The Huggable Robot Probo, a Multi-disciplinary Research Platform

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Abstract. The concept of the huggable robot Probo is a result of the desire to improve the living conditions of children in hospital environment. These children need distraction and lots of information. In this paper we present the concept of this new robot. The robot will be employed in hospitals, as tele-interface for entertainment, communication and medical assistance. To communicate according to the social rules, the robot needs the ability to show facial expressions. Using a well defined set of Action Units (AU) it's possible to express some basic emotions. A prototype of the robot's head, capable of showing these basic emotions is presented. In order to express emotions, an emotional interface is developed. The emotions, represented as a vector in an 2D emotion space, are mapped to the DOF used in the robot.

Key words: emotional interface, human-robot interaction, huggable robot, multi-disciplinary research platform

1 Introduction

A hospitalization can have serious physical and mental influences, especially on children. It confronts them with situations that are completely different from the these at home. In hospital, a child's experiences are more limited due to the closed and protective environment, which leads to many difficulties [1]. The social robot Probo will assist in providing information and moral support.

The development of the social robot Probo is part of the ANTY project, of which the main objective is to offer solutions to some specific needs of hospitalized children.

Another aspect of the ANTY project is the creation of a multi-disciplinary research community. The first prototype will be used as a test bed to investigate future possibilities and approaches to anticipate on arising social problems in Probo's work environment. Therefore, collaboration with pediatricians, sociologists and psychologists is a must. New opportunities, such as: Human-Robot Interaction (HRI) and Robot-Assisted Therapy (RAT), will be investigated.

Besides the development of the prototype and the set up of a multi-disciplinary research community, the project also aims at being an educational stimulant for technological innovation by collaborations with other research groups and (high)schools.

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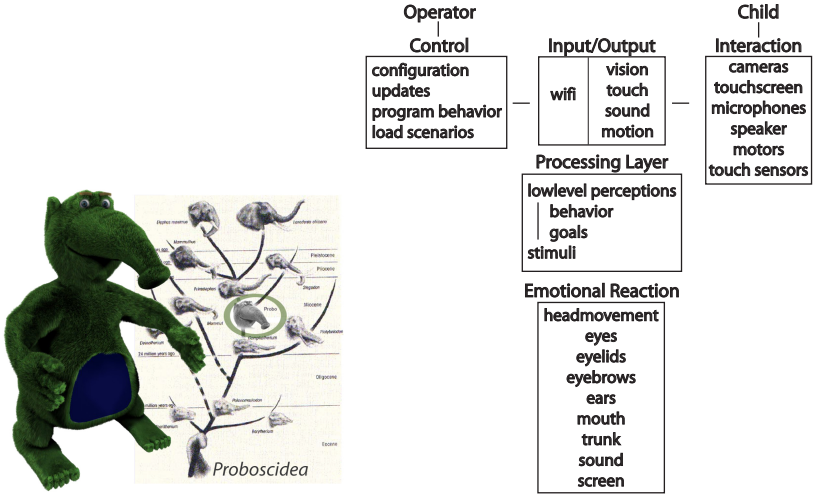
This paper focuses on the conceptual ideas behind the robot Probo and some results of preliminary examinations that lead us to the actual prototype of an actuated robot head, capable of showing facial expressions.

2 Concept Probo

2.1 Operational Goals

In hospital, children need to be distracted from the scary and unfortunate hospital life e.g. by getting in contact with their family and friends. Furthermore, they require moral support and they have specific needs for relevant information about their illness, the hospital environment, medical investigations, etc. [1]. Several projects already exist that aim to use Information and Communication Technologies (ICT) like internet and webcams to allow hospitalized children to stay in contact with their parents, to virtually attend lectures at school and to provide information [2].However, these ICT applications are usually computer animations displayed on PC, television screens or laptops. Moreover, people are used to interact with embodied creatures and have evolved communication skills, which both need a body for expression [3].

Bearing this in mind, the development of a 3D social robot has started. The robot is about 70 cm tall and equipped with a fully actuated head and a touch screen to comfort, inform and address children in a playful manner.



(a) A 3D computer model.

(b) Probo as a Robotic User Interface (RUI) between an operator and a child.

