The Reign of Catz & Dogz

The second AISB symposium on the role of virtual creatures in a computerised society

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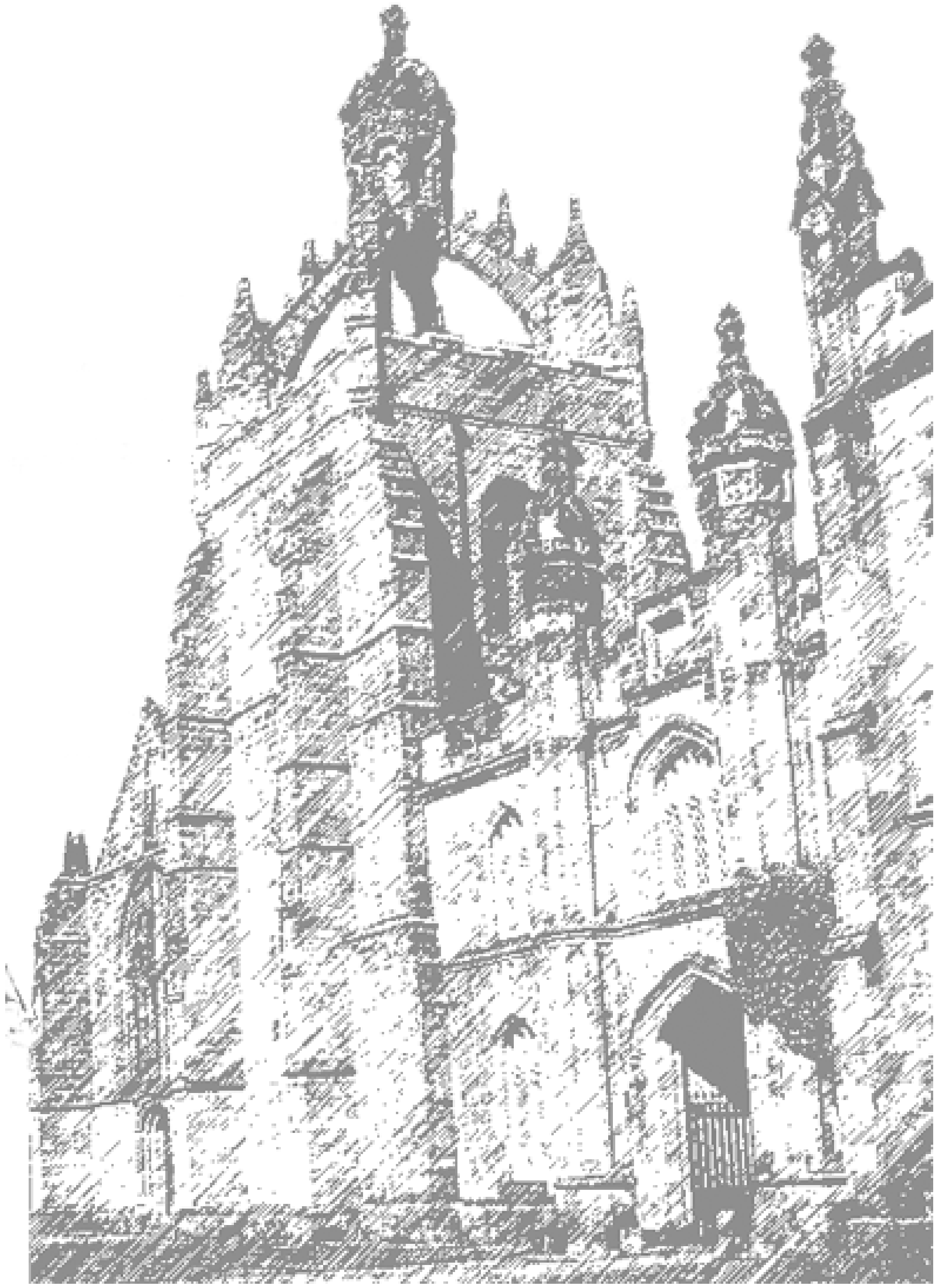
AISB '08



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The second AISB symposium on the role of virtual creatures in a computerised society

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The AISB'08 Convention: Communication, Interaction and Social Intelligence

As the field of Artificial Intelligence matures, AI systems begin to take their place in human society as our helpers. Thus it becomes essential for AI systems to have sophisticated social abilities, to communicate and interact. Some systems support us in our activities, while others take on tasks on our behalf. For those systems directly supporting human activities, advances in human-computer interaction become crucial. The bottleneck in such systems is often not the ability to find and process information; the bottleneck is often the inability to have natural (human) communication between computer and user. Clearly such AI research can benefit greatly from interaction with other disciplines such as linguistics and psychology. For those systems to which we delegate tasks: they become our electronic counterparts, or agents, and they need to communicate with the delegates of other humans (or organisations) to complete their tasks. Thus research on the social abilities of agents becomes central, and to this end multi-agent systems have had to borrow concepts from human societies. This interdisciplinary work borrows results from areas such as sociology and legal systems. An exciting recent development is the use of AI techniques to support and shed new light on interactions in human social networks, thus supporting effective collaboration in human societies. The research then has come full circle: techniques which were inspired by human abilities, with the original aim of enhancing AI, are now being applied to enhance those human abilities themselves. All of this underscores the importance of communication, interaction and social intelligence in current Artificial Intelligence and Cognitive Science research.

