Probo, a friend for life?

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A story about robots

"*I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth"*.

These were the famous words of President John F. Kennedy on May 25th 1961 to announce a spectacular financial boost given to the space industry and realize an American dream. And now, the year 2006, people are actually living in the international space station while robots are exploring the Mars surface. All great changes and scientific breakthroughs required a dared vision on the future and persistent believe in technological ingenuity.

A dream alike is shared today in the robotics community to develop a personal autonomous humanoid robot. Imagine a robot whose legged structure is perfectly adapted to the human environment and which is able to walk around and perform some standard household duties, relieving its owners even from the task of instructing him to attend these duties. It welcomes all the family members coming home while recognizing their face and responding to specific inflections in their voices. It will react in an adapted way depending on their mood and emotional state by focusing on facial expressions and specific voice patterns. The humanoid house pal stores personal information of each family member and even tracks their daily schedule to support them as a highly sophisticated personal assistant. This intelligent, skillful and versatile machine will not only coordinate many of our annoying administrative tasks, guard the house, and so on, but will become in a sense an artificial social family partner.

This might rather seem a scenario for a science-fiction plot but this dream is being pursued today, step by step and in many different research disciplines. In the last decade Japan has heavily invested in creating astonishing robot hardware models. House guarding robots such as the four legged robot "Banryu" [1] developed by Sanyo and Tsmuk Inc. are commercially available, the same goes for the humanlike robot on wheels, "Wakamaru" [2], developed by Mitsubishi Heavy Industries. The latter model is intended as a house pal but acts rather as an elaborate computer, able to navigate through the house independently. But one of the most astonishing robotic achievements has been made by

Honda with the development of “Asimo” [3], which is a fully actuated versatile, child-sized humanoid. This robot is able to make highly dynamic running motions, recognize people’s faces and voices and already performs some intelligent navigation although still in a controlled laboratory environment. And surely important to mention is the ambitious and heavily sponsored “Humanoid Robotics Project (HRP)” [4] of the Japanese government, which aims at exploring new applications on industrial, social and private level for humanoid robots and which resulted in the elaborate humanoid robot research platform “HRP-2” [5].

The developments on speech production and recognition, facial display, gesture recognition, multimodal communication and artificial cognitive capacities made the robots more human-like and thus the shared dream came one more step closer to become true. With robot “BIRON” [6], which is a project supported by the EU[1], an important development in human-robot interaction, person tracking, was realized. To enable the robot to detect people who want to interact with him, the robot performs person tracking to detect all people in its vicinity and an attention mechanism selects the communication partner based on sound source localization and the orientation of human faces. BIRON can also talk with its communication partner by first analyzing the spoken instruction via speech recognition and then processing it in the speech understanding module to extract the semantics of the spoken instruction. The robots created by Angelo Cangelosi and colleagues at Plymouth University, UK[2] [7], can even teach each other new words or phrases by combining words previously learned in their verbal communication. The “Talking Heads experiments” by Luc Steels[3] [8] and colleagues, late nineties, raised questions in similar research; how do words get their meaning? How should machines interact with humans? And is Artificial Intelligence (AI) possible? On the other hand “iCat” [9], which is a robot cat developed by Philips, demonstrates another human capability, social intelligence, during a game set via verbal interaction and expresses emotional states by facial expressions. The effects of emotion in speech tend to alter pitch, timing, voice quality and articulation of the speech signal. Taking into account these effects, robots will be able to distinguish its owner’s voice from those of other people and to recognize the emotions on the voice by continuously listening to what the owner says, computing the intonation parameters of the sentences it hears and classifying them to react in an appropriate expressive mood to the detected emotion [10].

