Emotirob: Companion Robot Project

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Abstract — **This paper presents our work on the therapeutic robotics project EmotiRob which is the continuity of the MAPH (Active Media For the Handicap) project in emotion synthesis. Our aim is to maintain emotional interaction with children. For this, word, movement, and emotion synthesis are used. Here, we strive to define a robot face which is a compromise between expressive richness and mechanical simplicity. We propose a method for modeling and dynamizing a face able to express emotions.**

I. Introduction

Research in psychology has shown that facial expressions play a major role in the coordination of human conversation [1]. Consequently, facial expressions constitute an essential method of human communication.

For the moment, robots used for social reasons are very mechanically and intellectually limited, and are usually used for entertainment or recreational purposes.

Robotherapy in the field of robotics tries to apply the principles of social robotics with the added goal of improving the psychological and physiological state of those who are sick, secluded, or suffer from physical or mental handicaps. The robots seem to be able to play a part in accompanying and awakening them, and for that purpose should be equipped with a maximum of capacities of communications.

This project is considered as part of the robot companion field. Robots are usually used to build products, to move objects or to specifically transform an object. Currently, research in robotics is focusing on cooperative multi-robot systems that perform complex tasks with humans. The other new challenge is to build systems that will offer behavior enrichment through their interaction with humans.

Some studies already exist in the field of RAA: "Robot Assisted Activity" and, more precisely, in the field of RAT: "Robot Assisted Therapy.

The first experiments in this field of robotics carried out with the elderly in a retirement home and the Paro (fig.1) (2) [3] seal built by T. Shibata[1] (AIST, Japan) [3] [4] clearly showed that robot companions can give a certain amount of moral and psychological comfort to fragile people

In this context we began an experiment using the Paro robots, lent by T. Shibata, to check whether or not the reaction / interaction with the robots was dependent on cultural context. French people are typically more distant toward new machines than the Japanese. The experiment took place in two different places: Kerpape[2] where Paro was used by therapists with 6 to 12 year-old disabled children some of whom were in wheel chairs, and IEA[3] where Paro was used with autistic teenagers (12 to 14 years old). These experiments showed us two principal directions in which it would be interesting to work.

The first one deal with mechanical problems: the robot must be very light, easy to take and to handle, easier than Paro; moreover, it must have a great deal of autonomy.

The second one leads to changing the man-machine interaction: the psychological comfort that the robot can provide is related to the quality of the emotional tie that the child has with it. It seems obvious that this bond can be considerably reinforced if the robot companion is endowed with a minimum of capacities of comprehension of human words and if it is able to express emotions in return. It is thus advisable to reconcile the constraints of a light and autonomous robot to those of capacities of comprehension and expression.

Thus in the EmotiRob project, the goal tends toward the realization of a robot which has fundamental qualities of Paro: a fluffy animal, pleasant contact, presence of sensors, etc. We want to equip this robot with the necessary capacities of perception and comprehension of natural language so that it can build a formal representation of the emotional state of its interlocutor. Lastly, the project also comprises the design of a model of the emotional states of the robot and their evolution, in order to make its reactions seem as natural as possible. To carry out this project, the research program includes collecting child language recordings and building a corpus allowing for the linguistic studies of child language in context. In turn, it should help with SLU (Spontaneous Language Understanding) issues and, more generally, with NLP- related research the ultimate purpose of which is to model the expression of emotions through speech prior to the actual manufacturing of the robot.

II. Outline

In this paper, the different works on emotions and robotics will first be discussed. Then, we will explain the experiments carried out with Paro and young disabled children in Kerpape. In part 5 we describe the solutions we propose for drawing and evaluating the face of the robot. Finally, our method to make the face dynamic is presented.

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III. WHAT ABOUT EMOTIONS?

A. Limits of this work

The final goal for EmotiRob is the complete creation of a real companion robot. The present work is to determine how a robot can express emotions and how they could be believable.