In addition to providing a home for state-of-the-art research in specialist areas, the convention also aimed to provide a fertile ground for new collaborations to be forged between complementary areas. Furthermore the 2008 Convention encouraged contributions that were not directly related to the theme, notable examples being the symposia on "Swarm Intelligence" and "Computing and Philosophy".

The invited speakers were chosen to fit with the major themes being represented in the symposia, and also to give a cross-disciplinary flavour to the event; thus speakers with Cognitive Science interests were chosen, rather than those with purely Computer Science interests. Prof. Jon Oberlander represented the themes of affective language, and multimodal communication; Prof. Rosaria Conte represented the themes of social interaction in agent systems, including behaviour regulation and emergence; Prof. Justine Cassell represented the themes of multimodal communication and embodied agents; Prof. Luciano Floridi represented the philosophical themes, in particular the impact of society. In addition there were many renowned international speakers invited to the individual symposia and workshops. Finally the public lecture was chosen to fit the broad theme of the convention – addressing the challenges of developing AI systems that could take their place in human society (Prof. Aaron Sloman) and the possible implications for humanity (Prof. Luciano Floridi).

The organisers would like to thank the University of Aberdeen for supporting the event. Special thanks are also due to the volunteers from Aberdeen University who did substantial additional local organising: Graeme Ritchie, Judith Masthoff, Joey Lam, and the student volunteers. Our sincerest thanks also go out to the symposium chairs and committees, without whose hard work and careful cooperation there could have been no Convention. Finally, and by no means least, we would like to thank the authors of the contributed papers – we sincerely hope they get value from the event.

Frank Guerin & Wamberto Vasconcelos

The AISB'08 Symposium on the Reign of Catz and Dogz '08: The second AISB symposium on the role of virtual creatures in a computerised society

The Reign of Catz & Dogz symposium aims to explore aspects of interaction with anthropomorphised embodied devices such as Aibo, Pleo, Paro and Nabaztag, software such as Catz, Dogz and Nintendogs, as well as the numerous non-commercial devices and systems that have been developed in many research labs. Manufacturers market these devices as human companions for people of all ages: Tiger Toys Furby is meant for children, Sonys Aibo was (Sony have sadly discontinued this product) aimed at people in their twenties and thirties, and Matsushitas Tama is targeted at older people. Virtual pets started to gain worldwide popularity in the late 1990s when Japanese toy manufacturer Bandai released the Tamagotchi. About the size of a key ring, a typical Tamagotchi had a small black and white screen, three buttons, a speaker, a motion sensor and a microphone. Users could feed, clean and play with their Tamagotchi, call it via the microphone and chase away predators by shaking the unit. The pet would evolve over time and would eventually either die or fly away. It is clear that many users became attached to their pet, with many actually mourning its death. Turkle [1] has labelled answers to the question of how we should interact with such devices, important, even 'urgent'.

The world-wide popularity of many of the commercial examples of such artefacts provides evidence of the widespread appeal of interacting with artificial representations of creatures. Despite this huge commercial success, fundamental, unanswered, questions remain as to the benefits, companionship, or enjoyment that users gain from owning a virtual pet. It is also unclear, for instance, as to whether different people play, or interact, with virtual pets for differing reasons.

Catz & Dogz '08 will consider the future role that interactive artificial creatures will play in a society populated with pervasive computers, personal robots and ambient intelligence, following on from the successful Catz & Dogz '07 symposia.

The day will feature four invited speakers. Delegates will be able to attend the AISB plenary speaker, Jon Oberlander from University of Edinburgh. In addition, three speakers are coming specifically for Catz & Dogz. Christoph Bartneck has been active in social robotics research for many years and has been a key player in this area. He is an assistant professor in the Department of Industrial Design at the Eindhoven University of Technology with a background in Industrial-Design and Human-Computer Interaction. Graeme Ritchie from Aberdeen University will be talking about his research on computational humour V applying AI to write jokes. This should be of interest to delegates who may some day want to give their devices the ability to be humourous. Lastly, David Benyon from Napier University will give delegates an undate on the Companions Project, a 4-year, EU funded Framework Programme 6 project, involving a consortium of 16 partners across 8 countries. The aim is to develop a personalized conversational interface, one that knows and understands its owner, and can act as an alternative access point to resources on the Internet.

