

# Whole body Emotion Expressions for KOBIAN Humanoid Robot – preliminary experiments with different emotional patterns –

Massimiliano Zecca<sup>1,2,3,4</sup>, Yu Mizoguchi<sup>6</sup>, K. Endo<sup>6</sup>, F. Iida<sup>6</sup>, Y. Kawabata<sup>6</sup>,  
Nobutsuna Endo<sup>6</sup>, Kazuko Itoh<sup>3,7</sup>, Atsuo Takanishi<sup>1,2,3,4,7,8</sup>

<sup>1</sup> Institute for Biomedical Engineering, ASMeW, Waseda University, Tokyo, Japan [zecca@aoni.waseda.jp](mailto:zecca@aoni.waseda.jp), [takanishi@waseda.jp](mailto:takanishi@waseda.jp)

<sup>2</sup> Humanoid Robotics Institute (HRI), Waseda University, Tokyo, Japan

<sup>3</sup> Italy-Japan Joint Laboratory on Humanoid and Personal Robotics “RoboCasa”, Tokyo, Japan

<sup>4</sup> Global Robot Academia, Waseda University, Tokyo, Japan

<sup>5</sup> ARTS Lab, Scuola Superiore Sant’Anna, Pisa, Italy

<sup>6</sup> Graduate School of Science and Engineering, Waseda University, Tokyo, Japan

<sup>7</sup> Advanced Research Institute for Science and Engineering, Waseda University, Tokyo, Japan

<sup>8</sup> Department of Modern Mechanical Engineering, Waseda University, Tokyo, Japan

**Abstract—** Personal robots and robot technology (RT)-based assistive devices are expected to play a major role in our elderly-dominated society, with an active participation to joint works and community life with humans, as partner and as friends for us. In particular, these robots are expected to be fundamental for helping and assisting elderly and disabled people during their activities of daily living (ADLs). To achieve this result, personal robots should be also capable of human-like emotion expressions.

To this purpose we developed a new whole body emotion expressing bipedal humanoid robot, named KOBIAN, which is also capable to express human-like emotions. In this paper we presented three different evaluations of the emotional expressiveness of KOBIAN. In particular, we presented the analysis of the roles of the face, the body, and their combination in emotional expressions. We also compared Emotional patterns created by a Photographer and a Cartoonist with the ones created by us.

Overall, although the experimental results are not as good as we were expecting, we confirmed the robot can clearly express its emotions, and that very high recognition ratios are possible.

## I. INTRODUCTION

In our society getting older and older [1, 2] there is considerable expectation for a growing need for home, medical, and nursing care services to assist people, both from the physical and psychological points of view [3]. For this purpose, robots are expected to perform human tasks such as operating equipment designed for humans in dangerous environments, provide personal assistance, social care for the elderly, and cognitive therapy [3, 4], as well as entertainment and education. These new robotic devices must be able to move in the human environment, moving objects around and naturally interacting with the people, thus assisting them both physically and mentally. An example of such a scenario is shown in Fig. 1.

In recent years, several robots have been developed to investigate the socio-emotional aspects of human-robot interactions, in particular in Asian countries. Our group, too, has been investigating the fundamental technologies of service RT system that shares the living environment with elderly people and supports their comfortable life [5-10].

In order to achieve communication ability similar to the one of the humans, the hardware itself should be close to human. We propose that humanoids should be designed to balance *human-ness*, to facilitate social interaction, and *robot-ness*, to avoid false expectations about the robots’ abilities [11, 12]. In fact, if we realize a hardware which is totally similar to human, or if there is some unbalance among its parts, non-similarities might give a quite eerie and uncanny impression to the human partner.