Here, our approach is restricted to facial expressions. However, this limitation is due only to this being the first phase of the work. In the future we intend to integrate our face onto a body, the movements of which will amplify the facial effects.

Based on the Ekman [5] work on facial expression, we use the results of the coding system FACS [5] and JAFFE [6] decomposition of expression which is well accepted. We have used the same basic emotions in our system, thus limiting our study to these six basic expressions: fear, joy, anger, surprise, disgust, sadness.

To express these basic emotions, FACS suggest using 14 degrees of freedom instead of about the two hundreds that the human is able to control with facial muscles. Due to our target which is to integrate our system onto a real robot, we want to limit the number of degrees of freedom. Therefore, the FACS or EMOFACS requirements cannot be applied as they are used to simulate the emotion of a real human head. Here, our intentions differ in that we are looking for emotion generation on an artificial robot.

Our system must be simple enough to guarantee reliability and robustness. So our target is to find a minimal number of degrees of freedom to give an acceptable feeling of emotion in a robot. This system must also be actually possible to build.

B. Emotion Synthesis and social interactions

Emotion synthesis is an artificial reproduction of the way that human beings express their emotions in a social human context. Being able to express emotions is a way for a robot to communicate with a human. Without emotion expressions, users will interpret the interaction as a lack of interest from the robot and will then block the communication.

Robots (like Kismet, Paro, Necoro, Aibo, Asimo, etc.) capable of social interaction are then characterized by their ability to have behaviors close to those of humans.

Emotion is an expression of one's internal state. Joy and fear are different emotional states that we can characterize with physiological and psychological criteria. Through emotion synthesis, those criteria are imitated to bring about a believable artificial emotion. This artificial emotion is then used to reinforce communication: verbal or non verbal.

C. The basic emotions

As Ekman, we have worked on the six basic emotions: fear, anger, joy, sadness, disgust, surprise [7].

They can be combined to perform more complex emotions. A seventh "emotion" also needs to be added which is no emotion, neutral feeling and rest.

D. Expression of Primary Emotions

The expression of emotion by a machine would improve the quality of interaction between the man and the machine. The absence of emotion is one of the difficulties mentioned in man/machine relationships [8].

We use three different physical means to express emotions:

- voice which is a principal means. Discourse, words with their intonation, their speed, their modulation … all of these factors are used to give information on the emotional state
- body position: gesture, movement associated to the discourse increases the perception of the emotional state
- facial expressions: mouth, eyebrow, eyelid … contribute to the facial expression of emotion.

When confronted with these three items, it seems easiest, robotically, to first build a system based only on facial expressions. Secondly, a body can be added to the face and then gestures can be dealt with to increase emotion generation. Voice is a very difficult problem; therefore we are actually considering building a dumb robot.

IV. PRELIMINARY STUDIES ON PARO

A. Evaluating and testing Paro

The Paro robot developed in Japan by the researcher T. Shibata is used in this experimentation [9]. This robot is provided with sensors which enables it to react to caresses or when it is held. It turns its head toward the sound source and reacts to its name. In addition it emits small sounds.

Fig. 1. Robot "Paro"

B. The evaluation grid

Clinical Observation: In order to study the impact of the robot on the stress of the children, a grid of evaluation was developed. This grid contains a list of behaviors with the way to evaluate them. A mark from 1 to 5 is given while following axes on motricity, mimicry and vocabulary.

Mark of reactivity: One also notes, on a cursor with dimensions from 1 to 10, the reactivity with "Paro": Touching, Smiling, Cuddling, Coaxing, Kissing, Disdain, Indifference, Disregard, Rejection and Tears.