The range of papers being presented is wide. Steve Yohanan from the University of British Columbia is talking about the sensation of touch and using touch to interact with devices. This is espcially relevant to virtual pets given the propensity of people to interact with pets, especially dogs, through stroking. Kristof Goris and Jelle Saldien from Vrije Universiteit Brussel, discuss their robot Probo, a social device intended to be used with children in hospitals. Cheng Guo from Calgary will present on interfaces, alternative to keyboard, mouse and monitor, to interact with robots using the human skills of spatial awareness and physical object manipulation. Finally, in what is probably our most technical paper, Ben Goertzel is presenting a method for simulating emotion driven beahviour in robots. Ben is on the board of a number of companies exploiting his AI research.

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On the design of an emotional interface for the huggable robot Probo

Jelle Saldien and **Kristof Goris** and **Bram Vanderborght** and **Dirk Lefeber**[1]

Abstract. Recently, more robots are being created to interact with human beings in order to satisfy certain social needs. From this point of view we started with the development of a social robot named Probo, intended to comfort and emotionally interact with hospitalized children. In this paper we present the objectives of this new robot and describe the concepts of the first prototype. The robot will be employed in the hospital, as a tele-interface for entertainment, communication and medical assistance. Therefore it requires the ability to express emotions, in order to do so, an emotional interface is developed to fully configure the display of emotions. The emotions, represented as a vector in an emotion space, are mapped to the degrees of freedom used in our robot. A 3D virtual model is created, providing realistic visual feedback to evaluate our design choices for the facial expressions. Images of these expressions were used in a comparison test with children.

1 INTRODUCTION

The development of the huggable robot Probo is part of the ANTY project, of which the main objective is to bring some solutions to the problems and special needs of hospitalized children. A hospitalization has a serious physical and mental influence, particularly on children. It confronts them with situations which are completely different from the ones at home. In hospital, children's experiences are more limited due to the closed and protective environment, which leads to many difficulties [11].

In medical applications, especially in the United States, animal-assisted therapy (AAT) and animal-assisted activities (AAA) are becoming commonly used in hospitals [5]. AAT and AAA are expected to have useful psychological, physiological and social effects. Some psychological studies have already shown that animals can be used to reduce heart and respiratory rate [1], lower levels of stress [2], progress mood elevation and social facilitation. Nonetheless animals are difficult to control, they always have a certain unpredictability, and they are carriers of disease and allergies. Therefore, the use of robots instead of animals has more advantages and has a better chance to be allowed in hospitals. Recently, social pet robots are utilized just for these purposes, termed robot-assisted therapy (RAT). For example the seal robot Paro, who is used for pediatric therapy at university hospitals [20][21]. Currently, Sony's dog robot AIBO [24], Philips' iCat [25] and Omron's NECORO [14] are also being tested for RAT.

The main idea for our robot Probo is to create a friend for children, functioning as an interface between the real, sometimes hard and difficult, hospital world and the imaginary and happy, fantasy world in which children grow up. The robot will also be used as a multidisciplinary research platform, giving other researchers the opportunity to improve and explore the possibilities of RAT. Communication will be the first focus of this robot, having a fully actuated head, capable of expressing a wide variety of facial expressions in contrast to the robots Paro, Aibo and NECORO. The robot iCat also focuses on the facial expression of emotions but lacks the huggable appearance and warm touch that addresses to the children. Probo will emphasize his expression of emotions by using his nonsense affective speech.

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2 PROBO

2.1 A huggable robotic imaginary animal

Figure 1. A 3D computer model representing the huggable robot Probo.

The name *Probo* is derived from the word ***Proboscidea***, the order containing only one family of living animals, ***Elephantidae*** or *the elephants*, with three living species (African Bush Elephant, African Forest Elephant, and Asian Elephant) [26]. During the period of the last ice age there were more, now extinct species, including a number of species of the elephant-like *mammoths* and *mastodons*.

The external of the robot in figure 1 resembles an imaginary animal based on the ancient mammoths. The main aspects are a huggable appearance, an attractive trunk or proboscis, and an interactive belly-screen. The internal mechanics of the robot will be covered with foam and a removable fur-jacket, in such a way that Probo looks and feels like a stuffed animal. With this approach, choosing an imaginary animal as the basic design, there is no exact similarity with a well-known creature. Thereby avoiding Mashiro Mori's uncanny valley [16], stating that as a robot increases in humanness, there is a point where the robot is not fully similar to humans but the balance between humanness and machine-likeness is uncomfortable for a user. The combination of a caricatured and zoomorphic [9] representation of a mammoth-like animal is more useful and effective to accomplish our goals, than using more complex, *realistic* representations. The color of our robot is green, because this color evokes mainly positive emotions such as relaxation and comfort. In [13] the relationship between color and emotion were tested, whereas the color green attained the highest number of positive responses (95.9%), closely followed by yellow (93.9%). The majority of emotional responses for the green color indicated the feelings of relaxation and calmness, followed by happiness, comfort, peace, hope, and excitement. Green was associated with nature and trees, and thus creating feelings of comfort and soothing emotions.