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If a robot is intended to interact with people, it needs an active vision system that can serve both a perceptual and communicative function. An active vision system is able to interact with its environment by altering its viewpoint rather than passively observing it. Since its cameras can move, the range of the visual scene is not restricted to that of the static view. Regarding the real-time and real-world space perception, it needs a stereo-vision system with obstacle detection and requires adequate software algorithms. On top of the detection system, path planning including real-time SLAM (Self Mapping and Localisation) is needed and poses a real challenge, especially for legged robots [11]. Several technologies such as face detection, identification, and stereo-vision with obstacle avoidance behaviour are already implemented in Sony "Qrio" [12]. Since the vision sensor has a limited view angle, it is impossible to view simultaneously the multiple objects whose locations are distributed wider than the view angle. Thus, the robot needs the capability of memorizing the objects' spatial locations, so that the robot can behave intelligently with objects naturally distributed in a real world setting. A dialogue using the long-term memory gives the perception of higher intelligence to a user than a dialogue without memory. Beside "Image Processing" research at the IRIS[4] research group at the VUB[5] is also focussed on "Machine Vision" (e.g. facial analysis and synthesis).

One of the newest applications of AI is the creation of sociable robots. Autonomous sociable robots use their own internal goals and motivations to become socially participative "creatures". They pro-actively engage people in a social manner not only to benefit the person (e.g., to help perform a task, to facilitate interaction with the robot, etc.), but also to benefit itself (e.g., to promote its survival, to improve its own performance, to learn from the human, etc.) [13]. Hence, social interactions with people are valued not just at the interface, but at a higher level as well. Such robots not only perceive human social indications, but at a higher level also model people in social and cognitive terms in order to interact with them. The robot maps the human's social model to underlying computational systems. Therefore the robot's social behavior is a product of its computational social "psychology". An example of such a sociable robot is "Kismet" [14] of the MIT[6] Artificial Intelligence Lab. Kismet is designed to be a robotic creature that can interact physically, affectively, and socially with humans in order to ultimately learn from them. The robot is designed to elicit interactions with the human that afford rich learning potential. Kismet has a substantial amount of infrastructure that should enable the robot to leverage from playful, infant-like interactions to foster its

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social development. These skills and mechanisms help it to cope with a complex social environment, to tune its responses to the human, and to give the human social cues so that he/she is better able to tune him/herself to Kismet. This allows the robot to be situated in the world of humans without being overwhelmed or under-stimulated [15].

Most of the novel robotic applications mentioned above are created in Japan, where not only the government is heavily investing but most of the effort is given by the big Japanese Companies. Some major players in humanoid robotics are Honda ("Asimo") and Toyota ("Partner Robot" [16]) who lead in a technology race amongst each other, but also companies such as Fujitsu ("Hoap" [17]) and Sony ("Aibo" [18] and "Qrio") have humanoid robot projects. For the more general social robots and novel robotic applications in a direct human environment an extensive list of commercial activity can be drawn, ranging from automatic vacuum cleaners, e.g. the "Roomba" of the American company iRobot [19], to mobile interactive tour guiding robots for museums, e.g. "RoboX" of the Swiss company BleuBotics [20]. Although the latter two companies are not Japanese, one can say that most commercial activity is being developed in Japan which might be a thread for the future positioning of European businesses, since it is expected that this new domain in robotics will definitely boom. Recent predictions of the Japanese Robot Federation expect the robotics market to represent 35 Billion dollars by the year 2010 (left Fig.1.), which is larger than the current Japanese PC market. The market of semiconductors was characterized by several waves: going from the analog wave over the first digital wave of the personal computer to the second digital wave focusing on consumer networks. Subsequent to these waves, the robotics wave is expected to take place (right Fig.1.). These developments should be watched carefully in Europe, and investing in emerging robotic technologies might not only be a step closer to realize an ambitious technological dream but moreover be essential to be able to participate in a promising global economic activity.