Table 1. evaluation grid

Behaviors	Clinical Elements
Aggressiveness - Anger	Threatening or abrupt movements (toward the robot or accompanying people), aggressive or irascible, frown, mimicry of dissatisfaction
Anxiety	Distressed mimicry of the face, astonished eyebrows, fear of touching it, autogestuality of comfort
Stress	Stereotyped movements: facial or movement tics (nail biting, scraping), movements of escape (turns back, rises), insults, hyperactivity of the body or part of the body
Contempt	Gestures, words or mimicry of contempt, sniggers
Escape	Movements of escape (rises, turns back), leaves the room
Rejection	Refusal to speak, to touch it, diverts eyes, sighs
Sadness	Apathy, tears, lifelessness of the face or the body, sighs, weak voice, your monocorde
Joy - Pleasure	Smiling, laughing, sparkling eyes, merry voice, tonic and opened position, words of satisfaction
Confidence	Settles comfortably to speak, eye contact, confides, trustful attitude, words of confidence, interacts with interlocutor
Relaxation	Modification of position of the body: uncrosses legs, loosens fingers, stereotyped arrest, calm and serene attitude, absence of aggressiveness in gestures. Modification of the face: relaxation of eyebrows, opens eyes, appeasing voice, outlines smile or smiles, absence of aggressiveness in the words

C. *Experimentation*

From January to October 2004, two Paro robots were tested at the Kerpape center in order to study the impact of an artificial animal on the psychological and physiological appeasing of the disabled person or on their socialization. In 2005, a complementary study was made.

This work was meant to find the possibility of the definition of new features for robots able to significantly modify the psychic comfort of people in distress.

In the Kerpape center, the experimentation related to a population of children having a motor handicap (mobility, sensitivity disturbance...) and/or associated cognitive disorders (speech difficulties, perception...). Several of the children integrating this study were in wheel chairs and some were also far from their family.

In the IEA, the experimentation dealt with a population of children and teenagers from 8 to 15 years of age who suffer from learning difficulties and social adaptation.

In this context, Paro could be an interesting vector of emotional investment. For this experimentation, Paro was used by six health professionals (two teachers and four psychologists) in order to study the impact of a robot medium between the therapists and the children to create social interaction.

The results obtained at the time of this first study show that the Paro robot produces a real positive effect during its use with mentally disabled children for whom Paro is used as mediator. Nevertheless, this first experimentation showed the limits of a system like Paro. Indeed, the noted reactions are different according to: the disability of the child, his/her psychological situation and his/her knowledge of robotized objects.

D. *Result*

Without going into the detail of the evaluations, which are too intricate to explain here, the Paro robots seem to be globally interesting tools for this type of work. For positives results, see [9]

However, a certain number of negatives points are to be improved:

- energy autonomy is too weak,
- too heavy for children with little strength,
- handling needs to be made easier as it slips out of the children's arms,
- not enough mimicry,
- interaction with the robot could improved by using spoken language,
- cuddly toy coating is difficult to wash (problem of hygiene: saliva etc...),
- sounds emitted need to be diversified according to emotions,
- position of on/off button is problematic for children who were victims of sexual contact,
- possibility needed to temporarily stop the interactivity when the child is very aggressive with the robot.

E. *New features expected*

The current project is to design a new robot by taking these features into account. Our idea is to provide a system with two levels. The first is a single robot similar to Paro, but having taken into account the above mentioned remarks. The other is to increase the capacities of this physical robot to generate emotions by the addition of a virtual companion which would have coordinated movements with the physical robot and would be used as an "intelligent interface" to manage a higher level of interaction through linguistic communication.

V. INTRODUCING EMOTION EXPRESSIONS IN THE ROBOT

A. *Face synthesis for MAPH*

The aim is to define a face which can express basic expressions with less DOF that we can use with FACS.

1) A simple face

While using some of the primitives of the Ekman face, we will define articulated faces and, from these faces, will build the six primary emotions by handling basic elements on this face [10].

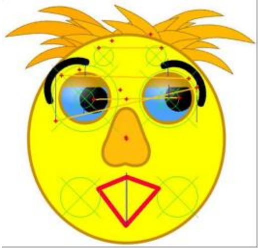
The animated elements of the face are comparable to the bodies of the human face which are handled by the units of action FACS. For example, elements can be the eyes, the mouth, the nose, the ears or the hair.