2.2 A tele-interface

We want to employ our robot Probo as a tele-interface focusing on entertainment, communication and medical assistance. A touch screen in the belly of the robot creates a window to the outside world and opens up a way to implement new and existing computer applications.

2.2.1 Entertainment

Young children have a need for distraction and entertainment, providing them with a robotic user interface (RUI) will extend the possibilities of interactive game playing and include the capability of emotional feedback.

2.2.2 Communication

Hospitalized children are sometimes placed in a social isolated environment, strongly reducing the communication with friends and family. The robot can function as the perfect interface to contact others using standard videoconferencing techniques. The eyes of the robot will house the cameras, whereas the screen in the belly will display the image, resulting in the possibility to do interactive video-communication.

2.2.3 Medical Assistance

The robot interface 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. The unknown environment will be first explored and examinations will be described in a child friendly manner. By using predefined scenarios with pictures, video and sounds Probo can pre-experience, by using its emotions, the medical routines together with the child. A good preparation before the examinations will reduce the child's fear, providing the doctor with better results when assessing the child's pain factor.

2.3 A social interface

The children will have some basic expectations as the robot represents a living animal, resulting in the necessity to react on primary stimuli and to have natural movements. In order to establish some bond with the children, Probo must be able to communicate. In our daily life we rely on face-to-face communication and the face plays a very important role in the expression of character, emotion and/or identity [6]. Mehrabian [15] 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. Facial expression is therefore a major modality in human face-to-face communication. To start face-to-face communication with children our robot is equipped with an intriguing trunk, provoking the children to interact with the robot and stimulate them to maintain focused on its face.

In [3], Breazeal defines four classes (social evocative, social interface, socially receptive, sociable) of social robots in terms of (1) how well the robot can support the social model that is ascribed to it and (2) the complexity of the interaction scenario that can be supported. With this project we want to start working with our robot as a social interface, providing a *natural* interface by employing human-like social cues and communication modalities. In this first phase the focus is the construction of a physical prototype with an actuated head,trunk and facial expressions.

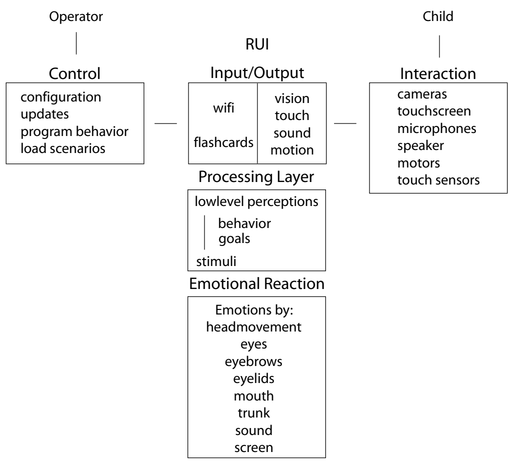

Figure 2. The Robotic User Interface (RUI) between an operator and the children

2.4 Operational Concept

At first, the prototype is a RUI (Figure 2) interacting with the children and controlled by an operator. The operator can be anyone who wants to communicate with the child, in particularly caregivers and researchers. The robot functions as an interface performing preprogrammed scenarios and reacting on basic input stimuli. The input stimuli, coming from low-level perceptions, are derived from vision analysis, audio analysis and touch analysis. Those stimuli will influence the attention- and emotion-system, used to set the robot's point of attention, current mood and corresponding facial expression. The vision analysis includes the detection of faces, objects and facial features such as facial expressions. Audio analysis includes detecting the direction and intensity of sounds and the recognition of emotions in speech.

To realize a full, body sense of touch, a sensitive skin needs to be implemented. A good example is being developed (by Stiehl et al. [23]) for a therapeutic robotic companion named: The Huggable. A specific behavior-based framework is being developed to process these input stimuli. The framework is based on earlier work of Ortony, Norman and Revelle [17], 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 scenarios and automotive activity; and the reflective level supports higher-order cognitive functions, including behavioral structures and *full-fledged* emotions, finally resulting in a sociable robot. As we start out with a social interface, the reactive and routine level are being implemented. At this stage there is a shared control between the operator, configuring behavior, emotions and scenarios, and the robot, having basic autonomous reactions. Further research and development is needed to enhance the robot's emotions and behavior, by implementing a cognitive software architecture at the reflective level to successfully reach a sociable robot in the end. Therefore we started with the study and implementation of joint attention mechanisms for human-robot communication.

