Studying People's Emotional Responses to Robot's Movements

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Abstract. With a deeper interaction between robots and humans, the emotional rapport between the two is becoming ever more important. The interpretation of emotion expressed by robots has been widely studied with humanoids and animal-like robots, which try to mimic biological beings similar to those people is used to interact with. Considering the uncanny valley issue and the practical and theoretical questions related to implement bio-inspired robots, it may be argued whether also object-like robots can express emotions so that people can satisfactorily interact with robots that can have functional shapes, not necessarily bio-insipired. This paper presents some study cases done to identify body features that allow emotion projection from an object-like robot body. The study was done in two phases: a pilot experiment, and a formal trial. The results show that is possible to project different emotions by exploiting angular and linear velocity of the robot.

1 Introduction

In many applications, the shape of the robot has to match functional criteria; an example for all: the robotic vacuum cleaners. With the large diffusion of autonomous robots, it is interesting to investigate how a robot having a functional, possibly non-bio-inspired, shape might express emotions to involve the human user in an emotional relationship. People tend to treat objects showing some perceived autonomy as humans; it happens with computers [15], which do not have any bio-inspired shape, and with robots [18] as well.

Moreover, human-human interaction does not always begin when people are close to each other so to see each other faces. In cases when people know each other before hand, this interaction begins from the moment when each person realizes the presence of the other from distance. While approaching it may be impossible to see others' faces. Despite this, people can have an idea of others' current emotional state, just using other movement cues and body posture [12], and this influences how each one will treat the other during the rest of the interaction.

There are few works that have studied emotion expression based on whole body features. Most of the works in emotion projection focus on how to show emotion using robotic platforms that resemble human bodies [3, 11] (i.e., NAO platform) or getting humans characteristics to show emotions (e.g., face) [8, 4]. In both cases it is considered that human-robot interaction begins when the robot is close enough to the person. [8] consider the approaching distance in their studies, but they do not consider the speed at which the robot get close to the person. This makes it necessary to study different features that could improve emotion projection, and, as a consequence, the whole human-robot interaction. The experimental pilot study presented in this paper is aimed at identifying features that could be used by a robot with a generic shape to show emotions from distance, then giving the opportunity to engage people from distance, rather than waiting until they get close. Thus, the platforms we implemented for this experiment didn't have any kind of face or bio-inspired body. A first pilot experiment was to done to verify whether the change of speed during the displacement was enough to convey emotions. From the feedback collected in the pilot, new features were added to the platform as upper body movement and rotation of the base while proceeding. The results show that is possible to convey emotions, and that some emotions are more clearly recognized than others.

This paper is organized as follows. In section 2, some previous works done in conveying emotions with body are reviewed. Section 3 describe the pilot done to test the hypothesis. Section 4 explains the second trial done.

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2 Related Work

One of the most well-known expressive robots is Kismet [4], a robotic face able to interact with people and show emotions. The face has enough degrees of freedom to portray the basic emotions suggested by Ekman [7]. The interaction studied with this platform was using a human as caregiver and the robot as the receiver. At first glance it may seem that the system is capable to engage people in a long term interaction, as humans do in their life. As relationships in interaction is not just established for short term, but also in long term, there have been works that have focused their attention on how to generate systems capable of long term interaction, such as Valerie [2, 10]. In this work, the researchers aim at generating a robotic platform that has personality and character. To obtain this, a software architecture based on the TAME architecture [14] was built; it implements four components: traits, attitudes, moods, and emotions. The emotion projection is done through a virtual face in a LCD monitor. This enables the elimination of mechanical problems and constraints to generate all the emotions, and makes it possible to use the facial expressions generated from Vikia [6]. As in Kismet, Valerie is capable to project the basic emotions suggested by Ekman.

Using the same virtual face of Vikia, in [5] was studied which features encourage people to have a short term interaction. It was found out that the existence of a head improves the wish of people to interact with artificial devices. To reduce the interaction requirements, the experiment consisted in asking people to answer a poll. In the experiments, only people not used at robots were considered. The position of the head was considered, but not the velocity and the trajectory that the robot used to approach.

