DEVELOPMENT OF AN ARTIFICIAL DYNAMIC FACE APPLIED TO AN AFFECTIVE ROBOT

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Abstract—Facial expressions are fundamental to social relationships. Thus, socially affective robots are developed to express and recognize emotions, considering six basic facial expressions: happiness, sadness, disgust, fear, anger and surprise, besides the neutral state. The objective of this work is to develop and validate an artificial dynamic face for an affective robot to interact with humans. For this, a robot face is composed of simple humanoid features, besides different colors and animations. 101 adults and 328 children and teenagers evaluated the six facial expressions of the robot. The results demonstrate that the recognition average rate is greater than 85%.

Keywords—Affective robot, artificially dynamic face, facial expressions

1. Introduction

Facial expressions are fundamental in social relationships. In a conversation, where the emotion is conveyed, 55% of the information is influenced by facial expressions, while the verbal part is responsible for 7% and the vocal is responsible for 38%. (Mehrabian, 1968). Being the majority part of the information delivery, facial expressions are indispensable to reinforce the emotion associated with phrase (Mehrabian, 1968). There are five primary facial expressions, called universal, that are detected independently of the region where the individual is and his/her exposition to the media. Such expressions are: happiness, sadness, disgust, anger and fear (Ekman, 1993).

Based on those expressions, affective robots are being created with various purposes, ranging from commercial to therapeutic ones, as those destined to interact with children with autism. In this case, the robot can be used to promote improvements of the social response in these children, because they interact better with robots, since these are more predictable and easier to understand (Duquette, Michaud and Marcier, 2008).

Considering the importance of facial expressions in a social relationship, the building of affective robots considers relevant aspects in the design of robot faces. According to the work of DiSalvo et al. (2002), for the development of a dynamic artificial face of a humanoid robot, there are some parameters which enable the face be considered more human, in relation to the presence of the facial components, the eyes contribute with 81.25%; the eyelids, 18.75%; the eyebrow, 16.67%; the nose, 29.16%; the mouth, 62.50%; and the ears, 43.75% (DiSalvo et al., 2002).

In the category of affective robots, the robot RQ-TITAN can be highlighted. It is capable of improving its sociability of imitative aesthetics interaction, where the face is composed of a smartphone that exhibits positive, negative and mixed expressions (Lee, Kim and Kang, 2012). An example of robot capable of generating a continuous range of affective expressions of various intensities is the anthropomorphic Kismet, which engages people in a natural and expressive face-to-face interaction and learns from them. Their affective expressions take into account concepts of valence (pleasure-displeasure), arousal (attention activity), and stance (personal agency, control); moreover their compositions comprise basically movements and combinations of eyes, mouth, lips, ears, eyebrows and jaw (Breazeal, 2002).

Another anthropomorphic robot is the FACE (Facial Automaton for Conveying Emotions), a realistic face able to interact with external environment, through changes in its expressions, based on six emotion (happiness, sadness, surprise, anger, disgust and fear). In addition, FACE is able to engage in social interactions by modifying its behavior in response to the human behavior, using its capability of imitative learning strategy. This robot is used in interaction with children with autism, stimulating them to learn emotions through imitation of its emotional faces and behaviors (Pioggia et al.,...
Taking into account the relevance of the presence of a face to an affective robot, this work shows the developing of a robot face that is dynamic to emotional expressions.

2. Proposals

The goal of this work is the development of an artificially dynamic face for a new robot that is being built in the Federal University of Espirito Santo (UFES) for the interaction with children with autism. The building of the new robot is based on a mobile robot prototype, known as MARIA (Mobile Autonomous Robot for Interaction with Autistics) (Figure 1). It is a mobile robot with a special costume and a monitor to display multimedia contents, designed to stimulate social interaction skills in children with Autism Spectrum Disorder (ASD), promoting eye gaze, touch, and imitation. Although the usability of this robot was demonstrated, it has some limitations, such as the fact of the robot be only remotely controlled, and not having an emotion recognition system onboard (Valadão et al. 2016).

![Figure1. The robot MARIA, UFES, Brazil.](image)

The pilot study with MARIA, described in Valadão et al. (2016), showed the need to create a new version of this robot in order to include new devices to catch the ASD children’s attention and enhance the probability of interaction with them, both in terms of quantity and quality.