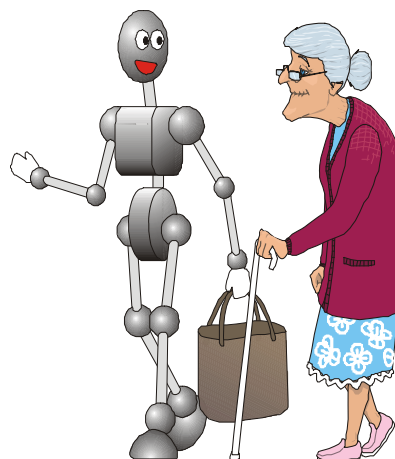


Fig. 1: Typical application scenario for a whole body emotion expressing humanoid robot.

### A. Whole type emotion expressing humanoid robot KOBIAN

For this purpose, in the last years we have developed the whole body emotion expressing humanoid robot KOBIAN [8, 10], based on the head of WE-4RII [9] and on the body of WABIAN [13]. KOBIAN is 1400 mm tall, and 520 mm wide. Its weight is 62 Kg. The preliminary evaluation of the whole body emotion expressions showed that the body of the robot clearly improves the emotion recognition [10]. There was in fact an average increment of +33.5 % compared to simple facial expression recognition [8], with the most notably increments for Anger (+61.7%) and Surprise (+68.5%).

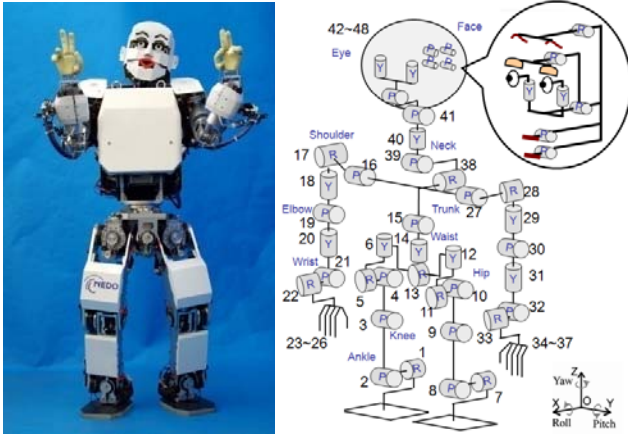


Fig. 2: Picture of the whole body emotion expression humanoid robot KOBIAN (left), and distribution of its DOFs (right).

### B. Objective of this paper

This paper presents the preliminary evaluation of several whole-body emotional patterns implemented on KOBIAN. In particular, Sec II presents the preliminary evaluation of the roles of face, body, and their combination in emotional expressions. Sec III presents the preliminary evaluation of new emotional patterns created in collaboration with a photographer and a cartoonist. Sec IV presents some additional patterns created to overcome the limitations of the previous one. Section V, eventually, presents a detailed discussion on the above results, and the conclusions.

## II. PRELIMINARY EVALUATION 1: ROLES OF FACE, BODY, AND THEIR COMBINATION IN EMOTIONAL EXPRESSIONS

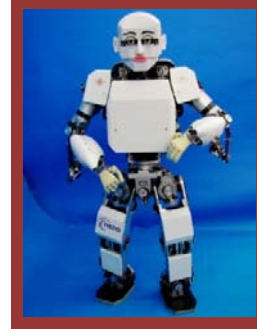
### A. Preparation of the Stimuli

As a preliminary experiment, we decided to evaluate the difference in the perception of whole body emotion expressions in case of presence (or absence) of facial expressions. The facial expressions were obtained from the preliminary experiments presented in [8]; the body postures were derived from the ones presented in [10].

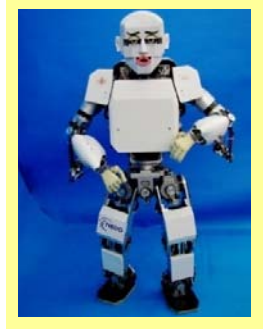
### B. Experimental Evaluation

A group of 30 people (male: 28, female: 2, average age: 26) kindly participated to this evaluation after giving their informed consent to the experiment.

