [22] proposed a system that responds to user's frustration by interaction. The interaction is made through dialogues (small questions/answers) and induces support when the user answers with frustration. The user is playing a very slow and annoying game, with long delay times. In parallel, the computer asks the user his emotional state through multiple answers questions, and displays some supportive messages depending on the user's answer. Results have shown that the users play the annoying game for a longer time when the computer shows empathy to her situation than when the computer does not. One more time this show the interest of empathy in collaboration between human and computers.

In a computer version of the game of blackjack, a virtual player has been programmed as an agent with empathy. The agent interacts with the users as a player of course, but also by displaying messages and emotions through facial expressions. The agent is able to feel empathy towards the other user's situation but also his own situation. This means the agent is happy when the player wins but also when he wins himself. The set of emotions is limited to happy, sad and neutral (no expression). The messages can be supportive and complaining to the user but also self oriented. S. Brave et al. in [18] studied the likability, caring, trustworthiness, dominance, positive and support feelings of the agent, described by the users in the four possible situations. Results have shown in most of the cases that the agent induced measured feelings to the users when it was displaying empathy to the user and even more when it was also self oriented. This studied demonstrates once more the positive effect of empathy in human-machine interaction.

In a simple treasures hunt game McQuiggan and Lester [15] programmed an agent that cooperates with the user. The agent is able of facial and body expression as well as text expression. Depending on the user's behavior the agent will display supporting or irritating behavior related to the treasures hunt. For example if the user takes time to find a treasure, the agent will blame the user, and even more if he is looking twice in the same place. If the user displays high skills to discover treasures, the agent will display happiness, compliments and support. If the time is limited, the agent will pressure the user. The

study has demonstrated the interest of such agent in the video game area. Such character can influence the user and make the experience of the video game more entertaining.

All those works are centered on the human-computer direct interaction and the improvement of the interaction using empathy is evident. None of those works have been yet deeply understanding the user's motivations and feelings but mainly answering to the user's emotional state. Therefore we have in the study of empathy in its full definition a strong contribution that can be made. Also the fields of application are now quite limited but it makes no doubt that a lot more can be found soon (e.g. as personal advising, problem explanation or individualized interaction).

5. Validation and conclusion

In this survey we described the main computational models of emotions with their pros and cons, and the current implementations in computer science. There might be no best model to describe the emotions but a combination of those models brings the best answer when applied to a real situation. The best contribution that can be made in the synthesis of emotions should first come with a strong real application (the purpose) and the adaptation of the chosen model to the situation.

We brought also in this survey a recent idea, the empathy. Empathy is a quite new field of research in the human machine interaction. This approach of emotions will bring a new view of programming emotions because it partly answers the question "why emotions?". Indeed, the emotions are not only a motor to express behaviors, but also a mean of expression. Through emotions are expressed the reasons that induced a specific behavior, and empathy allows to understand, learn, and answer to the emotions. It seems that there is still a huge work to do to be able to define and to understand empathetic process, as well as simulating them. Such work would benefit both psychology and artificial intelligence fields.

We proposed to find a field in which we can highlight possible contributions and we have found a new field of interest in the study of emotions. Because emotions and empathy cannot be dissociated, a research in empathy should contribute a lot in the synthesis of emotions. Maybe the approach by empathy is completing the definition emotions which stayed until now far from the real meaning of emotions. In another point of view we can imagine that the first studies conducted on emotions have always been implying empathy, but mainly from the user. We might have here the field that will bring the next generation of human-machine interactions. I personally think that the study of empathy will provide the solution for new adaptive and individualized interactions between human and machines. In other words, it may lead to a real collaboration between human and machines.

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III. *Processing the emotions: empathy, our first attempt to use empathy*

Abstract

The synthesis of emotions receives a great interest in many domains. When the concept of emotions is included in a human-machine interaction, the interactivity is a lot improved: the machine shows better adaptation to a social environment and it is more entertaining for the user. In decision making and learning process also, the inclusion of emotions as a new parameter opens a way to a new heuristic process and agent's behaviors. Emotion models have been broadly studied in the past years and many models and implementations are now available. The next step in the study of emotions is also the understanding of the messages they carry as means of communication. In order to achieve such communication we, humans, need to project our self in another state of mind and emotions, this process is called empathy. We introduce in this paper the new ideas brought through this concept of empathy and an application of a simulated empathy within a game.