2.5 Display of emotions

For the display of the emotions most of the Degrees Of Freedom (DOF) in the face are based on the Action Units (AU) defined by the Facial Action Coding System (FACS) developed by Ekman and Friesen [8]. 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. Which are often supported as being the 6 basic emotions from evolutionary, developmental, and cross-cultural studies [7]. Because our robot does not have a human face and for simplifying the design, some of the AU are missing, others are replaced and some are added. The lack of the lower eyelid and a fixed upper lip lead to missing AU, the AU regarding the nose movements will be replaced by the movement of the 3 DOF trunk and the movement of the ears and the greater visual influence of the trunk will add extra gestures to express the emotions.

2.6 Mechanical Design

The first prototype of the robot has a fully actuated head and trunk. By moving its head (3 DOF), eyes (3 DOF), eyelids (2 DOF), eyebrows (4 DOF), ears (2 DOF), trunk (3 DOF) and mouth (3 DOF) the robot is able to express its emotions [19]. The trunk of our robot is the most intriguing element according to the children, used to grab and maintain the child's attention. When a child interacts with the trunk, he points his attention towards the face of the robot, locating itself in the scope of the onboard cameras, allowing to do proper vision analysis. Using the cameras in its eyes the robot will be able to focus on a point of attention and follow it with natural eye-movements [10]. The robot will use eyebrows, ears and eyelids to express moods and feelings. The robot must as well fulfill the specifications to operate in a hospital environment and to guarantee a smooth interaction with the children. The intrinsic safety when dealing with child-robot interaction is of very high priority. Children are expecting a huggable friend that never has the intention to hurt them. Flexible materials and compliant actuators are being applied considering these constraints. Because of the high requirements on hygiene requested in hospitals, the fur of our robot can easily be replaced and washed before each visit. The prototype measures about 66cm in height and 32cm in width.

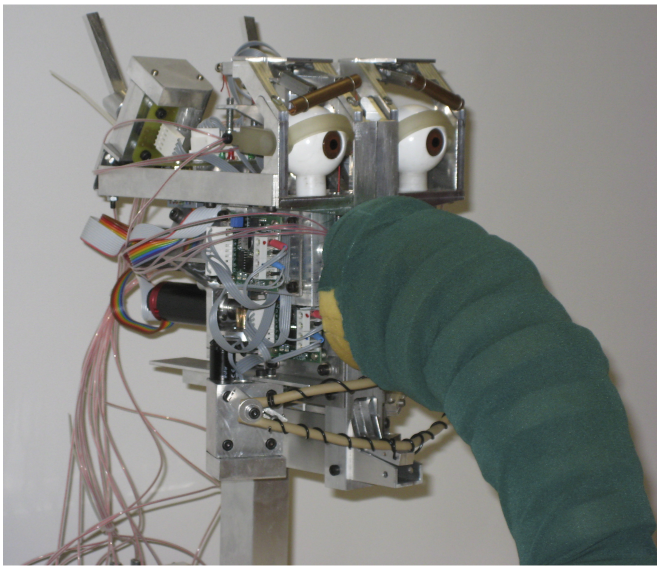

Figure 3. The prototype of the head of Probo

3 FACIAL EXPRESSIONS

3.1 Emotional interface

Several theorists argue that a few select emotions are basic or primary, they are endowed 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 [7] [12]. To realize a translation from emotions into facial expressions, emotions

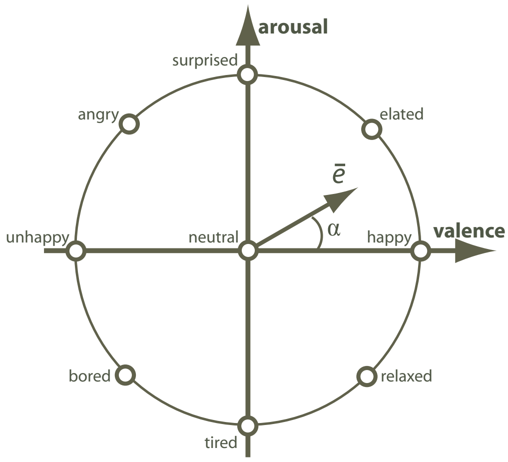

Figure 4. Emotion space based on Russells circomplex model of affect.

need to be parameterized. In the robot Kismet [4], facial expressions are generated using an interpolation-based technique over a three-dimensional, componential *affect space* (arousal, valence, and stance). In our model we started with the two dimensions; valence and arousal to construct an emotion space, based on the circumplex model of affect defined by Russell [18], which has as well been implemented in the robot EDDIE [22]. In our emotion space we use a Cartesian coordinate system, where 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 4). 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 specific value for each angle ($0° - 360°$) of each DOF. When selecting one DOF, we set a value for each basic emotion on the unit circle and use linear interpolation to attain a contiguous relation. By adding more (optional) points or values the curve can be tuned to achieve smooth, natural transitions between the different emotions. An example is shown (Figure 5) for the DOF controlling the eyelid, extra points were added in the first half of the emotion space respectively starting and ending with the happy emotion ($\alpha = 0° = 360°$).