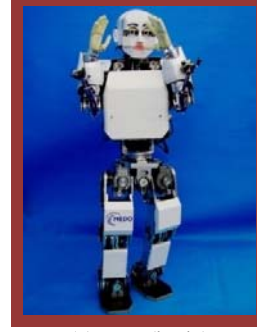
Seven pictures – one for each of the basic emotions, i.e. Anger, Disgust, Fear, Happiness, Surprise, Sadness, plus an additional Perplexity – showing only body postures, and 7 pictures showing body posture + facial expressions were shown in random order by using Presentation (Neurobehavioral Systems, Inc., Albany, CA, USA); the responses were recorded with the same software. Some examples are shown in Fig. 6(a)~(f).



(a) Anger (body)



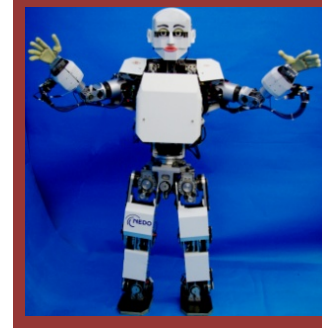
(b) Anger (body+face)



(c) Fear (body)



(d) Fear (body+face)



(e) Happiness (body)



(f) Body (body+face)

Fig. 3: Some examples of the pictures used in the preliminary evaluation. (a), (c), and (e) refers to the body only condition, while (b), (d), and (f) to the body+face condition.

The recognition ratio  $r(p_i, e_j)$  for each video was calculated as follows:

$$r(p_i, e_j) = \frac{N_{i,j}}{N} \quad (1)$$

where  $p_i$  = picture # $i$  ( $i=1\dots14$ ),  $e_j$  = emotion # $j$  ( $j=1\dots7$ ) (6 emotions + perplexity);  $N_{i,j}$  : number of responses ( $p_i, e_j$ );  $N$ : total number of people. The collected data were transcribed in

Excel (Microsoft) and saved for further processing. Part of the elaboration has also been carried out in Matlab® (The Mathworks).

### C. Results

Fig. 9 presents the results for this preliminary experiment. Data for facial expression recognition ratio are taken from [8]. These results confirmed our preliminary findings [10] that body can greatly enhance the emotional expressiveness of the robot. In this case we obtained an average recognition ratio of 70.0% for the whole body+face, while facial expressions were correctly recognized only in 44.6% of the cases. Moreover, these data proved that body posture alone is most of the times not sufficient for a correct recognition, with the only exception being sadness. The Average recognition ratio, in fact, is only 33.8%.

It is also worth noticing that the patterns labelled as “Other” (i.e. not considered as belonging to one of the predetermined emotions) were 55.0% in case of facial expressions only, 70% for body expressions only, but only 13.4% in case of body+face expression, thus confirming the high expressiveness of KOBIAN.

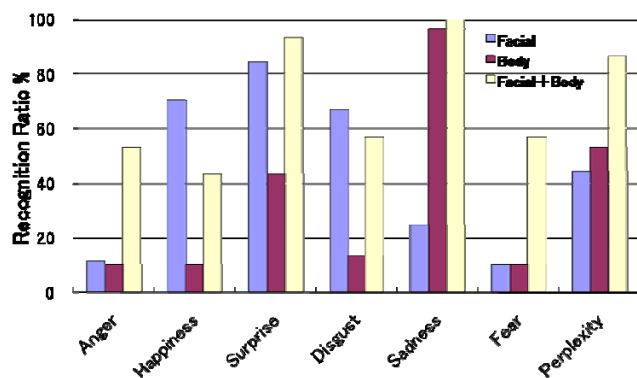


Fig. 4: Recognition ratio for the patterns prepared by the cartoonist.

## III. PRELIMINARY EVALUATION 2: NEW EMOTIONAL PATTERNS

### A. Preparation of the stimuli

The preliminary results obtained with the previous experiment were encouraging but not yet sufficient. Therefore we decide to take some professional advice on how to create the emotional patterns. In particular we asked one professional photographer (with long experience in working with professional models) and one professional cartoonist (with long experience in creating exaggerative poses for cartoons) to design their original emotional poses for the selected 7 emotions: Anger, Disgust, Fear, Happiness, Perplexity, Sadness, and Surprise.