1. Introduction

According to Albert Mehrabian [8], 93% of a message in the face-to-face communication is expressed through non-verbal communication. Emotions take an important part in this communication. Many systems require research on the emotions, such as robots or dialogues agents. These interactions are nowadays interesting also the space industry to analyze and assist people especially for long missions [5].

We can describe three domains in the research for emotions: the expression of emotions, the reading of the emotions and the synthesis of the emotions. We are here focusing on the synthesis of the emotions which leads to the process of the emotional information.

In the human decision making process, emotions play an important role and especially in the social relationships. Interacting with emotions, a machine can integrate in a social environment a lot more efficiently. Indeed people will start to like it (with the affective meaning of "like"). We need to explore the role of emotions in this communication. Empathy can be seen as a process of emotions, that understands this communication.

This work aims to present our vision of empathy, accompanied with one application to demonstrate the advantage brought by the process of the emotional information in a human-machine interaction. The rest of the document will be organized as follows. Section 2 presents the related work. Section 3 presents our contribution on empathy. We will conclude in Section 4.

2. Related work

Here are presented some applications and the theories that make the background of our work.

2.1. Evolution of the theoretical models of emotions

Paul Ekman described the fundamental or basic emotions [4] that should be recognized by any human being (biologically universal). These emotions are: happiness, sadness, anger, fear, surprise and disgust.

An emotional system is first based on a theoretical model that describes how emotions are processed by humans or animals. Several different models have been used already for the computation of emotions.

The computational models of emotions have evolved since the OCC model [10] that presents emotions as results of events (but popular for its simplicity in implementation [1]). Roseman [13] and then Salomon [3] extended this approach, introducing the multidimensionality conditions eliciting the emotions. LeDoux [6] finally brought a Darwinian approach of the emotions as a process for survival. Emotional answers are processed to record a situation pattern of the brain state, which can be then quickly recognized later on. LeDoux has shown off in an example that a baby monkey, natively, does not fear a snake, but has learned to fear snakes through his mother's experience, already afraid of snakes. This approach gives to the emotions a purpose.

We have here an introduction of empathy in the use of the emotions as a strong communication process for survival. An efficient answer to this communication implies the notion of emotions recognition and empathy.

There is currently no universal model of emotions which covers all applications of the synthesis of the emotions. However, LeDoux's emotional brain is not just trying to simulate emotions, but brings the idea of the use of emotions with causes and consequences, as part of a bigger process: survival.

2.2. Work around empathy

In computer science the investigations on empathy are very recent and only a few works has been strongly led toward that direction. We will focus in this part on three works that implement artificial empathy.

Delay time due to computation usually raises the user's frustration. Rosalind Picard [11] proposed a system that responds to user's frustration. The interaction is made through dialogues (small questions/answers) and induces support when the user answers with frustration. The user is playing a very slow and annoying game, with long delay times. In parallel, the computer asks the user his emotional state through multiple answers questions, and displays some supportive messages depending on the user's answer. Results have shown that the users play the annoying game for a longer time when the computer shows empathy to her situation than when the computer does not. One more time this show the interest of empathy in collaboration between human and computers.

In a computer version of the game of blackjack, a virtual player has been programmed as an agent with empathy. The agent interacts with the users as a player, but also by displaying messages and emotions through facial expressions. The agent is able to feel empathy towards the other user's situation but also his own situation. This means the agent is happy when the player wins but also when he wins himself. The set of emotions is limited to happy, sad and neutral (no expression). The messages can be supportive and complaining to the user but also self oriented. S. Brave et al. in [9] studied the likability, caring, trustworthiness, dominance, positive and support feelings of the agent, described by the users in the four possible situations. Results have shown in most of the cases that the agent induced measured feelings to the users when it was displaying empathy to the user and even more when it was also self oriented. This studied demonstrates once more the positive effect of empathy in human-machine interaction.