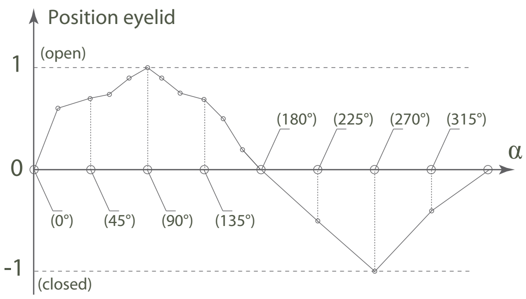

Figure 5. Adjustable interface for defining the value off the DOF (controlling the position of the eyelid) for each emotion (angle α).

An emotional interface (Figure 6) has been developed where the user can fully configure the facial expressions and use the emotion space to test the different emotions and transitions. The user will have visual feedback from a virtual model of the robot.

3.2 Virtual model

A virtual model of Probo has been created to evaluate our design choices and to advance on user testing, without the need for an actual prototype. The model is created combining the mechanical designs, made in Autodesk Inventor, with the visual exterior of our robot, represented by the skin, attached on the mechanical moving parts, using

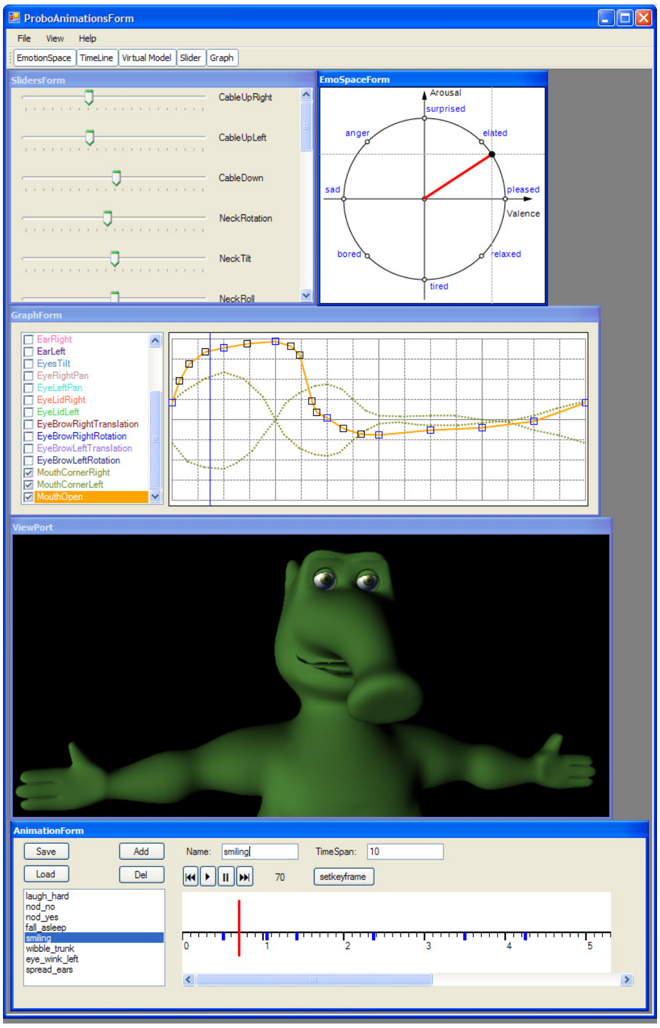

Figure 6. Emotional interface for testing facial expressions.

Autodesk 3ds Max. The mechanical parts are linked together to obtain kinematical movements for realistic visual motions of the model. The movements can be controlled by using sliders to set the desired angle for each DOF and simulating actuation of the parts (Figure 7). This model has also been implemented in Microsoft XNA environment where it is linked with the emotional interface and used to create different animations. Each animation consist of different key frames, which hold the values of the DOFs at a given time. There is a linear interpolation between the key frames resulting in a contiguous animation. The emotional interface can be used to easily insert emotions at a certain point in an animation. The different animations are stored in a database. The animations will be employed later to build scenarios for the robot.