After providing the informed consent to the experiment, each artist spent one day each playing with the robot in order to find the best possible posture for each given emotion. The resulting poses are presented in Fig. 5 for the Photographer and Fig. 6 for the Cartoonist.

As can be clearly seen from these pictures, some of the poses realized by the two artists are very similar (Anger, for example), while others are completely different (Happiness or Surprise, for example), thus showing the influence of their personal background. It is also worth noticing that most of the poses were completely different from the ones prepared by the members of our lab [10].

A professional Japanese actor was asked to replicate these emotional expressions. The 14 different expressions (7 for the Cartoonist, 7 for the photographer) were repeated several times. The movements of the actor were recorded and used as a base to create the motion patterns for the robot. The best matching videoclips were then selected and used for the evaluation phase.



Fig. 5: Emotional postures realized by the cartoonist. From left to right, top to bottom: Anger, Disgust, Fear, Sadness, Perplexity, Happiness, and Surprise.

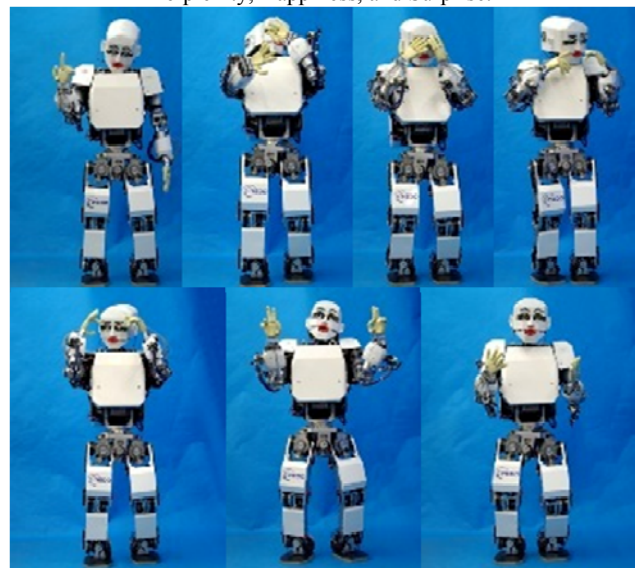


Fig. 6: Emotional postures realized by the photographer. From left to right, top to bottom: Anger, Disgust, Fear, Perplexity, Sadness, Happiness, and Surprise



### B. Experimental Evaluation

A group of 31 people (male: 29, female: 2, average age: 26) kindly participated to this evaluation after giving their informed consent to the experiment.

21 short videoclips of 7 emotions (Anger, Disgust, Fear, Happiness, Perplexity, Sadness, Surprise) 3 types (Student, Cartoonist, Photographer) were shown to the subjects. The videos were shown in random order by using Presentation (Neurobehavioral Systems, Inc., Albany, CA, USA); the responses were recorded with the same software. Each video was consecutively shown 3 times before moving to the next one. The subjects were asked to choose the emotion that they thought the video robot was expressing among a predetermined list. The recognition ratio  $r(v_i, e_j)$  for each video was calculated as follows:

$$r(v_i, e_j) = \frac{N_{i,j}}{N} \quad (2)$$

where  $v_i$  = video # $i$  ( $i = 1 \dots 21$ ),  $e_j$  = emotion # $j$  ( $j = 1 \dots 7$ ) (6 emotions + perplexity);  $N_{i,j}$  : number of responses ( $v_i, e_j$ );  $N$ : total number of people. The collected data were transcribed in Excel (Microsoft) and saved for further processing. Part of the elaboration has also been carried out in Matlab® (The Mathworks). The results of this experiment are presented in Fig. 7.