The new version of this robot is named N-MARIA (New-Mobile Autonomous Robot for Interaction with Autistics), being composed by a mobile robot (Pioneer 3-DX), speakers, a height close to that of a child and a ludic and friendly structure whose face is a tablet that exhibits emotional expressions. The dynamic face proposed for this robot converges with the building of humanoid characters that along with other features, such as mobility and speech, caught the attention and interest of children with autism.

Thus, the artificial face for the N-MARIA takes into consideration the following elements: eyes, eyelashes, eyebrows, mouth and nose, highlighting feminine characteristics, which can be exploited using accessories. Moreover, the capability of the robot face to express emotions and communicate generates greater value to the affective robot. Thus, considering the shortage of studies about the development of emotional expressions to affective robot in Brazil and the significance of emotional cues to a social interaction (Mehrabian, 1968), the proposal of this work has innovative potential. Finally, to verify the assertiveness of the proposed emotional expressions, they are validated by adults and young participants.

Animated faces become the child-robot interaction more entertaining and friendly. This is an important feature and the main goal of creating dynamic faces to the N-MARIA robot. Social robots can help to create the bridge between two humans, as seen in Valadão et al. (2016), since they are predictable and trustful for children with autism (Duquette, Michaud and Marcier, 2008).

Even, it would be interesting to implement in the robot a means of the identification of the human face during the interaction, using viola jones algorithms, for example, in order to the robot dynamic faces react to the expressions produced by the child.

3. Materials and Methods

The artificially dynamic face consists of a set of the six primary facial expressions (happiness, sadness, disgust, fear, anger and surprise), characterized by the presence of eyes, mouth, nose, eyelashes and eyebrows, projected and exhibited in two dimensions. In order to design the emotional patterns to each part of the face, an exploratory study was constructed from the visual analysis of several images on search sites.

The affective feature of the artificially dynamic face was implemented in a tablet that acts as the robot face. The animation is done using two different software: Piskel, which is free software used to elaborate all the images, whose transitions are made in a conjunct of layers, so the animation can be smoothed. The other software is the Unity 3D, which makes possible the creation of animations, triggered by certain parameters, as a click of a certain button, a remote control or the position of a click in the screen, and the capacity to import a program written in C# to Android.

Each artificial emotional expression displays a different color (based on emotional aspects from cartoons) and is composed of eyes that blink in a regular pattern and a mouth that moves when the robot communicates with the child through a pre-programed speech. These aspects can improve the ludic information of the artificial face, which can generate an increasing interest and attention of the child, ensuring a more natural interaction (Lee, Kim and Kang, 2012). The transition of the emotional expressions can be made by clicking in the upper right corner of the screen (tablet), in such way that the expression changes to the next one, while a click in the left bottom corner changes the expression to the last one shown.
This work has the approval of the ethics committee of UFES (number 1.121.638). In order to evaluate the robot emotional expressions, adults, teenagers and children were invited to answer the emotion demonstrated by each robot expression, according to their own opinion. Then, a success rate (in percentage) was calculated.

The validation had the participation of 101 adults (56 man and 45 woman), with ages ranging between 19 and 41 (M: 24.20 and SD: 5.03); 241 children (113 girls and 128 boys), with age ranging between 7 and 12 years (M: 10.12 and SD: 1.22), and 87 teenagers (47 girls and 48 boys), with ages ranging between 13 and 17 years (M: 13.85 and SD: 0.81). Each participant fills a form with his/her name, age and the name of the emotion in the spaces enumerated from 1 to 6, according to his/her own opinion. The static emotional facial images were exhibited one by one in a tablet, with the possible answers of emotions. Besides, all were informed that the emotion display could be repeated, if that was the case.

4. Results and Discussions

Considering that the affective robot N-MARIA is designed for children with autism, dynamic faces were designed in a simple way to ensure they are more predictable for these children. This parameter is very important, since the unpredictability can generate anxiety reactions in these children (Won and Zhong, 2016). The emotional faces designed for the affective robot are shown in the Figure 2, and a representation of facial movement, that makes mention to the robot’s dynamic face, is demonstrated in Figure 3.