Moving forward and using the human like platform NAO [16], Canamero and collaborators [3] studied the perception of key poses to show emotions. They suggested that using the same techniques used to show emotions in virtual characters could not be used in robots, due to the fact that virtual characters have not any physical constraint, while robots are constrained by their physical capabilities [17, 3]. Thus, they proposed a set of poses that could be used to express emotions with the NAO. However, these key poses are done in the same place, lacking of any translation of the robot in the environment. Additionally, it was studied how the head position helps to project emotions. To evaluate the correctness of each position, they performed an experiment where people were asked to say which emotions the robot was trying to convey. On the other hand, Haring and collaborators [11] go one step further and generate a sequence of actions for each of the following emotions: anger, sadness, and joy. Moreover, they accompanied each sequence of actions with eye colors and sounds, which improve the emotion interpretation. Since there is no solid theory associated to emotions and colors, colors related to each emotion were selected by following their own preferences. From the experiment resulted that the color did not increase emotion interpretation.

Daryl [8] was built as an anthropomorphic robot, without facial expression neither extremities, but with moving features. It was used to test whether it is possible to project emotions using other ways rather than the ones used by humans, as tail, ears, etc. This robot has a head, ears, ability to generate colors in a rgb-led positioned in its chest, a laser on its shoulder and a speaker system. The head has no capabilities to show facial expressions, but the head movements and robot translations are used to show emotions. Distance ws considered to show emotions, but not the velocity with which the robot gets close to people, neither the trajectory followed.

A drawback of all the mentioned works is that they focus only on features to show emotions with a static body, relying on the face or human-like characteristics, thus most of the current commercial platforms could not convey any of the features studied to project emotions.

3 Pilot

This first experimental activity was aimed at verifying whether it is possible to show emotions just exploiting changes in the velocity of a robot base, and whether it had to be necessary to add new features to the platform. Thus, the pilot experiment was done by using an informal procedure, by just asking people which emotion was the robot trying to convey.

3.1 System

The system was composed of two parts: a robotic platform and an interface. The robotic platform was built as simple as possible in order to see the features related to displacement that could be exploited to project emotions. The interface is used to generate the different profiles of movement related to emotions which are then sent to the robot to be executed.

3.1.1 Robotic Platform

A robotic platform had to have no human-like appearance, so that people are prevented to try to relate the robot posture to the emotional posture that humans take. The platform was built using the Arduino Mega 2560 [1] as processor, three metal gear motors with 64 CPR encoders, and one servo motor to move a beam, as could be seen in Figure 1. The platform used a PID control to ensure to obtain the desired velocity, whose small value was considered as the most important feature for some emotions, such as Sadness.

Action profiles to show emotions are sent to the platform from the interface each time it has to perform them.

Figure 1. First version.

3.1.2 Software Interface

The interface has been designed to describe the linear trajectory of the platform, in order to express an emotion profile. Each emotion profile is composed by a sequence of points on the linear trajectory, where the value of the variables that can be controlled is given. The variables whose value is set at each point are: desired velocity, distance at which the desired velocity should be reached, and the acceleration. The two possible options for acceleration are ”as soon as possible” or ”at the end of the distance from the previous point”.

This interface allows the user to add and delete points, modify each point, see each point in a line, save, modify the whole profile, and provide comments for each emotion profile. Each point could be seen in a graphical line, which gives the user an idea of the position of each point. The distance used in the whole program is absolute, thus if it is necessary to make the robot to go backwards a negative distance should be introduced.

3.1.3 Communication

The communication between the interface and the platform is done through Xbee modules. There were implemented three messages:

- *Simple command:* tells the robot the angular velocity, x and y velocities. This command does not have any reply from the platform.
- *Stop command:* as its name suggest, it stops the platform even if it is executing a profile. This command does not receive any reply from the platform.

- *Profile command:* it is a special command that loads in the platform an emotion profile. If a profile is active no other command can be executed until it ends.

