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Dynamic behaviour conception for EmI companion robot.

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Abstract

This article presents research work done in the domain of nonverbal emotional interaction for the EmotiRob project. It is a component of the MAPH project, the objective of which is to give comfort to vulnerable children and/or those undergoing long-term hospitalisation through the help of an emotional robot companion. It is important to note that we are not trying to reproduce human emotion and behavior, but trying to make a robot emotionally expressive. The studies carried out on perception and emotional synthesis have allowed us to develop our emotional model of interaction: iGrace. iGrace actually allow a system display emotions as a static mode. This mode has ever been evaluated with our avatar: ArtE, we developped in Flash. The rate of satisfaction (86%) of the evaluation allowed us embeded static mode on our robotics platform: EmI – Emotional Model of Interaction. Now, we want add dynamics on EmI robot and add lifelike in its reactions. This paper will present different hypothesis we used for iGrace emotional model, algorithm for behaviour dynamic, evaluation for static and dynamic mode, and EmI robotics conception. We begin the article by MAPH and EmotiRob project presentation. Then, we quickly describe the computational model of emotional experience iGrace that we have created, the integration of dynamics and iGrace evaluation. We conclude with a description of the architecture of Emi, as well as improvements to be made to its next generation.

1 Introduction

Currently, research in robotics focuses on cooperative systems for performing complex tasks with humans. Another new challenge is to establish systems that provide enrichment behaviour by their interaction with humans. Research in psychology has demonstrated that facial expressions play an essential role in coordinating human conversation [1] and is a key modality of human communication. Social robots, very limited in their mechanics and their intellectual capacities, are mostly for purposes of amusement and fun people. Robototherapy, which is robotics field, tries to apply principles of social robotics to improve psychological and physiological state of people who are ill, marginalized or suffering from physical or mental disabilities. It appears that the robots can play a role of guidance and enlightenment. This requires providing them with a maximum capacity of communications. We met in recent years, the first robots such as Paro [2, 3], iCat [4], Cosmobot [5, 6], Kismet [7], etc.

In this context we began experiments [8] using the Paro robots to check whether or not the reaction / interaction with the robots was dependent on cultural context. 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.

2 MAPH and EmotiRob project

MAPH project (see synoptic in **Figure 1**) objective is to design an autonomous stuffed robot, which may bring some comfort to vulnerable children (eg, children in long hospital stay). However, a too complex and too voluminous robot is to be avoided. EmotiRob project, which is a subproject of MAPH aims to equip the robot from perception and understanding capabilities of natural language so that it can react to the emotional state of the speaker. EmotiRob also includes conception of a model for emotional states of the robot and its evolution.

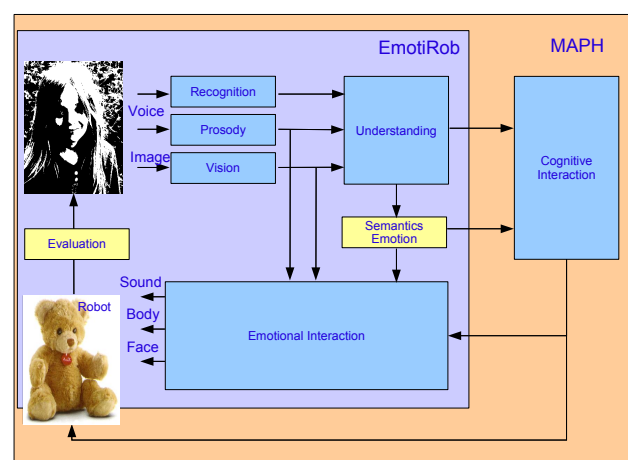


Figure 1: Synoptic of MAPH project, including EmotiRob sub-project

The experiments we conducted on the perception and emotional synthesis, allowed us to determine the most appropriate way to express emotions and have an acceptable recognition rate to our public. And thereby deduce the minimum degrees of freedom required to express the 6 primary emotions. The second step was the definition and description of our emotional model iGrace [9], instance of the generic model GRACE [10], to have a nonverbal emotional reaction to the speech of the speaker. The experiments conducted allow hypothesis validation of the model that will be integrated on the robot: EmI. EmI, under construction during this study, a virtual avatar: ArtE, was created to represent EmI conscience. Art-e must display the same facials expressions as the robot, so they both not have the same constraints. ArtE allows work and tests on behaviour dynamics, whose good results will be used by the robot. ArtE has five expressive components : eyebrows and mouth - which are the same as the robot - and eyes, head and trunk. Each component has a role when an emotive experience is displayed. It is based on the six primary emotion and neutral.