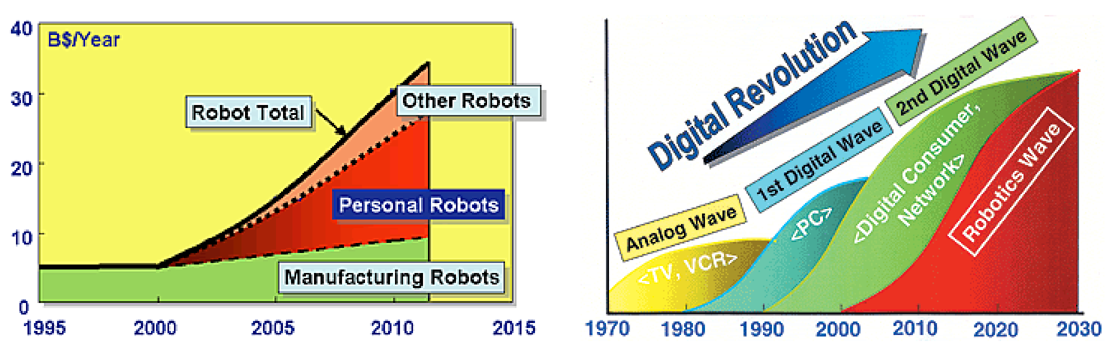

Fig.1. Predictions of the Japanese Robot Federation on the increasing market for personal and assistance robots[7]

Who is Probo?

About two years ago Ivan Hermans, president of the Anty Foundation [21], visited the MECH[8] department of the VUB, in his search for a technology partner to realise his youth dream: creating an intelligent huggable robot that is able to play with hospitalized children, thus making the hospital a livelier place. His enthusiasm combined with the stamina of some researchers resulted in an ambitious project aiming at the development of this robot and the creation of a multidisciplinary research community concerning autonomous social robots. The project, financially sponsored by the Brussels Capital Region, started with the combined efforts of the R&MM[9] and DSSP[10] research groups of the VUB and is currently enlarging its community in a wide range of expertise, such as, speech technology, machine vision, artificial intelligence, psychology, etc.

In Belgium alone some 300.000 children are hospitalized for long periods of time or suffer from chronic diseases [22]. These children have a strong need to be distracted from the scary and at the same time boring hospital live by e.g. getting in contact with their family and friends. Furthermore, they have specific need for adapted information about their illness, the hospital… and in general they require a lot of moral support. Different projects exist which aim to use Information and Communication Technologies (ICT) like Internet and webcams to allow these children to stay in contact with their parents, to virtually attend lectures at their school, etc. [22], [23]. Probo addresses both the information and communication aspects and the need for support and companionship of hospitalized children [24].

Probo is an imaginary animal type with its own identity, including a name, a history and also friends and family. The name Probo is derived from the word proboscidea. Proboscidea is an order containing species of the elephant-like mammoths and mastodons. Probo has to be seen by the children as a friend who is visiting them. Probo's visit will distract the children from their hard daily reality in the hospital and will make them feel special. The around 60 cm tall robotic pal (Fig.2.) will recognize the children's

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[7] Summary Report on Technology Strategy for Creating a "Robot Society" in the 21st Century, Japan Robot Society.

[8] Department of Mechanical Engineering

[9] Robotics & Multibody Mechanics research group, department of Mechanical Engineering

[10] Digital Speech and Signal Processing research group, department of Electronics and Informatics

emotions on the one hand and will show its own emotions by making use of facial expressions, gestures and speech on the other hand.

Fig.2. Artists rendering of Probo, a huggable robot

To create a window to the outside world Probo will use a (touch)screen in its belly. A child, aged 3-8, is exploring the world and is very creative. Showing interactive educational games and information on the screen will distract the child and at the same time stimulate further development of its senses. Besides, the screen is an interface to the worldwide web and allows contact with family, classmates, and friends, etc using standard videoconferencing techniques. As such the child will feel less isolated and will keep contact with its favorite ones. In our modern highly informative society it is important to integrate personal computers in the life of children at a young age. The use of Probo and its enjoyable interface instead of a regular PC or laptop can lower the child's ICT apprehension threshold and capitalize on the curiosity of the child. This concept can be used not only for hospitalized children but also for children in general or even seniors. And last but not least, the screen in Probo's belly can be used by medical staff to make the children easy about medical routines or operations by providing appropriate information via their pal Probo. In the same philosophy, Probo can accompany the child to comfort it during difficult medical procedures. Thus in summary, Probo has to act as a semi-autonomous agent for entertainment, communication and medical applications.