In a treasures hunt game McQuiggan and Lester [7] programmed an agent that cooperates with the user. The agent is able of facial and body expression as well as text expression. Depending on the user's behavior the agent will display supporting or irritating behavior related to the treasures hunt. For example if the user takes time to find a treasure, the agent will blame the user, and even more if he is looking twice in the same place. If the user displays high skills to discover treasures, the agent will display happiness, compliments and support. If the time is limited, the agent will pressure the user. The study has demonstrated the interest of such agent in the video game area. Such character can influence the user and make the experience of the video game more entertaining.

All these works are centered on the human-computer direct interaction and the improvement of the interaction using empathy is evident. None of those works have been yet deeply understanding the user's motivations and feelings but mainly answering to the user's emotional state.

3. Empathy

3.1. Definition

The novel approach is not only to focus on the emotions process itself, but also on the utility of emotions. We explained previously that emotions make a strong mean of communication. Like any mean of communication, there is a message sent and a message received. The reception of such (emotional) message is made through empathy.

The definition of empathy has not been fixed yet because it is physiological, psychological and philosophical concept. Kohut [14] defines the empathy as *"the capacity to think and feel oneself into the inner life of another person."* There are two main views of empathy. It can be seen as a cognitive process, allowing taking another's perspective (inference on another's feelings, Ickes, 1993), and it can be seen as an affective phenomenon (feeling with or feeling for another, Batson et al. 1997). Both views are of course not incompatible and human empathy certainly assumes both roles.

3.2. The communication through emotions

We insisted very much on the use of emotions as a mean of communication. More than just the words, emotions make the communication purpose clear (whether it is positive or negative for example). We decide to see the emotions as reinforcers of communication. By empathy an agent understands a message, that is specifically transmitted in each emotion.

What messages should we understand through emotions? R. J. R. Blair describes in his work how a specific empathized emotion brings a very specific message and by empathizing another's emotion, an interlocutor understands the message expressed through this emotion. According to his work in [2] and [12] we are setting the table 1 explaining the role of five of the basic emotions.

Emotions can be appetitive or aversive stimuli of the empathetic reaction. The meaning of the expression of the emotions is related to the judgment of the current action, if it is going to be repeated or not, and the attitude that should be observed toward it. The role of the emotions can be also directly related to the listener, and might be able to change her behaviour.

Emotion	Category	Prob. to repeat action	Influence on current action	Influence on listener
Afraid	Aversive	Decrease		
Sad	Aversive	Decrease	Discourage	Request for reparatory
Happy	Appetitive	Increase		
Disgusted	Aversive			Warning on food (or anything related to tastes)
Angry	Aversive		Stop	Change her behaviour which is violating rules.

Table 1: Role of emotions in the human-human communication

As an improvement to human-machine interactions, we use emotions in order to carry such message. By evolution, humans have learned a protocol of communication through emotions. This protocol is not going to change, and we use it to reinforce the communication between human and machines. A model of empathy has to be aware of it, to understand emotions from humans and appropriately interact. A machine can then express itself the responding emotions in order to induce a anticipated reaction from the user.

3.3. Aspects of empathy

There is no formal model of empathy yet studied and the research in the human-machine interaction is still at its early steps but we focus on the two views of empathy:

The affective aspect (feeling for and with another) is related to the anticipation process, and we join here previously commented LeDoux's point of view on the role of the amygdalae in the emotional process, and why the baby monkey learns the fear of snakes through his mother.

The cognitive aspect (taking another's perspective) is directly related to the information retrieval process (we look for the causes that make another's precise state of mind).

The affective aspect doesn't focus on the causes of an emotional state, but on the emotional state. It consists basically in copying an emotional reaction to a specific state. In that case, the agent feels for and with another, which means it is capable to have the same feelings in the same situation. Emotions are used as reinforcers for learning process. They have shown their efficiency through the Darwinian evolution. In the case of fear as a process for survival, we had for example a baby monkey that associated the fear feeling from his mother triggered by the snake so created in his own a fear for snakes.