3 iGrace – computational model of emotions

Before beginning our project, we did two experimental studies. The first experiment [8] was carried out using the Paro robot to verify if reaction/interaction with robots depended on cultural context. This experiment pointed out that there could be mechanical problems linked to weight and autonomy, as well as interaction problems linked to the robot due to lack of emotions.

The second experiment [11] was to help us reconcile the restriction of a light, autonomous robot with understanding expression capacities. Evaluators had to select the faces that seemed to best express primary emotions among a list of 16 faces. It was one of the simplest faces that obtained the best results. With only 6 degrees of freedom [12], it was possible to obtain a very satisfying primary emotion recognition rate.

It's with these informations we started conception of our emotional interaction model. iGrace (see **Figure 2**), which is based on the emotional model GRACE that we have designed, will allow us to reach our expectations. It is composed of 3 main modules (described shortly in the following subsections) which will be able to process the received information:

- "Input" Module
- "Emotional interaction" Module
- "Output" Module

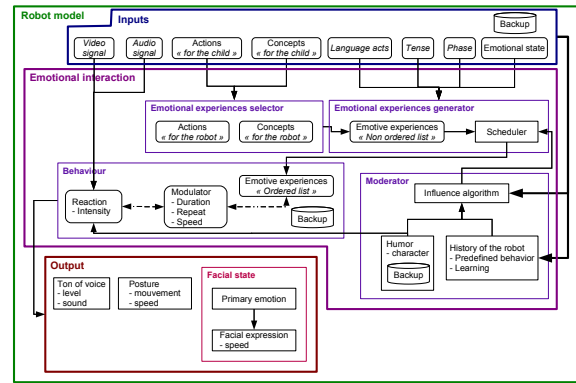


Figure 2: iGrace – Emotional interaction model

3.1 "Input" Module

This module represents the interface for communication and data exchange between the understanding module and emotional interaction module. This is where the parameters of event discourse can be found, which help to obtain the information necessary to make the process go as well as possible for interaction between the child and his/her robot companion. The parameters taken into account are the following:

- Video signal: help to follow the movements of the child, to get his facial expressions and to stop the system when the interlocutor exhibits inappropriate or unexpected behaviour.
- Sound signal: will enable understanding, as well as ensure the robot's safety in the case of loud screams or a panic attack assimilated to a signal that is too high.
- Actions "for the child": represent a group of actions that are characterised by verbs (ex. eat, sleep, play, etc.) which children most often use.
- Concepts "for the child": represent main themes of a child's vocabulary (ex. family, friends, school, etc.).
- Act of language: inform us if the discours is a question or an affirmation
- Tense: situate the discourse in time : past, present or future.
- Phase: represents the state of mind that the child is in during the discourse.

3.2 "Emotional interaction" Module

Knowing that it is limited to only primary emotions through facial expression to maintain nonverbal discourse,

we must be able to express ourselves through the other elements of the human body. To do this we decided to integrate the notion of emotional and behavioural experience into our module. The 100 emotional experiences in our database will give us a very large number of different behaviours for the model. However, we have decided, for now, to limit ourselves to only fifty entrees of emotional experiences. This diversity is possible thanks to the principle of mixing emotions [13]. Four main elements of interaction can be found in the model:

- Moderator
- Selector of emotional experience
- Generator of emotional experience
- Behaviour

3.2.1 Sub-module "Moderator"

It tells if the character, mood, personality, and history of the robot have an influence on its beliefs and behaviour. The personality of the robot, taken from the psychological definition, is based on the MBTI model [14] which enables it to have a list L_1 of emotional experiences in accordance with its personality. This list will be weighed in function to its mood of the day.

3.2.2 Sub-module "Selector of emotional experience"

This module helps give the emotional state of the robot in response to the discourse of the child. The child's discourse is represented by the list of *actions* and *concepts* that the speech understanding module can give.