3.2 Methods

As the intention of the pilot was just to test whether the hypothesis was correct, it was conducted in a very informal way. Therefore, no questionnaires were used. When people approached to us during the exhibition at the last year's Researchers' Night, and asked about our work, then they were showed an emotion. After that, a short interview was performed, to get their appreciation about the emotion that they perceived and the features that they used to come up to identify that emotion. At the beginning of the pilot the beam was without the white wire, so that people just ignored the movement of the beam, due to the beam's dimensions. To improve the projection of the movement the white wire was added. The emotions showed in this phase were: Happiness, Anger, Sadness and Fear.

3.3 Results

The main conclusion of this pilot was that it was necessary to add new features to project emotion as Happiness and Curiosity, which were not well perceived by people. The features that were then added were: angular velocity and upper part control, that could bring more information.

4 Second Trial

The second trial was done at the Museum of Science and Technology in Milan. The experiment was conducted for three days, and the participants were high school students and families that were attending the exhibit.

4.1 System's Modification

From the comments received during the pilot, there were decided to do changes on the platform and the interface to add new features: upper movement and angular velocity.

4.1.1 Robotic Platform

Two beams attached to a servo motor, and another one to move the upper part of the body back and forth, were added. The two beams could be controlled either to do an asymmetric movement, to resemble the movement of shoulders when walking, or to close at the same time, as could be seen in Figure 2. In both cases, the desired angle can be configured in the last version of interface. platform was covered with foam, and a light blue cloth covering the foam. The light blue color was selected because it is known to be a neutral color, and it would not generate any bias in the audience. The final version of the platform could be seen in Figure 3.

4.1.2 Interface

The new variables that could be controlled in the interface are: angle restrictions, maximum angle, upper body position, and upper maximum angle. When the angle restriction is active, the rotational movement of the robot is going to be constrained to the maximum angle. When the upper maximum angle is positive, it determines the angle at which the beams are going to move, but when it is negative it gives

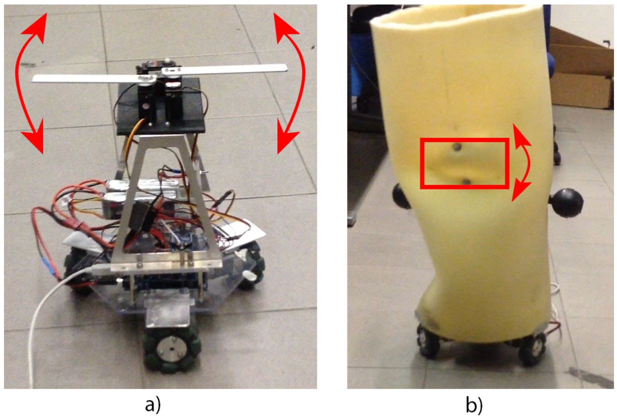

Figure 2. a) Back of the platform without foam, each red arrow shows the movement of beams. The movement is controlled independently. b) Front of the platform without the blue cloth. The red rectangle highlights the space of the body that is moved, and the red arrow shows that is possible to move it in both directions.

Figure 3. Final version.

the angle at which both beams are going to close. The interface could be seen in Figure 4.

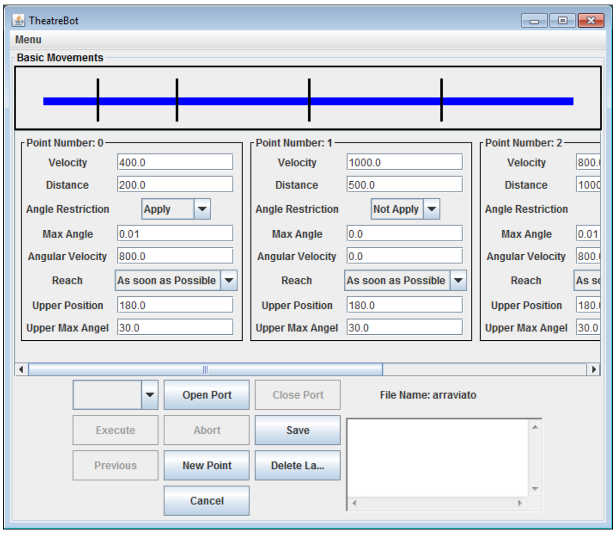

Figure 4. Final interface used to program the emotions conveyed by the robot.