Probo's prototype

Although Probo will look and behave like a huggable pal for hospitalized children, it implements some design restrictions. Strict rules concerning hygiene, mobility, noise, usage of electronic devices, etc are applied in hospitals. The robot will be devoted to children (no one knows better how to break stuff), so it has to be strong and light while still being pleasing to the touch. These demands imply restrictions on used materials, actuation mechanisms and overall control strategies. The design, realization and control of the movements of Probo's prototype will be studied by the R&MM research group within the VUB department MECH.

Probo has to be seen as a real living huggable pal with its own identity, so the creativity and imagination of the children is very important in the conceptual design of the creature. That's why Probo's colors, looks and shape have been chosen by children themselves. In the first prototype the movements are limited: the head with trunk, mouth, eyes, eyelids, eyebrows and ears will be actuated. Probo's arms will not be actuated but will be made out of a flexible material so that they can be placed in a desired position and hold some specific tools. The body which holds the screen and the legs and feet will be static. Meanwhile the R&MM research group will develop an arm and grasping mechanism which can be implemented in the prototype later on.

The actuators will not use standard motors but a principle of soft actuation. Soft actuation is an innovative actuation principle in the world of robotics. In fact it is the opposite of a classic high precision positioning actuator, typically used in industrial applications. Soft actuation has an inherent flexible behavior by placing elastic elements in series with the motor before attaching the actuated robot joint. This way the joint can easily be moved when an external force acts on it. A standard motor actuation does not allow much external deviation due to the high reflected inertia of the transmission unit and must thus be seen as a rigid joint. Soft actuation gains a lot of interest in the social robot community which has no need on accurate position control but prefer intrinsic safety and flexibility. The use of the soft actuation principle together with well-thought designs concerning the robot pal's filling and huggable fur is essential to create Probo's soft touch feeling.

By providing the possibility of moving the head, showing facial expressions and sound production on the one hand and make use of data captured through built in cameras and microphones on the other hand, it will be possible for Probo to communicate with the children. The prototype of Probo will have a simple form of artificial intelligence (AI); it will react autonomously in a basic environment although it will bear a living pet-likeness. Parallel to the internal AI of Probo an operator can take control of some behaviors of

Probo by a tablet PC, provided with a specific GUI[11] and wireless connection to the robot. This way Probo's functionalities increase spectacularly and allow an operator to make Probo react more properly to specific situations. To ensure the coherence of Probo's identity, an a priori choice has to be made for each child whether Probo will be presented in its autonomous version or controlled by a human. Additional possibilities are that a human operator simulates an autonomous control program by following a prescribed protocol to determine what Probo should do next (such experiments are often referred to as wizard of Oz experiments [25]).

A first prototype is primordial to reach the ambitious underlying objective of the entire project; the development of a technological multidisciplinary pool around robotics, including a wide irradiation which can positively influence certain essential evolution towards technology in our society. This ambitious project is started in October 2005 with two Phd students, supported by the Brussels Capital Region, and the first prototype is expected at the end of 2008. Until now many researchers and students have joined the Probo-team to work on projects within the entire concept, e.g. the development of Probo's fur which will be completed at the end of 2006. A preliminary head/neck system is used at the moment as a test case for further development.