Table 1: Extracts of emotion vectors for a list of words (action or concept)

Word	Vector					
	Joy	Anger	Surprise	Disgust	Sadness	Fear
Dad	1	-1	0	0	-1	-1
Mum	1	-1	0	0	-1	-1
Sister	-1	-1	0	-1	-1	0
Kill	-1	1	0	0	-1	0
Kiss	1	0	0	0	-1	0
Eat	1	0	0	0	-1	0

Table 2: Definitions of emotion vector coefficients.

Coefficient	Definition
-1	We do not know if the emotion is implicated
0	Emotion not implicated
1	Slightly implicated emotion
2	Very implicated emotion

Each action and concept of the discours is associated with a vector allowing know the emotion of the system for this word (see example on **Table 1**). For each emotion, we have

a coefficient representing his degree of implication for this word (see **Table 2**).

Table 3: Association extracts between emotions and emotional experiences

Emotion	Emotional experiences
Joy	Happiness, contentment, euphoria, etc.
Fear	Panic, anxiety, fear, fright, etc.
Anger	Rage, agitation, detest, fury, hate, etc.
Sadness	Grief, deception, depression, sorrow, etc.
Surprise	Wonder, surprise, etc.
Disguss	Nausea, contempt, etc.

Form this list of *action* and *concept* associated to there emotions, we can determine a list L_2 of emotional experiences that are linked to the discourse. In fact, thanks to the categorisation of emotions in layers of three that Parrot [15] proposes, we can associate each emotion with emotional experiences (see example in **Table 3**).

3.2.3 Sub-module "Generator of emotional experience"

This module defines and generate the adequate behaviour(s) the reaction that the robot should have to the child's discourse. The information processing is done in three steps which help give a weighted emotional experience list:

1. consists in processing the emotional state that has been observed, and given in "Input" module, in the child. This state is generated by a spoken discourse, prosody and will be completed by facial expression recognition. It will give us a list L_3 of positive or negative emotional experience represented the affect of emotional state of the child.
2. consists in combing our 3 lists (moderator(L_1) + selector(L_2) + emotional state(L_3)) into L_4 .
3. consist in taking into account the meaning of the discourse to find the appropriate behaviours. The goal of this third step is to recalculate the emotional experience coefficient in function of parameters of the discourse like affect, action, etc [9].

3.2.4 Sub-module "Behaviour"

This module lets the behavioural expression that the robot will have in response to the child's discourse be chosen. From list L_4 , we have to extract N emotional experiences with the best coefficient into a new list L_5 . To avoid repetition, we have to filter the emotional experiences that had already been used for the same discourse. A historical base of behaviours associated to the discourse would help in this process.

3.3 "Output" Module

This module must be capable of expressing itself in function to the material characteristics it is made of: microphone/HP, motors. The behaviour comes from the emotional interaction module and will be divided into 3 main sections:

- Tone "of voice": characterized by a greater or lesser degree of audible signal and choice of sound that will be produced by the robot. Within the framework of my research, the interaction will remain non-verbal, thus the robot companion should be capable of emitting sounds on the same tone as the seal robot " Paro ". These short sounds based on the works of Kayla Cornale [16] with " Sounds into Syllables ", are piano notes associated to primary emotions.
- Posture: characterized by the speed and type of movement carried out by each member of the robot's body, in relation to the generated behaviour.
- Facial expression: represents the facial expressions that will be displayed on the robot's face. At the beginning of our interaction study, we mainly work with "emotional experiences". These should be translated into primary emotions afterwards, and then into facial expressions. Note that emotional experience is made up of several primary emotions.

4 Dynamic behavior

Dynamics is setting up in order to increase expressiveness of the model. The purpose is to give the robot a mean to express itself freely, even in absence of speech or other external events. This free expression is designated with the term "dynamics". There is a link between dynamics and temperament, personality, mood, experience etc.

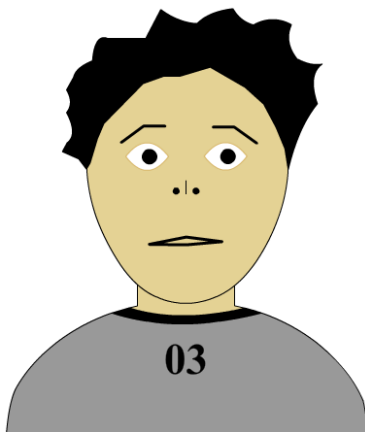


Figure 3: ArtE avatar

Dynamics is implemented on a basic avatar (see Figure 3) in order to make easier and faster evaluations. This study

applies to eyebrows and lips movement - that are the same for robot and avatar - and eyes, head and trunk, relative to the avatar. This one has voluntarily more degrees of freedom than the robot because, a future release of itself, more sophisticated, has to be integrated in mobiles, such as telephone, pda, etc.