### C. Results

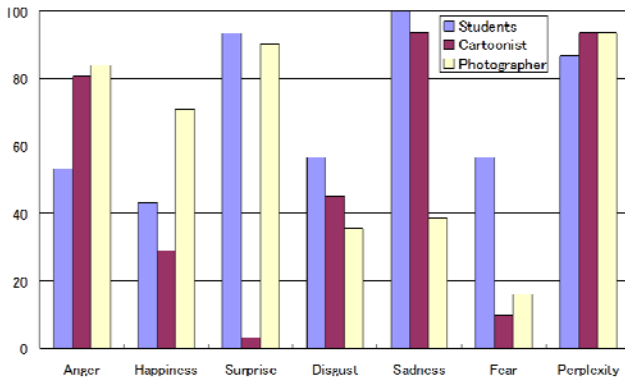


Fig. 7: Recognition ratios for experiment #2.

As it can be seen from Fig. 7, the results are really mixed. On average, the performance of the two specialists (average recognition ratio of 70.5%) is almost identical to the one of the students (average recognition ratio of 70 %). However, the results are very different case by case and emotion by emotion.

In particular, Anger was more correctly represented by the two specialists (recognition ratios of 80.6% and 83.9% for the cartoonist and the photographer, respectively, vs 52.3% for the students).

Happiness expressed by the Photographer (71.0%) was also better than the one of the Student (43.3%); the happiness of

the Cartoonist, instead, was more difficult to understand (29.0%).

Surprise is more or less the same for the Student (93.3%) and for the Photographer (90.3%); the one of the Cartoonist, instead, was not recognized at all.

Disgust, Sadness, and Fear are better expressed by the Student's poses, although the recognition ratio (in particular for Disgust and Fear) is still quite low (56.7% in the best cases). Sadness was correctly recognized in 100% of the cases for the Student, 93.5% for the Cartoonist, but only 38.7% for the Photographer.

Perplexity, eventually, is better expressed by the two professionals (both 93.5%) than the Student (86.7%), but the results are very close.

It is worth noticing, however, that also the emotions expressed by the actor weren't always recognized well (although the data are not presented here due to space limitations). Further experiments in this sense are therefore necessary.

## IV. EVALUATION 3: ADDITIONAL EMOTIONAL PATTERNS

### A. Preparation of the stimuli

As the preliminary experiment was not completely successful, we asked the Cartoonist and the Photographer to re-think their postures, in particular the ones which obtained a very low recognition ratio.

In particular, the photographer was asked to recreate (a) Anger; (b) Disgust; (c) Fear; (d) Happiness; and (e) Sadness (Fig. 8). Perplexity and Surprise were considered to be sufficiently well recognized and therefore they were not changed.