We use this aspect of empathy to anticipate user's reactions in interactions. After experiencing user's emotions on a specific interaction, the computer extracts patterns of situations that trigger user's satisfaction or frustration. Then, without solving any possible trouble, it anticipates user's behaviour and brings some of the satisfactory response. This can also be used to understand the user's tastes and provide her a personalized interaction (like a tone of voice, a set of colors etc.). The affective aspect of empathy can be directly applied to improve advertisement systems by considering user's feelings.

The cognitive aspect, inference on other's emotions, is very important for example to the psychological assistance. Indeed it allows the understanding of a situation. By taking another's perspective, an agent understands where are the causes that provoked a specific emotional state. Since it has originally another point of view (before taking the user's perspective), it can show the user the source of his situation and bring if needed solutions. For example, a psychological assistant can encourage the repetition of action that brought happiness in the past, or show a precise point that brought anger to the user so she can find by herself solution on it, or also be presented possible solutions from the base of knowledge of the assistant.

We use the cognitive aspect for classical types of interactions: to adapt the user's behaviour (as shown in the next example), or to retrieve the features that cause troubles to the user and solve them (comparable to Rosalind Picard's computer that responds to user's frustration), but also to retrieve the features that brought satisfaction and repeat them.

In the empathy expressed between human, there are generally both of the aspects of empathy. It is common sense that first humans feel the emotion and then think about it. This can be explained by the mechanics of empathy, including the role of amygdalae and mirror neurons as described in [2]. Future applications of empathy in a long term will probably implement both aspects.