Probo's face to face communication

We rely on face-to-face communication in our daily life. Mehrabian, Professor at the University of California Los Angels, showed that only 7% of information is transferred by spoken language, that 38% is transferred by paralanguage and 55% of transfer is due to facial expressions [26]. Facial expression is therefore a major modality in human face-to-face communication. Several theorists argue that a few emotions are basic or primary. They are selected by evolution because of their proven ability to facilitate adaptive responses to the vast array of demands and opportunities a creature faces in its daily life (Ekman, 1992; Izard, 1993) [27], [28]. The emotions of anger, disgust, fear, joy, sorrow, and surprise are often supported as being basic from evolutionary, developmental, and cross-cultural studies (Ekman and Oster, 1982) [29]. These emotions will be expressed by Probo using its facial expressions and the production of sound and speech. The idea of the emotional communication is to process the inputs from the sensors and translate them into perceptions. Those perceptions are evaluated by the behavior, the current emotion and the current drive to trigger an appropriate reaction, possibly mimicking some emotion response [30].

[11] Graphical User Interface

Human’s diverse ways of communicating with each other, is one of the most important elements in a social society. The ability to use different communication channels effectively is essential for a good participation in our society. We need the abilities to speak, to feel empathy and to build strong friendships. Development of these abilities starts at the early ages and will have an impact on our further life. Children who have communication impairments are at a disadvantage in every way, including their ability to be educated, their success on social, academic and vocational life [31]. Therefore, special care should be given to hospitalized children since they are far from the natural environment needed to develop their socialization skills [22]. Probo is one of the projects that focus on that.

Because Probo has its own identity it can try to build up a personal friendship with a child. It is important for the children that they can identify themselves with their friend Probo and that they can talk about their family and friends. Probo needs to have the children’s attention to initiate and maintain a face-to-face communication. The robot pal will try to make eye-contact and use the movements of its trunk together with the creation of sounds to grab their attention. When doing face-to-face communication, the facial expressions become very important. A fully actuated head will give Probo the ability to produce facial expressions and to show its emotions. Implementing a voice and a nonsense language will complete Probo’s communicational skills. This language will be cross-cultural and understandable for most of the children regardless of their own native language.

Besides communicating its own emotions to the children, Probo will also be able to recognize certain moods and emotions expressed by the children. Sometimes a child's emotions are not that obvious and, like all of us, children can experience several emotions at the same time. It is hard to discover what a child is feeling at a certain time. We can try to analyze the child's body language; we can listen for hints in a child's tone of voice and search for clues in a child's facial expression. Recent research topics about how children's emotional development can affect both their physical and mental health gain a lot of interest by scientists. Those studies show that children who are “emotionally intelligent” are more likely to be self-confident, perform better in school, have less behavioral problems, have better overall health, get along better with friends and others, and can process their parents' marital conflict better [32]. Probo can be used in the term of robot assisted therapy to improve the development of the children’s emotional intelligence and social skills. Currently, Probo’s emotion recognition module is purely speech based: several acoustic characteristics of the child’s speech are measured and form the basis for classifying the speech as belonging to one of a set of predefined attitudes or emotions, such as neutral, anxious, commanding, begging, etc. While our current system achieves state of the art performance, it requires a substantial amount of child specific training data to learn the classifier and we are therefore actively researching how to make Probo's vocal emotion recognition module speaker (child) independent [35].

Probo's nonsense speech

"Whenever I hear people talking about "liberal ideas," I am always astounded that men should love to fool themselves with empty sounds. An idea must be vigorous, positive, and without loose ends so that it may fulfill its divine mission and be productive. The proper place for liberality is in the realm of the emotions."
Johann Wolfgang von Goethe (1749 - 1832)

When people speak, by nature they use acoustic effects in their voice. These acoustic effects are of great importance for the expression of emotions and feelings. Vocal communication and expression of emotions appears to be language independent to some extent [33]. So we can easily recognize emotions even in a language which we don't understand. Dr. Robert W. Schrauf, associate Professor of applied linguistics at Penn State, has suggested that all cultures have in common a small number of "emotional" words, but that every culture has multiple ways, sometimes quite different, of making nuance to them. Probo's speech communication will take into account that approach. Probo will speak a non-existing language and will be able to express primary emotions.