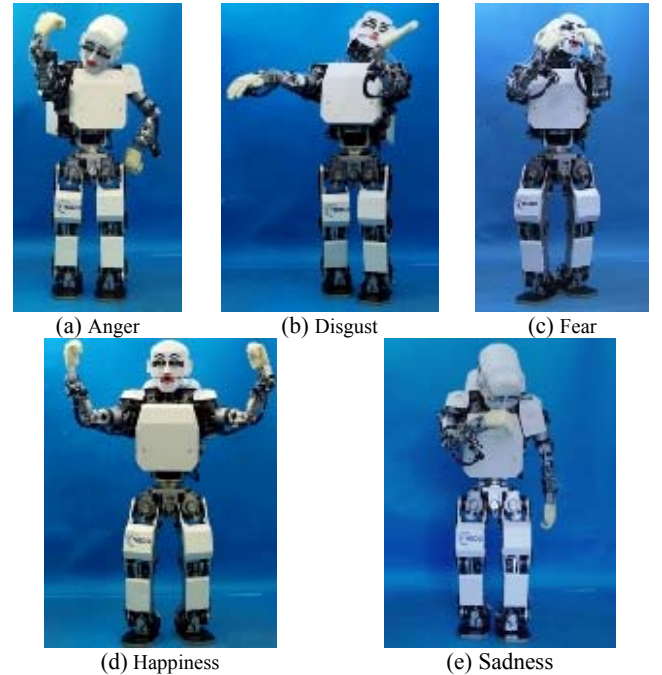
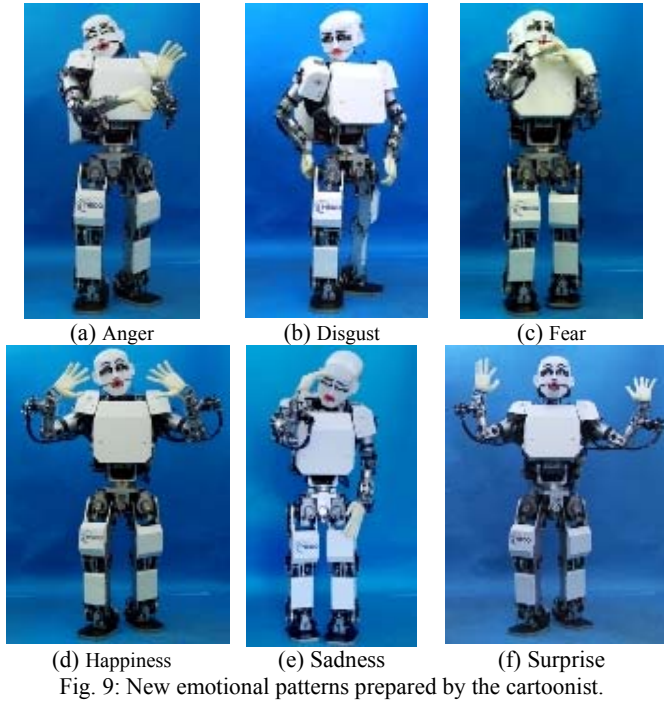


Fig. 8: New emotional patterns prepared by the photographer.

The cartoonist, instead, was asked to recreate (a) Anger;(b) Disgust;(c) Fear; (d) Happiness; (e) Sadness; and (f) Surprise (i.e. only Perplexity was considered to be sufficient).



These new stimuli were added to the previous ones, thus obtaining the following sets:

- C01: 7 original stimuli created by the Cartoonist;
- C02: 6 additional stimuli created by the Cartoonist;
- P01: 7 original stimuli created by the Photographer;
- P02: 5 additional stimuli created by the Photographer.

### B. Experimental Evaluation

A group of 33 people (male: 29;female: 4; age range: 21-54; average age: 27) kindly participated to this evaluation after giving their informed consent to the experiment.

The 25 short videoclips of the emotions were shown to the subjects in random order by using Presentation (Neurobehavioral Systems, Inc., Albany, CA, USA); the responses were recorded with the same software. Each video was consecutively shown 3 times before moving to the next one. The subjects were asked to choose the emotion that they thought the video robot was expressing among a predetermined list. The recognition ratio  $r(v_i, e_j)$  for each video was calculated as follows:

$$r(v_i, e_j) = \frac{N_{i,j}}{N} \quad (2)$$

where  $v_i$  = video # $i$  ( $i = 1 \dots 25$ ),  $e_j$  = emotion # $j$  ( $j = 1 \dots 7$ ) (6 emotions + perplexity);  $N_{i,j}$  : number of responses ( $v_i, e_j$ );  $N$ : total number of people. The collected data were transcribed in Excel (Microsoft) and saved for further processing. Part of the

elaboration has also been carried out in Matlab® (The Mathworks).

### C. Results

The results of this experiment are presented in Fig. 10. At a first glance, the results of this additional experiment seem to be overall negative, with a very low recognition ratio. However, also the patterns prepared by the Students (not shown), were affected by the same problem, with the overall recognition ratio lowering to 57.5%. This means that the group of people selected for this experiment had a very low recognition ratio by itself. This can be seen also from the recognition rate of Perplexity, which was 93.5% with the previous group, while in this case it reached only 76.4% and 70.5% for the Cartoonist and the Photographer, respectively (thus lowering by 16.9% and 22.0%).