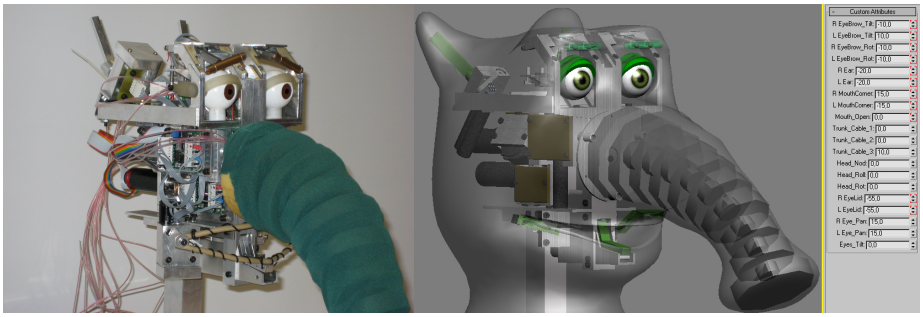
Fig. 1: Concept of the huggable robot Probo.

2.2 Huggable Imaginary Robot Animal

Probo has to be seen as an imaginary animal based on the ancient mammoths. Its name is derived from the word Proboscidea, the order of animals with a proboscis, including the species of the elephant-like mammoths. Figure 1a shows a 3D computer model of the imaginary robot animal, Probo. Its huggable and soft appearance, intriguing trunk, and interactive belly-screen are striking. The internal mechanics will be covered with soft materials and a removable fur-jacket. The green color evokes mainly positive emotions such as relaxation and comfort [4]. A sensitive skin (cf. The Huggable [5]) will establish a full body sense. These sense sensors, together with audio and video sensory, will be used as feedback signals during interaction.

Probo will function as a Robotic User Interface (RUI) between an operator and a child as shown in Figure 1b. First, the robot will be controlled by an operator (caregivers, researchers, medical staff, etc.). Later, vision, audio and touch analysis will generate input stimuli. Those stimuli will influence the attention and emotion system, used to set the robot's point of attention, current mood and corresponding facial expression. In this way the robot operates more and more autonomously and the role of the operator to control the different Degrees of Freedom (DOF) gradually decreases.

3 Actuated Robot head



(a) Prototype of the robotic head. (b) Virtual model of the robotic head.

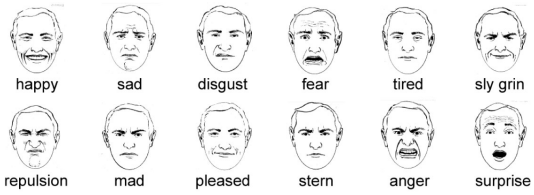
Fig. 2: Probo's actuated head with 17 DOF: eyes (3 DOF), eyelids (2 DOF), eyebrows (4 DOF), ears (2 DOF), trunk (3 DOF) and mouth (3 DOF).

3.1 Expression of Emotions

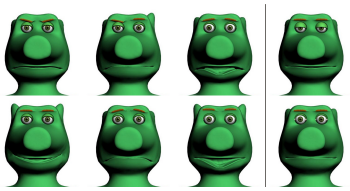
In order to communicate and interact with humans following the social rules, Probo needs the ability to express emotions. Therefore, a fully actuated head, for facial expressions, has been developed. In [6] the importance of facial expressions in human

face-to-face communication is described. For the display of emotions most of the DOF in its face are based on the Action Units (AU) defined by the Facial Action Coding System (FACS) developed by Ekman and Friesen [7]. AU express a motion of mimic muscles as 44 kinds of basic operation, with 14 AU to express the emotions of anger, disgust, fear, joy, sorrow, and surprise. These emotions are often supported as being the 6 basic emotions from evolutionary, developmental, and cross-cultural studies [8].

Figure 2a shows the prototype of the actuated robot head, with a total of 17 DOF [[9]]. Three additional DOF will enable the head to bend, nod and rotate. A virtual model (Figure 2b) of Probo has been created to evaluate our design. The model combines the mechanical designs with the visual exterior of the robot, represented by the skin, attached to the mechanical moving parts. The mechanical parts are linked together to obtain kinematical movements for realistic visual motions of the model. The movements can be controlled with sliders to set the desired angles for the DOF and simulating actuation of the parts. To test the recognition of facial expression the virtual model was used in a preliminary user-study. The study was based on a survey performed by Cynthia Breazeal evaluating the expressive behavior of Kismet [3]. We asked the subjects to compare renderings of the virtual model (Figure 3) with a series of line drawings of human expressions (Figure 3a). The results of these tests are described in [10].