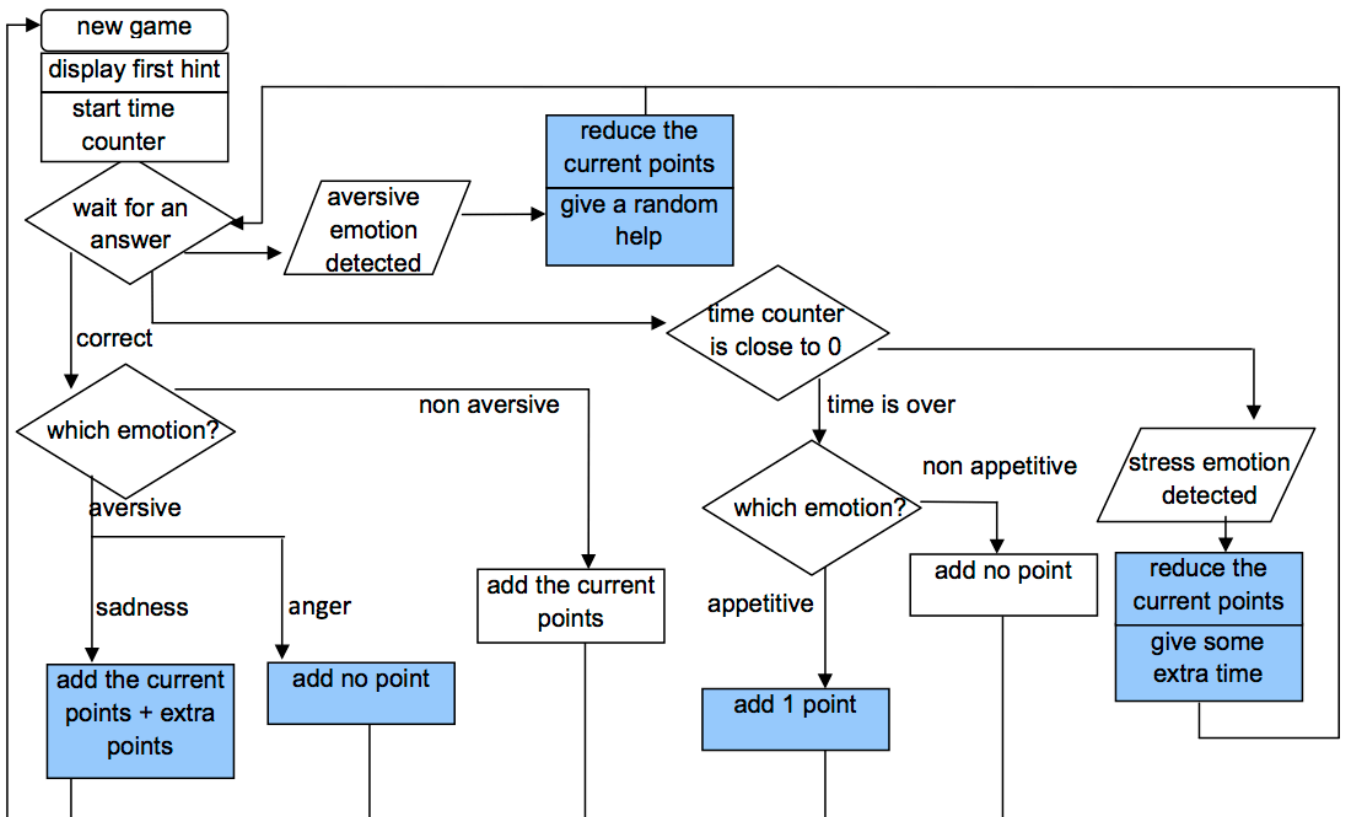


Figure 1: Diagram of interactions in the application (the reactions due to empathy are coloured)

3.4. Application

We wish to implement a game that will show the usefulness of empathy improving the user's experience considering her feelings.

Presentation

The game is a mix of a traditional hangman and an enigma game. The player has to find a word (or an expression) given a set of definitions. The number of letters of the answer is given as '_' like in the traditional hangman game. The player has a text input to give his answer. We assume to have a dispositive (with camera) that can recognize the user's emotions (through her facial expressions). Emotions read can be *happiness*, *sadness*, *anger*, *fear* and *surprise*. Indeed *disgust* doesn't apply in this type of game. The player wins the game by typing an expression that is the same than the answer to the enigma. Time to give an answer is limited. The user lose the game if no correct answer is given in the allowed time. Another game starts after one ends. To keep the interest of the game after a few turns, the user is given a score depending of her aptitude to answer correctly.

Functionalities

The computer, in order to keep the entertainment can interact with the user giving hints, modifying the display of the answer, and changing the time given. The computer can decide to show additional hints that can lead to the answer. The computer can show also some part of the answer to help the user to find the answer. The time (in seconds) allowed to give the answer can be modified in any way that can help the entertainment of the user. The computer decides on which action to take depending on user's emotions. Figure 1 displays the different states of the game.

The emotions the computer understands can be also classified. Therefore appetitive emotions are expressed through happy emotions, aversive emotions through anger and sadness, and surprise and fear are grouped in stress.

The machine is also able to display at any time text messages destined to the user. Those messages are accompanying the computer's actions, helping not only the user to notify such actions, but also to share feelings with it. The "personification" of the computer is important in order to read the user's emotions. The display of the messages can occur randomly during the game, but also whenever the user gives an answer, whenever the computer brings some help, when a different expression is read on the user's face, and also at the end of a game.

We can notice from figure 1 that the detection of emotions influence differently the execution flow of the game not in a straight mapped way but depending on different events. Those events brings the meaning to the emotions, i. e. the situation that elicited the user's emotion. This allows then the computer to answer the adaptively the situation. The display of messages doesn't appear in this figure because every state of the diagram is accompanied with a prerecorded message (randomly selected among a few not to bore the user). Each message is adapted to a specific state of the flow.

Example of the game

Affective and cognitive empathic reactions are specified using the short terms a. e. and c. e.).

Paul is our player. He is a temper man. Paul tries our game and the word he needs to find is "winner" (the word displayed is "_ _ _ _ _").

Computer: "Ready? You have 120 seconds".

"The first hint is: finishes a game".

(Paul is thinking and doesn't display any particular emotion but he suddenly has an idea and looks happy.)