Human-like speech requires naturalness and naturalness requires emotions. Today's e-creatures don't have feelings. However some of them can fake emotions amazingly well, making their interaction with humans more natural. As Probo will be communicating primarily with hospitalized children, whose reactions are very emotional due to their unfortunate situation, it is essential to apply emotions to Probo's speech communication. Alongside the vocal emotion recognition module, the language and speech production of Probo is also being studied by the DSSP research group within the VUB.

Because an intelligent free dialog with a human is currently beyond our technological capabilities, Probo will speak to the child using nonsense affective speech. In one of our current approaches [34], this speech is produced by using a database with natural expressive speech samples and a database with naturally spoken speech samples both recorded with a professional speaker. From the neutral speech examples, carrier sentences of the non-existing language of Probo will be produced by firstly segmenting the recorded utterances into several nonsense syllables and then concatenating them in the same syllabic structure as the desired emotional prosodic template which is selected from the expressive database. To produce emotional speech for that non-existing language, the same pitch and timing structure as found in the prosodic template are copied on the nonsense carrier phrase, a process that is known as prosodic transplantation and that effectively provides the synthetic output with a same intonation pattern as the natural expressive example [35] (Fig.3.). This can be viewed as a more natural sounding alternative to the synthetic generation of expressive prosody [10] and [15], at the expense of requiring examples of all relevant patterns to be prerecorded and stored in the database.

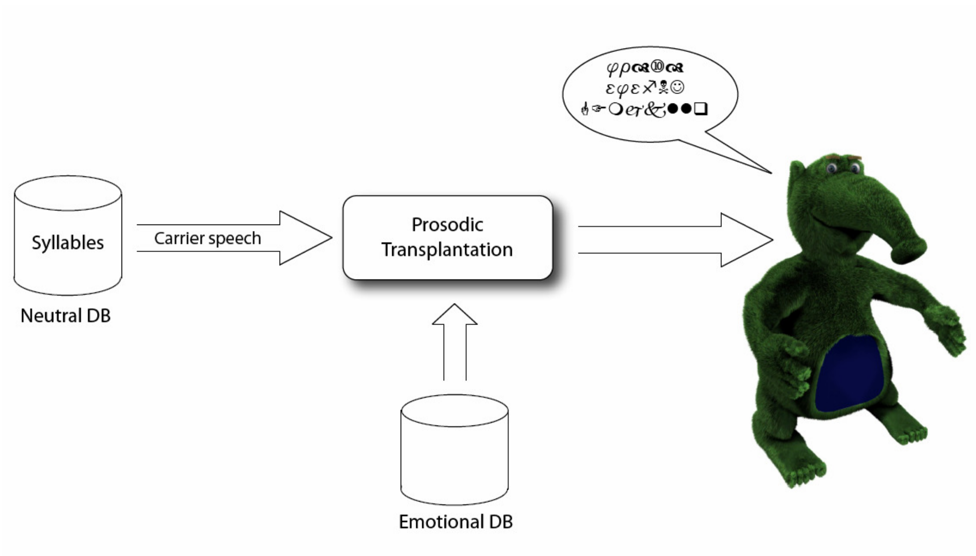

Fig.3. Emotional Nonsense Speech Production of Probo

Four primary human emotions including anger, joy, sadness and fear are expressed in the current prototype synthesis system. When the right emotions are applied to the nonsense carriers, Probo's voice will become natural and realistic. These human-like communicative skills together with its enjoyable interface should make Probo a very suitable friend.

Probo from weeping to smiling

The realization of such large-scale multidisciplinary project has to be divided in several steps. In a first phase, the robot will be used as an intelligent interface between researchers and children. Let's call it a "Robotic User Interface" (RUI) (Fig.4.). Later on in a second phase, the robot will become more and more autonomous. The researcher can load scenarios and choose a specific behavior for the robot. Children can interact with the robot by speech, vision and touch.