4 RECOGNITION TEST

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 [4]. We asked the subjects to perform a comparison task

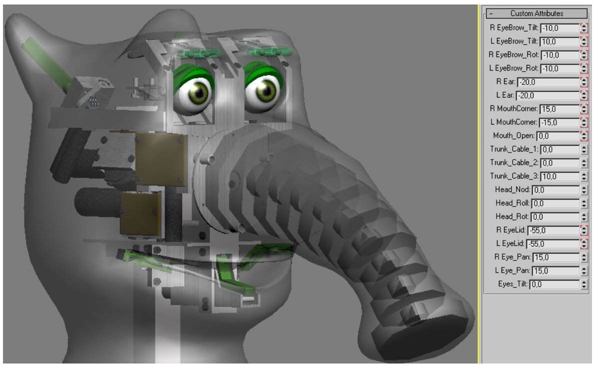

Figure 7. Virtual model with control slider for the DOF.

where they compared color images of the virtual model (Figure 8) with a series of line drawings of human expressions (Figure 9).

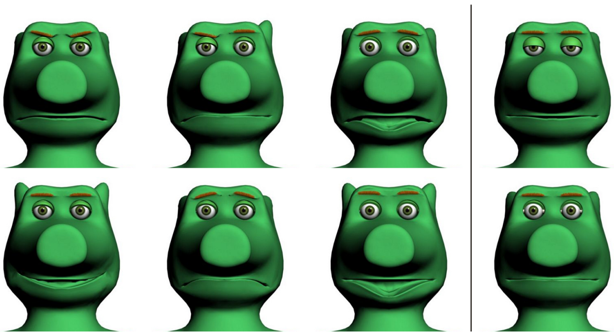

Figure 8. Facial expressions of the virtual model used in preliminary user-study. The 6 basic emotions (anger, disgust, fear, happy, sad and surprise) on the left and the emotions tired and neutral on the right.

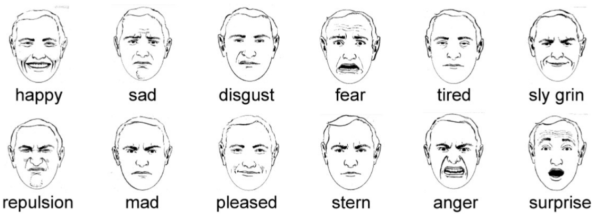

Figure 9. The sketches used in the evaluation, copied from Kismets survey, adapted from (Faigin 1990) [4].

Twenty-five subjects (6 - 8 years of age) filled out the questionnaire. The children were presented an image of our virtual model representing one of the 8 emotions. For each of those images they had to choose the best matching sketch representing human emotions. The results are shown in Table 1.

The results from the test show that the intended emotions *surprise, fear* and *happy* have a low similarity with the sketches. Because the sketches contain also a drawing stating a *pleased* emotion, the low result for *happy* can be explained. Combing the two gives even a 90%

Table 1. The result of the comparison test with children shown in percentage match.

% match	happy	sad	disgust	mad	fear	tired	surprise	neutral
happy	**54**	0	7	0	0	0	18	0
sad	0	**74**	9	7	15	2	0	0
disgust	0	4	**62**	4	3	0	0	4
mad	1	2	2	**66**	3	9	0	16
fear	0	0	0	0	**48**	0	29	0
tired	0	4	5	2	0	**87**	3	4
surprise	0	0	0	0	9	0	**28**	0
sly grin	5	0	2	11	5	0	0	0
stern	0	12	9	0	2	0	0	40
anger	2	0	0	3	0	0	7	4
repulsion	2	4	0	7	3	0	0	0
pleased	36	0	4	0	12	2	15	32

similarity between the *happy* emotion and a *happy* or *pleased* human face. The image expressing fear was often related to *sorrow* and *pleased*. There is a strong resemblance between the images representing *fear* and *sorrow* (15%). This can partly be explained because our model lacks lower eyelids resulting in a smaller difference in eye-opening. The lowest similarity was found with the *surprise* emotion, where slightly more children linked the *surprise* image with the *fear* sketch (29%). During the test, the observation was made that the children were really seeking for a visual resemblance without recognizing the underlying emotions. When performing the same test on fifteen adult people (20 - 35 years of age) the results (Table 2) were similar with the exception of *surprise*. Where the children had difficulties identifying the emotion of surprise most of the adults (81%) had a positive match. We also observed that some of the adults, first try to recognize the underlying emotions rather than just look for a graphical similarity, resulting in better matches.

Table 2. The result of the comparison test with adults shown in percentage match.