Computer (affective empathy): "ohoh! you're enjoying it!".

(Paul give the answer: "player".)

Computer: "That was close... to be intelligent... try again!"

Paul (angry): "And maybe YOU are intelligent?"

Computer (cognitive empathy): "ok ok, here is another hint for you: it can be you or me".

(There is now 20 seconds left.)

(Paul is afraid he cannot give his last answer and types in a goofy way when the timer counts 0)

(C. e.: Computer gives 30 extra seconds)

Computer: "haha! I got you!".

(Paul finally enters "looser" which is the wrong answer while the time dropped to 0.)

Computer: "And the correct answer was winner!"

(Paul laughed a lot when he discovered the correct answer was "winner").

Computer (c. e.): "Thank you for your fair play, here is a comforting price."

(C. e. : Computer gives a single point.)

(Paul smiles)

Mary is our next player. She has the same challenge as Paul and starts in the same conditions.

(Mary gives her first answer "looser".)

Computer: "Yeah, it is the answer... in another dimension maybe".

(Mary smiles.)

Computer (a. e.): "Aren't I so funny?".

(Quickly Mary gives the correct answer.)

Computer: "Congratulation you won!".

Mary (sad): "This game is not really challenging "

Computer (c. e.): "Ok, you played well, I will give you some additional points... Cheer up!"

(C. e.: 5 extra points came to Mary's score.)

Mary chooses to continue to play and by some random process... got exactly the same question.

Mary (angry): "Again? What is this game???"

Computer (c. e.): "Ok, ok, I hope you'll feel better with that!"

(C. e.: Computer shows the first letter of the answer.)

Mary (angry): "And here is your difficult answer "

(Mary answers correctly.)

Computer: "Congratulation, you are a genius!"

Mary (angry): "Yeah, it can't be you "

Computer (c. e.): "Hey I'm just a computer, and you even won! No point this time for you!"

(C. e.: Computer gives indeed 0 point.)

(Mary smiles.)

Discussion

This game presents mainly the cognitive aspect of empathy. The computer reads the user's emotions and shows reactions that are empathic responses to the user's emotions. In the game situation, depending on the current situation (events), the computer can associate an answer adapted to the user's emotion in the frame of the event. It tries to reduce the situations when the user expresses aversive feelings and create appetitive feelings (bringing help or adding points). There is a limited affective process that is simulated through the text messages displayed by the computer as reactions to specific emotions. These messages explain that the computer feel for the user's and bring the user to accept the empathic response as an act of the game. Indeed, it allows the user to understand the computer's reactions. Without those messages, there is no understanding of the computer's actions, and the impact on the user's feeling cannot be predictable (maybe surprise then ignorance). We have

chosen to demonstrate those two examples of two different behaviours of the program. This way our examples shows a wide panel of situations encountered in the game, but especially we have shown the ability of adaptation of a program to different characters of users.

Validation of the application is done by collecting experience feedbacks from the users. These feedbacks would be compared with feedbacks from another application that provides the same features but does not consider the emotions from the user. The parameters we will measure are the time that the players spend playing the game. The scaled mood of the players after experiencing the game. The scaled feeling of the players toward the computer while they are playing, and the scaled feeling of their experience of the game. A conclusive implementation of our work will demonstrate by statistics a difference in favor of our implementation with using empathy in the measured time of the users playing the game and other parameters previously described.

There has been many implementations of games implying the use of emotions, and even empathy like previously described. Our application does neither focus on the likability of the computer as S. Brave's blackjack player, nor on the simulation of emotions induced by the user's behaviour like in the treasures hunt game of McQuiggan and Lester, but on the answer to user's feelings, closer to the spirit of R. Picard's computer that answers to frustration. Our approach is centered on a game that changes depending on the user's behaviour. Even if the player can cheat on the way she expresses her emotions after playing a while, this new way to conceive the game brings a new experience of the interaction with the computer.

4. Conclusion

We have introduced the notion of empathy as an improved point of view of the emotions completing the already used models. Emotions also carry messages that are expressed and understood by humans before even words. Empathy is the process that uses those emotions with the messages they carry. Empathy is composed then of two processes: one affective that copies a situation depending on another's emotions, another cognitive which processes another's emotions.