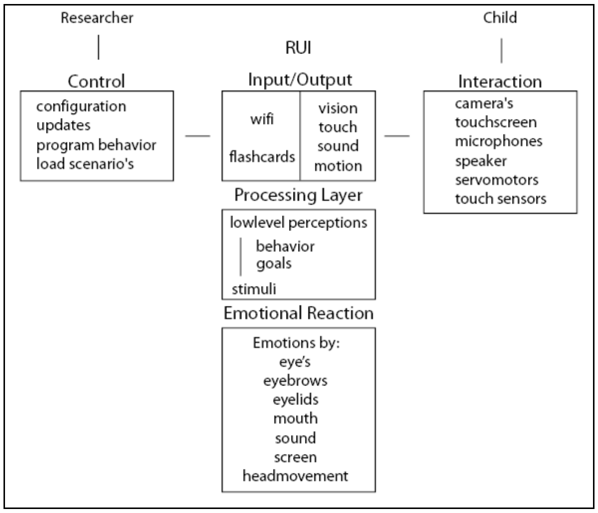

Fig.4. Robotic User Interface (RUI) for Probo

Depending on the configuration and settings done by the researcher, the robot processes the information from its inputs (audio, visual, touch) to generate the appropriate action and emotional status. The inputs are first filtered and analyzed into low-level perceptions. These perceptions will be assessed by the behavior and the active goals.

The method of processing is determined by the behavior system that is controlled by the researchers. A specific behavior-based framework will be developed to obtain this system. The framework will be based on earlier work of Ortony, Norman and Revelle [36], who focus on the interplay of affect, motivation and cognition in controlling behavior. Each is considered at three levels of information processing: the “reactive” level is primarily hard-wired and has to assure the quick responses of the robot making it look alive; the “routine” level provides unconscious, un-interpreted expectations and automotive activity; and the “reflective” level supports higher-order cognitive functions, including behavioral structures and “full-fledged” emotions. Gradually this framework will be implemented starting with the reactive level and building up towards the final goal where Probo has the ability to actually produce emotions based on the interaction, and express them to the outside world. When Probo is weeping, the children can try to bring comfort and put a smile on Probo’s face.

Prospects on the future

In the first phase of the project, which includes the construction of the prototype, the information will only be processed on the reactive level and most of the control is done by an operator. An important example of such a reactive process is the attention system that focuses the head and eyes on a preferred point of interest. In the second phase the routine and reflective level to make Probo more intelligent and autonomous will be developed.

Another aspect of the project is the creation of a multidisciplinary research community. The prototypes of the robot will be used to investigate future possibilities and approaches to anticipate on arising problems for Probo. Therefore collaboration with pediatricians, sociologists and psychologists is a must for the further growth of the project. Together with the medical staff new opportunities, such as "Robot-Assisted Therapy" (RAT), will be studied. In robot-assisted therapy, children's moods can be improved by interaction with a robot. Moreover, the robot "Paro" [37] encouraged children in a hospital to communicate both with each other and with their caregivers. In one striking instance, a young autistic patient recovered his appetite and his speech abilities during three weeks of treatment when the Paro was at the hospital [38].

Beside the development of the robot Probo, the project also aims to be an educational stimulant for technological innovation. All types of students from secondary schools, high schools and universities are very motivated to work on smaller projects, which find there place inside the bigger project.

This is just the start for the exploration of Probo's capacities. In the future we can think of Probo being the huggable friend the children always dreamt of. The soft, caring buddy that listens and soothes them when they feel alone and not understood. The silly and funny pal that warms their hearts and makes their eyes twinkle. The one and only friend they embrace for life. Now the final question is; could you open yourself up to a friend like Probo?

More information at: http://anty.vub.ac.be

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