4.2 Methods

The experiment consisted of three rounds, in each of which the robot was performing a different emotion, and the participants were asked to mark which emotion-related term, in a set of eight, best described what they believed the robot was trying to convey. There was not a specific group size for subjects, being this determined by the amount of people that got close at a given moment. Therefore, there were groups consisting of just one person and others with up to 24 persons. To avoid that people be influenced by others' experiments, different emotions for each group were proposed. The emotions implemented on the robot were: Fear, Disgust, Anger, Sadness, Happiness, Embarrassment, Curiosity, and Neutrality. The questionnaire included the seven emotions implemented plus pride. A total of 154 persons were interviewed including 55 males, 26 females and 73 persons that did not fill the gender question. Most of the people were aged between 16 and 19.

4.2.1 Emotion Description

The features that could easily perceivable by the observer are summarized in table 1; each selected feature is described as below:

- *Speed* is the average speed that the robot takes during the movement. It was discretized in five values: very slow (100 mm/s), slow (200 mm/s), normal slow (300 mm/s), normal (400 mm/s), and fast (800 mm/s).
- *Front/Back* represents the fact that the robot move backwards at some point in its movement; the possible values are: ”yes1“, which means that the robot just go back one time, ”yes2“ when the robot goes back twice, and ”no“ if the robot goes only forward.
- *Shoulder* considers the movement of the upper part: ”asymmetric“ when the two beams move asymmetrically, alternatively one forward and the other backward, ”close“, when the upper parts get close to each other, a combination of the two, and ”none“.
- *Shoulder Amplitude* is the maximum angle that is going to move the two beams. There are five possibilities: ”none“ (0°), ”small“ (10°), ”medium“ (30°), ”large“ (50°), and ”huge“ (70°).
- *Body Rotation* is the angular velocity of the robot, and it is classified a: ”none“ (0 mm/s), ”slow“ (300 mm/s), ”medium“ (500 mm/s), and ”fast“ (800 mm/s).
- *Body Rotation Amplitude* is the maximum angular angle that the robot can reach, and it could be: ”none“ (0°), ”small“ (0.1°), ”medium“ (0.3°), ”large“ (0.5°), and ”huge“ (0.7°).

4.3 Results

The results obtained could be seen in the table 2, which shows that the best emotion perceived is Fear and the worst one is Disgust, with 48.3% and 2.7% respectively. Also, it is interesting to see that there are movements that were designed to convey a specific emotion, but a different emotion was perceived. For example the intended Sadness was identified by 16.3% of subjects exposed to it, while 30.2% perceived it as Fear, and 25.6% as Embarrassment, thus making evident that the features used to represent it bring to uncertain classification. The Neutral emotion, in which we were trying to not convey emotion, was not perceived at all, probably because, in this setting, people expects the robot to show some emotion anyway. Nine answers where Unknown and have been dropped, as well as a number of unreadable ones.

Moreover, an analysis was done per groups, for each presented emotion. Excluding unknown and uncertain answers, we have considered the answers of each subject which was exposed to an emotion produced by the robot. For each emotion, we considered how many subjects in each group recognized it, how many identified a different emotion, how many identified the considered emotion when exposed to another one (in any of the other two experiences each did) and how many recognized an emotion different from the considered one when presented a different emotion. This lead for each presented emotion to a table like the one reported in table 3 for Happiness. For each of these tables the classification accuracy and the no-information rate (NIR), i.e. the accuracy that had be obtained by random selection, have been computed with the R package CARET [9], as reported in table 4. It can be seen also from these data that some implementations of emotion expression (i.e., Anger and Happiness) have been recognized by the respective panels, while others are not. This may depend on the specific implementation of the emotion expression as well as on the specific panels, and needs to be further investigated.

5 Conclusions and Further Work

Although human face can project a wide variety of emotions, human-human interaction do not just rely on the face, but also on the body to start interaction from distance and give cues that could help people to behave properly. Despite this, current efforts are focused on the study of face cues, and there are just few efforts to understand how to convey emotions with the possible limitations of non bio-inspired robotic platforms. Using a simple platform, we have studied if the change on velocity (angular and linear) could be used to express emotions. To do this, it was performed a pilot experiment to test whether it was possible to show emotions just by changing these features. Then, two other experiments were performed: in the first one the robots performed the actions alone, while in the second one, the same action where inserted in a coherent scene.
The result of this experiment shows that it is possible to convey some emotions using just movement and a non-bio-inspired embodiment.