We have presented in this paper an application of the cognitive aspect of empathy that improves the user's entertainment in a game situation. Once the implementation over, results from user feedback based study will demonstrate a new entertaining way to program interactions that actually care for user's feelings.

Enlarging the scope of our vision, we might have in empathy the next generation of human-machine interactions, which will certainly provide the solution for new adaptive and individualized interactions between human and machines. In other words, it may lead to a real collaboration between humans and machines.

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IV. Conclusion and overture

Since the survey work has brought a wide enough overture on works on emotions and on the potential power of the use of empathy, we will focus in this part on how to make the previous article more strong and credible.

If we have a look on the theory proposed in the preceding article, we will find it too general and imprecise. It globally states that taking into account user's emotions will improve her experience of the interaction.

In a system that expresses emotions, the use of empathy allows the machine to develop strategies of emotions, i. e. express some emotions that are not the one felt, but simulated emotions in order to achieve specific goals (Pelachaud, 2007). The understanding of the user's emotions is then part of a full computation that leads to the expression of an emotion from the machine which will have an influence back on the user (e.g. human is angry->machine express comforting feelings->human is not angry).

The key contribution will be made by defining precisely *how* we actually take into account the user's emotions, and on which purpose. The first idea proposed was a mapping the program's behavior depending on emotions. Each branch of execution of the program would be selected depending on the user's mood. The purpose would be to induce entertaining feeling to the user.

We can actually use the same method to fill in a base of knowledge about the user (instead or in addition of triggering another branch of the program) and then reuse this base as an entry while defining the program's behavior. As a result we will have a program that takes in account the user's character and emotions.

Such system should be designed individually for each application (branching, circumstances of the emotion elicitation) so it is not flexible enough to claim any adaptive characteristics, but still gives us a first idea on how a program that simulates empathy would react.

The quicker and most direct way we have to bring a contribution will be to enlarge one the previously given computational model of emotions to include the notion of empathy. To do so we need first of all to change the scenario and include the computer as another player.

If we take the example of the rock, paper, scissor game. Players cumulate points on each game. We set a dimensional space of emotions on their valence (positive, negative) and intensity. We put also anger (negative, high), sadness (negative, low), happiness (positive, high), comfort (positive, low). Supposing the user would use those 4 emotions only we will build a basic artificial player that just care about the points to compute one of those 4 emotions using the OCC model. We will build another artificial player that would take into account also users emotions. Questioning the user on her experience, we can finally deduce which behavior of the computer she preferred.

The contribution in that case will be on how we implement the OCC model in this very particular case, and especially in the case of emotion, how we bring a supplementary branch of modifiers we can call "Emotions of Agents"

The emotion recognized from the user can be described also by a set of values for the basic variables used in the OCC model. We would preset these values. These values would act then as modifiers of the corresponding variables for the artificial agent. If we follow the 5 steps previously described to implement the OCC model, it will extend the third step ("Interact depending on the intensity on a certain category").

If we simulate a case: the computer is winning by a lot of points difference. This should make him very happy (positive and high intensity), but the player shows sadness. A computer that doesn't care will just display high happiness. A computer that does care will read the sadness as a totally opposed emotions (in valence and intensity) and will reduce as its output the displayed valence and intensity, expressing a more neutral and comforting emotion.

It can be entertaining also to modify the "ability for empathy" of the computer, which with a full ability would copy the user's emotions, and a cut ability would not compute any care.

A validation of this work would be done by gathering users evaluations and comparing with an implemented OCC model that does not compute the user's emotions.

For one who would continue this study, it will need to implement the experience and define clearly the transition from the OCC model to this particular example.

Empathy is one strategy but it seems that we are able of a lot more (emotional contagion, seduction...), bringing human beings on lying with their feelings. Such study would have many applications, mainly in care and assistance of human beings. I would like to insist on the ability of such system to bring a unique experience adapting to different types of characters.