Considering the answers of the participants about the recognition of the artificially dynamic facial expressions exhibited on the tablet, the majority of the volunteers recognized them correctly, as it is shown by the figures 4, 5 e 6 and tables 1, 2 e 3. The x-axis shows the emotions displayed and the y-axis shows the percentage of correct answers by the volunteers.
In general, the medium hit taxes of recognition of expressions were 91% for adults, 92% for teenagers and 88% for children. The lower rate of recognition by children can be explained by the fact that they still are in developmental process of the ability to recognize expressions, reaching adult level competence at approximately 14 years of age (Breazeal, 2002).

Compared with other works, our rates were higher in relation to the average recognition rate (by children and adults) of 70.9% for the static images of a robot, versus an average of 77.6% for the video case (in which the robot performed a coordinated expression using face and body posture). Breazeal (2002). In Cañamero and Fredslund (2001), despite robot’s face in movement, the average recognition rate was of 55% for adults and 48% for children.

The fear emotion obtained the lowest hit taxes for all groups of the participants; the disgust emotion obtained the lowest hit rate for adults; and the same thing for the surprise emotion for teenagers. The difficulty of recognition of these specific emotions could be due to the fact that they depend on other forms of expressions, as gestures and vocalizations, as well as other clues provided by body posture and contextual elements, to be better understood (Cañamero and Fredslund, 2001; Mazzei et al., 2012).

In all groups, fear was more confused with surprise and vice versa. These misclassifications are strongly correlated with the similarity in facial features or similarity in affective assessment (Breazeal, 2002). Anyway, more attention will be paid to the improvement of these misunderstood expressions.

The dynamic face developed and shown in this work presents simplistic features, as those seen in RQ-TITAN (Lee, Kim and Kang, 2012). However, the number of animations of the dynamic face shown here is more accentuated. The proposed face have animations for each expression, including the transition between emotions and the idle animation (as seen in Figure 3), having a total of 19 animations, 3 for each emotion and an idle animation for the neutral state, making the robot more dynamic in the interaction. With the help of the engine used, the animations can be customized, ensuring a more dynamic interaction between the robot and the child.

The main problem of using a face that uses servomotors, as shown in Pioggia et al. (2008) and Breazeal (2002), is the difficulty to do alterations without spending a lot of work, by the need of changing every motor angle of actuation to reconfigure the expressions. Due to the pixel art characteristic of the dynamic face proposed in this work, alterations in the animations are easier to implement, because of the simple design and the mutable capability of the engine utilized.

In spite of a good accuracy to the identification of the six robot emotions (greater than 70%), more adjusts will be implemented in the artificial face, by the application of more movements and cues to better characterize the emotional expressions of the new affective robot.

5. Conclusions

The literature discussed shows the importance of the facial expressions for the human relationship, as well as for the social development, especially in therapies of behavioral disturbs. Socially affective robots are developed to increase the social interaction of people affected with such disturbs. Emotional dynamic faces are important features in the composition of affective robots, becoming useful for a more natural human-robot interaction.

This work shows the building and the validation of artificial dynamic faces to a social affective robot that will be used in human-robot interactions. Thus, this work adds more knowledge for the study about the development of socially affective robots and the facial and robotic expressions. Results of this paper demonstrate that the robot emotions obtained a high recognition rate, however, more adjusts will be made, mainly, in those emotional expressions that are more difficult in recognizing, in order to obtain a successful recognition rate higher than 90%.

New-MARIA is still in development, and tests will be made to test the system of cameras and sensors capable of capturing images of children with ASD, to identify classes of emotions and focus on an object or an image. New adjustments to the animated faces for interaction with such children have been proposed from the analyses exposed in this paper. These new aforementioned features were designed in order to facilitate the stimulation of social skills and the study of emotions and focus of attention. Moreover, for the New-MARIA five sub-systems will be proposed and tested, in order to allow autonomous navigation, robot control, multimedia interaction, social interaction, therapeutic-robot-child approach and automatic emotion recognition.

Specifically, in relation to dynamic faces designed for the new robot, the simplicity of the pixel art done in the faces has some limitations that can be suppressed with the use of other softwares, and new proposals of expressions using morph animation is a work already in progress. Finally, the artificially dynamic face can be integrated with an emotion recognition system, allowing creating affective computing applications, endowing the robot with an emotional intelligence for a more natural interaction with humans.
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References