Table 1. Features that could be perceived by the audience, their modalities

Emotion	Speed	Front/Back	Shoulder	Shoulder Amplitude	Body Rotation	Body Rotation Amplitude
Angry	Fast	No	Asymmetric	Medium	None	Very Small
Sadness	Very Slow	Yes-1	Close-2	None	Slow	Small
Fear	Normal Slow	Yes-2	Close-2 + Asymmetric	Small	None	None
Embarrassed	Slow	No	Asymmetric	Large	Slow	Small
Happiness	Fast	No	Asymmetric	Medium	Fast	Small
Disgust	Slow	No	Few Asymmetric	Small	None	Very Small
Curiosity	Normal	No	Asymmetric	Medium	Slow	Large
Neutral	Normal	No	Asymmetric	Medium	None	None

Table 2. Results obtained during the experiment. Each row is the emotion that was expected to convey, and the columns are emotions that audience perceived. The meanings of the symbols identifying rows and columns are: Cu = Curiosity, Di = Disgust, Ha = Happiness, Em = Embarrassment,Ne = Neutral, Fe = Fear, An = Anger, Sa = Sadness, , and Un = Unknown. The total column is the total amount of people that were shown each emotion, and the percentage the correct perception of the emotion.

Tested / Perceived	Cu	Di	Ha	Em	Ne	Fe	An	Sa	Total	Percentage
Cu	9	3	3	9	2	2	2	3	33	27.3%
Di	11	1	3	3	6	7	1	5	37	2.7%
Ha	4	0	28	2	4	3	15	2	58	48.3%
Em	11	0	3	8	0	9	3	2	36	22.2%
Ne	0	1	1	1	0	0	5	2	10	0.0%
Fe	29	5	2	25	2	22	3	2	90	24.4%
An	11	3	6	4	1	7	23	0	55	41.8%
Sa	5	1	0	11	2	13	4	7	43	16.3%

Table 3. Example of table compiled for each emotion on the subjects which have been presented each emotion (here Happiness).

Presented/Perceived	Happiness	Other
Happiness	28	4
Other	30	96

Table 4. Classification accuracy of the presented emotions by the single panels, computed as mentioned in the text, with corresponding 95% confidence interval, no-information rate, and p-value that accuracy is greater than the NIR.

Presented emotion	Classification Accuracy	95% CI	No-information Rate	P-Value [Acc > NIR]
Cu	0.56	(0.45, 0.67)	0.61	0.84
Di	0.52	(0.40, 0.63)	0.54	0.71
Ha	0.78	(0.71, 0.85)	0.63	2.8e-05
Em	0.58	(0.47, 0.67)	0.60	0.77
Ne	0.55	(0.32, 0.76)	0.55	0.59
Fe	0.60	(0.53, 0.66)	0.58	0.31
An	0.74	(0.65, 0.81)	0.61	0.001
Sa	0.66	(0.56, 0.74)	0.62	0.25

This suggests that it is important to continue working in this direction to refine the features to be used to this aim. Moreover, showing emotional states in a context that puts in evidence the stimulus that produced them (as it would happen in a real application) might improve the perception of the emotions, as it is known also for human-human relationships, and this will be studied in a future trial.
It will also be interesting to analyse the answers given by the subjects to identify possible features that this population associates to each emotion, in order to design emotion expression that could better matching a more general expectation.
This work is a first step in the identification of the features that could be used by a system to add affection to actions. This will enable a robot to show affection while it is performing the actions it was designed for, such as moving to clean a floor or bringing water to e person, which are, in general, different from what needed to project emotions only. The final aim of this work is to add to functionally designed actions possible emotional flavours coherent with the affective relationship that it is intended to obtain with the user, both for assistive applications, in robogames [13] and in entertainment. This work started within a project aimed at building an autonomous robot actor, which should not only interact with other human or robotic actors, but could also show in each action the emotion that can grasp the attention of the spectators and make the show succeed.

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