Taken independently, the animation of all these elements requires fourteen units of actions to express the primary emotions. We will join the mechanical operation of some of the elements in order to limit the units of actions.

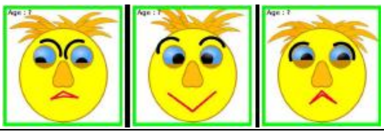
The "eyes" system can be made up of only one element in the case of complex face. For example, the eyelid and/or the eyebrow can be associated to the pupil. In this case, these elements will be interdependent and move together. We reduced the components of an eye in a subset, reducing the complexity of the related mechanical unit of the animation.

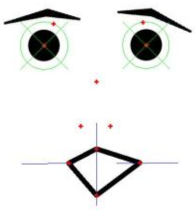
Reducing the complexity also goes in the direction of a simplification of the number of the elements necessary to build an expressive face. A simple mouth can consist of only one lip, but expressivity must be confronted and a model of mouth with two lips checked. Two eyes are not always necessary. Most of the time, they move in synchronization.

2) Composition of faces

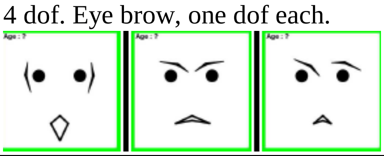


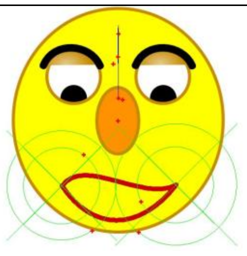
Hair complete
16 degrees of freedom
pupil and eyebrow are independent, mouth with 2 dof



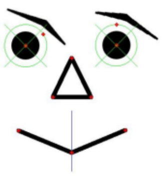


Simple (+ with nose)
6 dof eyes are fixed, the mouth has 4 dof. Eye brow, one dof each.

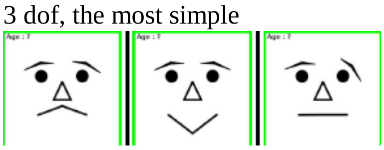




Yellow
7 degrees of freedom
the mouth is rich with 4 points in rotation



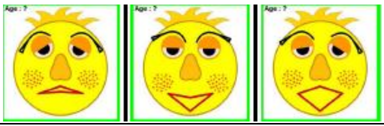
Nose simple
3 dof, the most simple

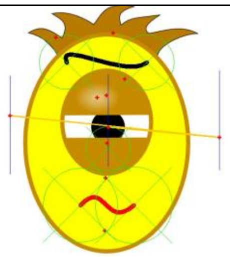


Rich
10 degrees of freedom
eyelid and eyebrow are coupled, pupil has 2 dof (translation on rotation), mouth with 2 dof

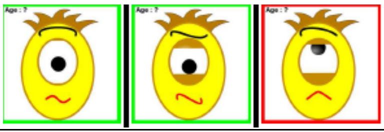
Hair simple

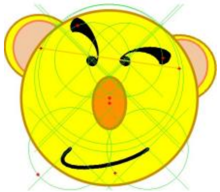
Naïve
4 dof





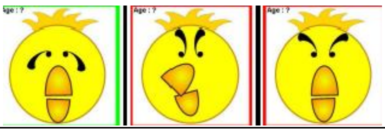
Cyclops
8 degrees of freedom
Based on eMuu robot.
All elements can move



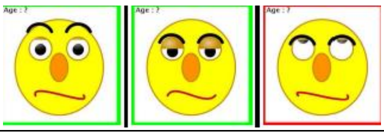


Ear
6 ddl

Beak
5 dof



Standard



B. Evaluation

After 1100 tests through internet, the analysis is made with 16 possibilities for one emotion for one face.

In our study we divided the people into three groups: less than 21 years old, 21-35 years old, and older. In fact this did not give us any significant information. The user satisfaction for each emotion is in a range of 53% to 90%.