4.1 Dynamics mode

Dynamics is composed of three modes : waiting mode, which is the initial state of the model, listening mode and playing mode.

Waiting mode : represents the behavior of avatar when there is no external events. The avatar is totally freedom, it can move as it wants and does not pay attention to hypothetical interlocutor.

Listening mode : represents the behavior of avatar in the case of interaction. For instance, it can watch a video, and has to react according to events, it can listen to a story or speak with an interlocutor. In this mode, it is not completely free to move because it must remain focused on the interaction.

Playing mode : represents the behavior of the avatar when it must express a particular emotion (asked by the interaction model at the following of an event). The avatar loses its freedom of movements and must express emotions as it is asked by the model. It keeps on displaying emotions, ones after others, as long as there is emotion to express. This mode has priority on both other modes and is active as soon as an emotion has to be expressed. Since emotions can be cumulated, the display mode is automatically deactivated when there is no more emotion. In this case, previously mode is reactivated.

These modes are illustrated by four dynamics parameters :

- breathing,
- eyes winking,
- gaze movement,
- face "grins".

4.2 Breathing

Emotions have impact on body [17]. So, each emotive experience will play a role on breathing. For instance, in the case of negative emotive experience, breathing can be accelerated (anxiety, stress, etc.) or suspended (big surprise, fear, etc.). Breathing is represented by the sinus function which allows obtaining a fluent movement of coming-and-going [18] : $f(t) = \sin(\omega t + \varphi)$. A simulation of breathing is made by applying a period of five seconds, a phase difference of $-\pi/2$ and an asymmetry between inspiration and expiration (inspiration is twice shorter than expiration). It is easy to make a variation of breathing, during simulation, by modifying frequency and amplitude.

4.3 Eyes winking

Eyes winking is an important phenomenon for human being. It allows giving realism to an agent [19]. It can participate to characterize the state of a person. For instance, number of winking increases with tiredness among others [20, 21]. So, it allows representing state of tiredness, stress, concentration of a person. It is decomposed into four steps :

- Eyelid is closing abruptly and rapidly.
- Eye is closed for a variable time.
- Eyelid is opening slower than it was closing.
- Eye is opened for a variable time. It is possible to shorten this phase to represent a person whose eyes are rapidly winking. In this case, it can be used to represent stress, for instance.

4.4 Gaze movement

Concerning human beings, gaze movement is never static [19]. Adding this parameter will increase realism of the avatar. A mode is setting up to simulate a free gaze movement : **watching grass grow**. It is a infinite sequence composed of three distinct actions :

Bezier : A pseudo randomly movement whose arrival point can be everywhere in the possible space.

Neutral : A pseudo randomly movement whose arrival point is the center of the eye (neutral position).

Break : Break in the movement, which allows giving the sensation that the avatar is focusing on something.

The trajectory of actions (except **Break**) is made by a cubic Bézier curve :

$$f(t) = P_0(1-t)^3 - 3P_1t(1-t)^2 - 3P_2t^2(1-t) - P_3t^3$$

The duration between the beginning and the end of the trajectory is randomly computed for each action, according to three parameters :

- Minimum possible duration for this action.
- Maximum possible duration for this action.
- Rate of utilisation of this action (frequency of apparition of this action)

It allows obtaining a big set of different trajectories, avoiding repetitive movements.

4.5 Face "grins"

Face grins is defined by a small variation in the position of eyebrows and/or in the form of the lips. It is used to make the face dynamic. For instance, this mechanism allows representing tics by provoking grins at regular intervals.

The face grins is set up in the same manner of the **watching grass grow**. It is a infinite sequence composed by three distinct actions :

Rictus : Small variation on eyebrows and/or on lips.

Neutral : Return to a neutral facial expression.

Break : Break in the movement, no variation of eyebrows or lips.

The duration between the beginning and the end of each action is computed in the same manner as the **watching grass grow**, using rate of apparition, minimum duration and maximum duration for each of these actions.