(a) The sketches used in the evaluation, copied from Kismets survey, adapted from (Faigin 1990) [3].



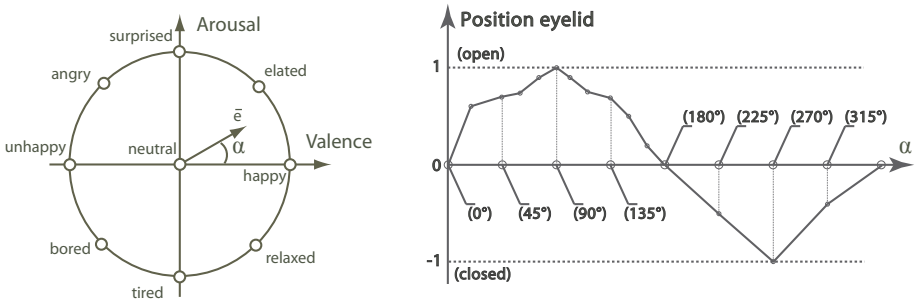
(b) The 6 basic emotions (anger, disgust, fear, happy, sad and surprise) on the left and the expressions tired and neutral on the right.

Fig. 3: Facial expressions used in preliminary user-study.

3.2 Attractive Trunk

The trunk is a special part in contrast with most other robotic heads (eg. [3], [11], [12]) that use eyes, eyelids, eyebrows and a mouth for facial expressions. The proboscis or trunk of our robot appears to be the most intriguing element according to a small survey amongst children aged 10-13. It is used for grabbing and maintaining the child's attention. When the child's attention is focused on the trunk, the child's face fits within the range of on board eye cameras. This simplifies the recognition of children's mood or emotional status. In this way the robot can react properly to different situations and it intensifies certain emotional expressions and it increases interactivity.

4 Emotional Interface



(a) Emotional space based on Russells circomplex model of affect.

(b) Adjustable interface for defining the values of the DOF, in this case an eyelid, for each emotion.

Fig. 4: Display of emotions.

To realize a translation from emotions into facial expressions, emotions need to be parameterized. In [3], Kismet's facial expressions are generated using an interpolation based technique over a three-dimensional, componential *affect space* (arousal, valence, and stance). Cf. [3] our model has two dimensions; valence and arousal to construct an emotion space, based on the circumplex model of affect defined by Russell [13].

Figure 4a shows the emotion space of Probo. The x-coordinate represents the valence and the y-coordinate the arousal, consequently each emotion $e(v, a)$ corresponds to a point in the valence-arousal-plane (Figure 4a). In this way we can specify basic emotions on a unit circle, placing the neutral emotion $e(0, 0)$ in the origin of the coordinate system. Now each emotion can also be represented as a vector with the origin of the coordinate system as initial point and the corresponding arousal-valence values as the terminal point. The direction α of each vector defines the specific emotion whereas the magnitude defines the intensity of the emotion. The intensity i can vary from 0 to 1, interpolating the existing emotion $i = 1$ with the neutral emotion $i = 0$. Each DOF that influences the facial expression is related to the current angle α of the emotion vector. An adjustable interface is developed to define the desired value for each angle $(0° - 360°)$ of the different DOF. By selecting one degree of freedom, we set a value for each basic emotion on the unit circle and use linear interpolation to obtain a contiguous relation. By adding more (optional) points or values the curve can be tuned to achieve smooth, natural transitions between different emotions. An example for the degree of freedom controlling the eyelid is shown in Figure 4b.

5 Conclusion

A fully actuated head, capable of showing facial expressions, has been designed according to the specific needs to express the basic emotions. An emotional interface has been

developed for the expression of a random emotion in a 2D emotion space by means of adjustments of the DOF. Simultaneously, the desired emotion is shown by the virtual model. In this way, all the DOF can be configured and tested without the need for a physical prototype. In the next phase the virtual model will be linked with the software controlling the physical prototype, resulting in a real time control interface that can be used by an operator.

The robotic head is part of the social robot Probo, which main objectives are to comfort, inform and address children in a hospital environment. The huggable imaginary robot animal, Probo, is to be used as a multi-disciplinary research platform. At the moment the possiblities of HRI and RAT are being explored by pediatricians, sociologists and psychologists.

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