Here, we present the faces having the highest result for each emotion and the global score for each emotion. First, two classes can be distinguished:

1- LOW score : Fear 53%, Surprise 61%, Disgust 68%

2- HIGH score: Anger 89%, Joy 77%, Sadness 89%.

By analyzing the drawing bellow, Fear and Surprise appear to be very similar. It seems that there is confusion between them and that could be the reason for this poor result. Facial animation is expected to clear up this confusion.

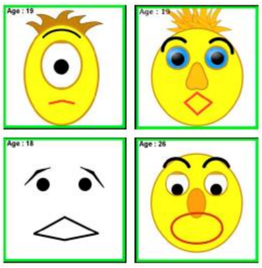


Fig. 2 : Fear

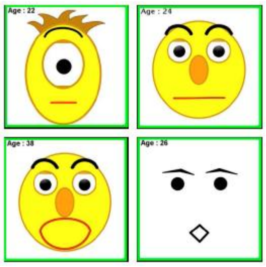


Fig. 3 : Surprise

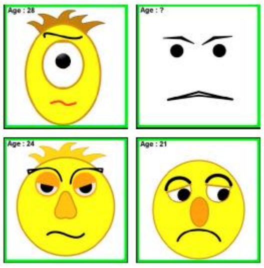


Fig. 4 : Disgust

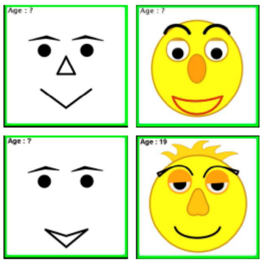


Fig. 5 : Joy

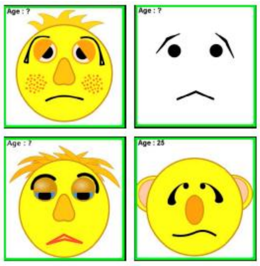


Fig. 6 : Sadness

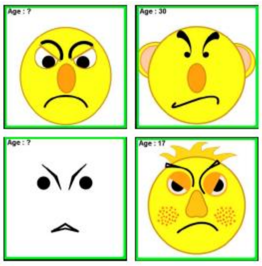


Fig. 7 : Anger

It can also be noticed that the "simple" face is present in the top 4 of each emotion. Globally this face with only 6ddl has the highest result. It seems that a high number of degrees of freedom does not increase the capabilities of expression of emotion.

Should this bring us to the conclusion that simple is the best for expression of emotion? We really do not know as this experiment was conducted over the internet, therefore with a population familiar with "emoticons". So they might not be the best people for this experiment. This remains a problematic issue.

On the other hand, we have limited our work to 14 different faces. Perhaps a better solution would be with a completely different design. Again, we should be prudent when coming to conclusions.

C. Conclusion: 6 degree of freedom is enough

We have presented research on the question "how can an emotion be simply drawn?" In this evaluation, based on a specific set of faces having different degrees of freedom, it can be noticed that the one with the highest score is not the most complex one. We have also noticed that some identical patterns are very well accepted for two different emotions. The limit to this work is that we have only worked on static faces; we believe that the expression of emotion is increased by the movement of the face. The question then is "do the patterns of emotion remain the same with dynamic expression?". This question will be discussed in the next chapter.