5 Experimentation

The objective of this experimentation is to evaluate and validate iGrace interaction model. For this experimentation, we can't asked children to give an objective evaluation and comment for reaction we generate. Because it is the beginning of the evaluation, only 10 people have already do it. We will present protocole, evaluation grid and results we have for these children.

5.1 Protocol

This evaluation was performed with a very large audience. To allow the maximum of people experiment our work we put in place a Website ¹ loading ArtE avatar, developed in Flash, that communicate with a distant server loading iGrace interaction model. This public, which is not the final target, will allows us validate iGrace model and reaction that ArtE can have for discourse.

The first thing the participants were asked was to choose a sentence they want send for ArtE. For each sentence, they have ton inform the system about :

- Action tense.
- Language act.
- Context of speech.
- Emotional state for discourse.

After they entered data, we asked us validate it and observed attentively reaction of ArtE. To finish they had to completed a small evaluation grid about emotions they recognized, reaction and mouvement of robot. Each person was asked to perform the following questions:

1. What were the recognizable emotions in the robot's behavior; how would they assess its intensity: certainly not, a little, a lot, I don't know.
2. The average speed of expression and the behavior length.
3. Did you see a combination of emotions? Yes or no.

¹<http://emotirob.dyndns.org>

4. Did the emotional sequence seem natural? Yes or no.
5. Are you satisfied with the robot's behavior? Certainly not, a little, a lot.

5.2 Results

The objective of this experiment is to evaluate reaction generate by iGrace model. We have in the same time evaluate again emotion recognition for ArtE. This rate which is very high for the moment (see **Figure 4**) confirm different choice we made for avatar expression. The final rate of satisfaction will validate parameters for a future avatar we will develop for mobile system.

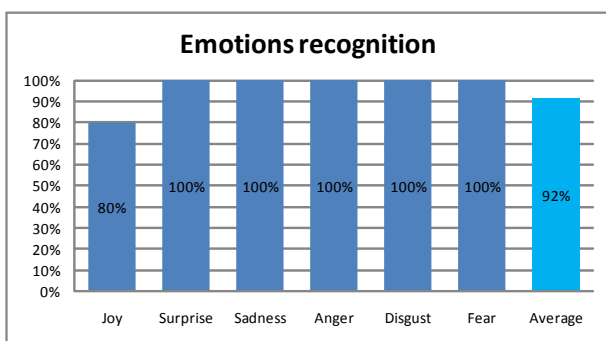


Figure 4: Percentage of emotion recognition for ArtE expression

The result actually obtain for reaction satisfaction is so promising (see **Figure 5**). The rate is not excellent but very acceptable for majority of user. Some comments let think that dynamics of movement can disturb user. If the length between end of reaction and new start of dynamics (for waiting another event) is too short, users doesn't know if the new expression is for discourses or other. For example, if a few time after an anger expression ArtE have a small rictus, seems like joy, user can think that this new expression is for discourses he validate just before. In reality, if a rictus is express, it's because ArtE dynamic mode as start after interaction.



Figure 5: Percentage of behaviour satisfaction for reaction

For movement evaluation, some parameters must be adjust. If sequence of emotion is very good, expression speed is very uncertain. New researches on association of expression speed and emotion affect have started.

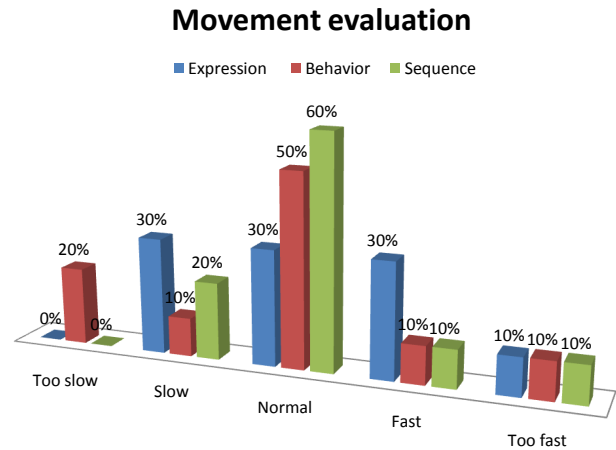


Figure 6: Movement evaluation

6 Robotics conception

This robot was partially conceived by the CRIIF for the elaboration of the skeleton and the first version of the covering (see **Figure 7(a)**). The second and third version (see **Figures 8**), was made in our laboratory. We will briefly present the robotic aspect of the elaborated work.