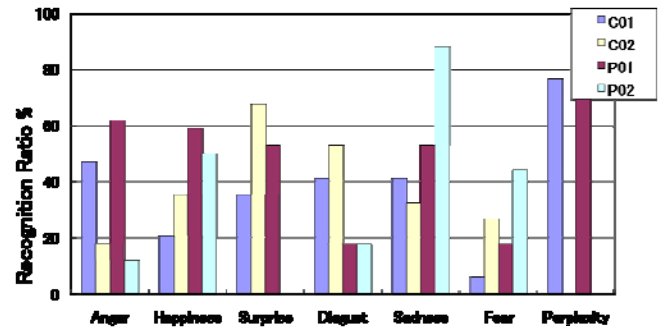


Fig. 10: Recognition Ratios for the different emotional patterns. C01, C02, P01, and P02 are defined at the end of Sec IV.A.

If we just compare the new patterns with the old ones, we can see that Happiness, Disgust, and Fear for the Cartoonist obtained a higher recognition ratio; while Sadness was a little bit lower. In case of the Photographer, instead, the results are exactly the opposite, with all emotions receiving lower recognition ratio while Sadness reached an amazing 88.2%.

### V. DISCUSSION AND CONCLUSIONS

In this elderly-dominated society, Personal Robots and Robot Technology (RT)-based assistive devices are expected to play a major role, both for joint activities with their human partners and for participation in community life. So far, several different personal robots have been developed. However, it is not clear what kind of ability is necessary to personal robot. We think that emotion expression of robot is effective for joint activities of human and robot. The robot should express in particular happiness and perplexity, which we thought being fundamental for a smooth and natural interaction with humans.

To this purpose we developed a whole body bipedal humanoid robot, named KOBAN, which is also capable to express human-like emotions [8, 10]. This new robot is based on the previously developed Biped Humanoid Robot WABIAN-2 [13] for the lower body, and on the Emotion

Expression Humanoid Robot WE-4RII [9] for the head. In this paper we presented three different evaluations of the emotional expressiveness of KOBIAN [8, 10].

In particular, in Sec II we presented the analysis of the roles of the face, the body, and their combination in emotional expressions. The preliminary results showed that the body alone or the face alone do not have the same expressiveness that the body plus the face can reach, thus showing the importance of having both aspects taken care of. Some limitation could be seen in the fact that – due to hardware constraints - the current platform can express only symmetrical facial expressions. Most of the expressiveness of the human being, however, is due to the unsymmetrical usage of facial features, such as eyebrows and lips. The next version of KOBIAN should address this aspect.

In Sec III we compared the Emotional expressions created by a Photographer and a Cartoonist with the ones created by us. After creating the emotional poses with the artists, we also created the emotional patterns in collaboration with a professional actor, to understand the correct timing of the movements. The results of this experiment were both encouraging and disappointing, as some pattern improved, while some other worsened (see Sec III.C for the details).

Eventually, in Sec IV we presented the realization of some additional emotional pattern, intended to overcome the limitations of the previous one. Again, the results were both encouraging and disappointing, as some pattern improved, while some other worsened (see Sec IV.C for the details).

The aspect that has created some problem is probably the timing of the movements of the robot while expressing the emotions [14]. The recognition ratios of the videos, in fact, were less good than the ones for the pictures. Although the patterns were created on the timing expressed by a professional actor, the limitations in the KOBIAN's hardware created a sort of Uncanny valley effect [12] which could not be seen in the pictures.

Overall, although the experimental results are not as good as we were expecting, we confirmed the robot can clearly express its emotions, and that very high recognition ratios are possible.

In the future, we would like to improve the current emotional expressions; we would also like to evaluate them with more people from different countries and of different ages. In addition, we will investigate the influence of outer covering and the effects of sound, movement, arms, and whole body. Furthermore, we will investigate what kind of robot is effective in human living environment by human-robot interaction experiment.

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