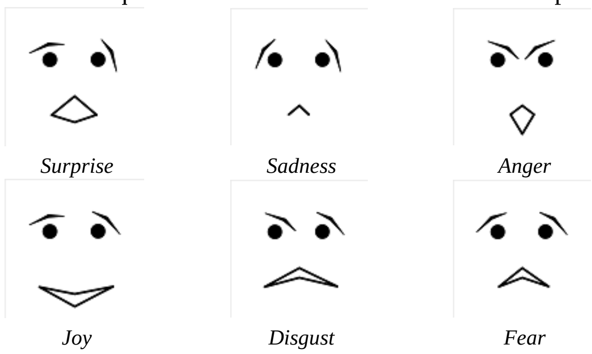


Fig 8. Faces resulting from evaluation

VI. Dynamic of Emotions

A. Methodology

The first work made it possible to generate and evaluate faces for simple emotions. We now have face models which are rather simple to implement for our robot

We can thus propose the construction of an innovating prototype equipped with better expressions than "Paro". This study has offered only static models of emotions [10], and it is now necessary to study the dynamics of these emotions [12], namely the links between the various emotions and the models allowing to transit from an emotion to another. This leads us to the subjacent question "is the transition mode from an emotion to another interpretable by the observer?"

It is also necessary to study the changes of states within the same emotion in order to return the expressivity of the more realistic and less automated robot. Indeed, the robot must be reactive and not fall into repetitive behavior in order to request the interest and the awakening of the children. It must also be able to react to external demands and to answer by an emotion adapted to the stimuli.

B. Animation of the faces

Contrary to certain projects which recommend the use of tools for animation, we have decided to create our own application. This application will be programmed in Java so that it is embarked on any type of system in the future.

1) How can we change emotions

The principle we use is based on the various relations which exist between the six basic emotions. We know that the emotions can be categorized, but we are still unaware of the various stages of movement between 2 emotions. Let us take a simple example: one wants to pass from an emotion of joy to an emotion of surprise. The question is to know whether or not other emotions are recognizable during them movement. The emotions which are recognizable at this time will be called emotions of transition or transients.

But to check our theories, we will compare different versions from the application which establishes several types of different movements:

- ✓ The first type of movement will be done directly: the passage between each emotion will be done in a direct way. No emotion of transition will be used.
- ✓ The second type of movement will be done using a single emotion of transition which will be the neutral emotion.
- ✓ The third type of movement will be done using several emotions of transitions. To carry out this type of movement, we have based ourselves on the studies of classification of the emotions in order to draw up a tree of transition [12] from it.

To produce this tree of transition, a hierarchical basis was used to deal with the six emotions which we had arranged according to the already existing methods [13] [14] [15] [16]. This organization is a mixture of the various existing models.

2) Movements of the control points

Secondly, we will study the way in which the points of control of the face must evolve during a change of state for each facial expression. With this intention we will study three possibilities:

- ✓ The displacement of the points will be synchronous. During a change of emotion, each point will begin and finish its displacement at the same time as all the others.
- ✓ The displacement of the points will be asynchronous. Various algorithms were established to carry out this stage: beginning of the movement of each point successively, choice of the point has to move in a random way, etc.
- ✓ The displacement of the points follows the preset line equation. The equations which we selected are as follows: accelerated, constant, direct, exponential, and sinusoidal. The rate of travel will relate to the value of the coefficients of the equation.

C. Evaluation and prospects

We carried out a series of tests with Internet users to find the equations and facial expressions for the various emotions, i.e. those which combine simplicity of recognition and natural movement. The results show that there are movement equations which are more adapted than others and that the simplest are sometimes preferred best. Some of the testers were surprised at the absence of transition emotions during some of the movement. Therefore, it seems that the use of a transition tree should not be dismissed.

More time will need to be spent on the issue of links between the emotions. Even if opinions on the subject vary, a satisfactory model must be created from it.

For the future, we envisage an adaptive or learning system for the dynamics of emotion.

VII. Conclusion

Due to previous experiment on Paro, we conclude that a companion robot needs to express emotions for a good interaction with children.

The work done shows that 6 DOF are enough to express basic emotions. The dynamic aspect of emotion transition is still to be improved.

EmotiRob project will build a robot using all Paro qualities and adding the 6 DOF for expressing emotions.

VIII. Acknowledges

EmotiRob is currently financed by the regional council of Martinique, for the development of the emotional synthesis, the regional council of Bretagne for the language comprehension, and the ANR for the construction of the robot.

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