The skeleton of the head (see **Figure 7(c)**) was completely made of ABS and contains:

- 1 camera at nose level to follow the face and potentially for facial recognition. The camera used is a CMUCam 3.
- 6 motors creating the facial expression with 6 degrees of freedom. Two for the eyebrows, and four for the mouth. The motors used are AX-12+. This allows us to communicate digitally, and soon with wireless thanks to Zigbee, between the robot and a distant PC. Communication with the PC is done through a USB2Dynamixel adapter using a FTDI library.



Figure 7: EmI first version conception

The skeleton (see **Figure 7(d)**) of the torso is made of aluminium and allows the robot to turn its head from left to right, as well as up and down. It also permits the same movements at the waist. There are a total of 4 motors that create these movements.

Currently, communication with the robot is done through a distant PC directly hooked up to the motors. In the short term, the PC will be placed on EmI to process while allowing for interaction. The PC used will be a Fit PC Slim (see **Figure 7(b)**), at 500 Mhz, with 512 Mo of RAM and a 60 Go hard drive. The exploitation system used is Windows XP. It is possible to hook up a mouse, keyboard, and screen for modifications and to make the system evolve at any moment.

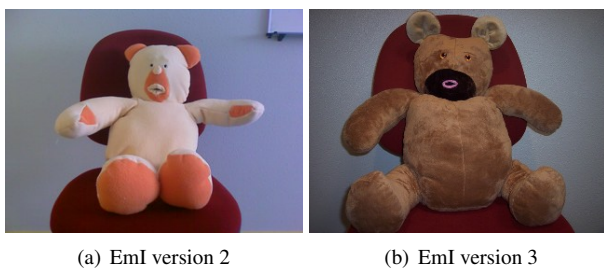


Figure 8: EmI conception

The conception of the last version of EmI (see **Figure 8(b)**) is quite similar of the first. Motors used for movement are the same but the skeleton of the head is now made with epoxy resin allowing best resistance. This version is not exactly finished but we actually it use for preliminary eval-

uation and experimentation with children. You can see on **Figure 9** an example of emotion expression for ArtE and EmI version 1 and 2.

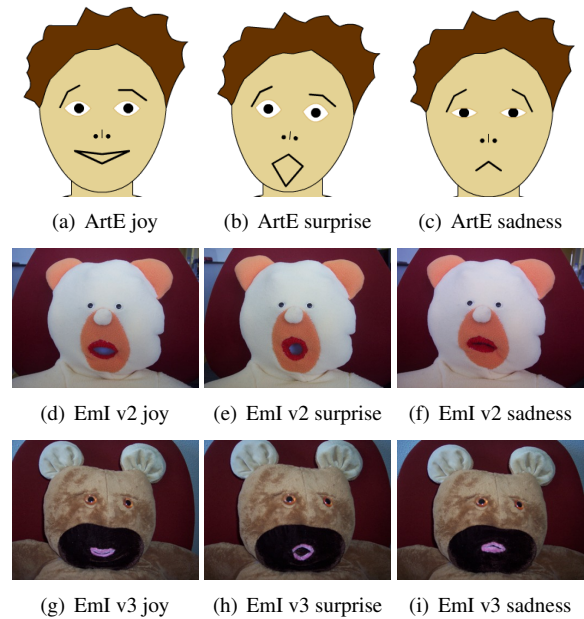


Figure 9: Comparison of some facial expressions

Because degrees of freedom used by ArtE are not the same that EmI, dynamics of movement will be different that what we use with ArtE. From all parameters (rictus, gaze movement, eye winking and respiration), only rictus and gaze movement will be used. Gaze movement will be convert by head movement.

7 Conclusion and perspectives

The experiment we are doing will allow us know if reaction generate by iGrace model are good. Because we have experiment this interaction with only 10 people, we can't say that these results are significant. The other users evaluation will allow validate or not our model of interaction. But we can say with these results that some modifications and adjustments must be done to improve expression and tacitly interaction.

If reaction satisfaction have good results with simulation of discourse, we will start a new experimentation with EmI and adding understanding module. This future experimentation will validate integration of iGrace on EmI and the reaction he can have for a real discourse.

8 Acknowledgments

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