% match	happy	sad	disgust	mad	fear	tired	surprise	neutral
happy	**56**	0	0	0	6	0	13	0
sad	0	**88**	0	0	44	13	0	6
disgust	0	6	**63**	0	0	0	0	0
mad	0	0	6	**69**	0	0	0	6
fear	0	0	0	0	**44**	0	0	6
tired	0	0	6	6	0	**81**	0	44
surprise	0	0	0	0	0	0	**81**	6
sly grin	19	0	6	0	0	0	0	0
stern	0	6	19	19	6	0	0	19
anger	0	0	0	6	0	0	0	0
repulsion	0	0	0	0	0	0	0	0
pleased	25	0	0	0	0	6	6	13

5 CONCLUSION

The first steps in the creation of a social interface succeeded. The interface can be used to program new animations that can be displayed using the virtual model. All the DOF of the physical prototype can be tested and configured. Using our emotional interface we can translate all the emotions into the values for each DOF. To fully cover all the emotions, we will extend the emotion space with a third dimension: stance, which will allow us to make more difference between anger and fear. The 3D virtual model has helped a lot with the mechanic CAD. By combining techniques from CAD and animation software, we created a fully realistic virtual prototype for simulation. In the next steps the virtual model will be connected with the software controlling the physical prototype, resulting in a real time control interface that can be used by an operator. The results of the preliminary test are taken into account for the preparations of a full scale user study. In this study the children will be asked to look for the underlying emotion instead of finding a matching sketch. The facial expressions of our robot will also be tested with different configurations for the trunk, to see how the trunk can emphasize certain emotions.

ACKNOWLEDGEMENTS

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The Haptic Creature Project: Social Human-Robot Interaction through Affective Touch

Steve Yohanan[1] and **Karon E. MacLean**[1]

Abstract. The communication of emotion plays an important role in social interaction. Research in affective display both in the social sciences and in social human-robot interaction has focused almost exclusively on the modalities of vision and audition; however, touch has received disproportionate attention. This paper presents an overview of the Haptic Creature project, where we seek to develop a deeper understanding of affect display through touch in the context of social interaction between human and robot. We also hope to gain knowledge on the role affective touch plays in supporting companionship. Drawing from studies on human-animal interaction, we are developing the Haptic Creature, a robot that mimics a small pet that interacts through touch. Details of the robot and related user studies are presented.

1 INTRODUCTION

In this paper we present an overview of the Haptic Creature project. The overall goal of our project is to investigate the use of affective touch in the social interaction between human and robot. We are specifically interested in the display, recognition, and influence of this form of touch. Additionally, we are interested in the role affective touch plays in fostering companionship between human and robot.

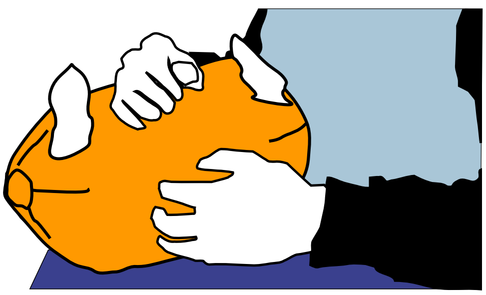

Figure 1. Human interacting through touch with Haptic Creature on lap.

Our approach is to leverage research in human-animal interaction by developing a robotic creature that mimics a small animal, such as a cat or dog, sitting on a person's lap (Figure 1). Dubbed the Haptic Creature, the robot interacts with the human through the modality of touch. In addition, we are developing a series of user studies that utilize the Haptic Creature to further the goals of the project. Both the robotic creature and the user studies will be discussed in further detail.

The structure of this paper is as follows. It begins with coverage of related work and motivation behind the project. The paper continues with specifics of the Haptic Creature robot. It then presents an overview of user studies being conducted as part of the project. Finally, the paper concludes with a brief summary of what has been covered.

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2 BACKGROUND

The Haptic Creature project draws from a variety of seemingly disparate research areas: socially interactive robotics, affect, touch, as well as human-animal interaction (Figure 2). From the perspective of these areas, this section introduces the related work and motivation behind the project, then concludes by differentiating the project from similar research.

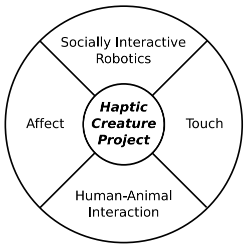

Figure 2. Research areas related to the Haptic Creature project.

2.1 Socially Interactive Robotics and Affect Display

Socially interactive robotics is a subfield of human-robot interaction studies. Fong *et al.* [8] describe socially interactive robots as ones "for which social interaction plays a key role ... [in order] to distinguish these robots from other robots that involve 'conventional' human-robot interaction, such as those used in teleoperation scenarios."

An important aspect of social interaction is *affect display*—the external manifestation of internal emotional state—as it helps to regulate and add significance to the interaction [4]. The two most studied modalities for affect display in humans are vision and audition.

In the case of vision, the use of facial expressions is commonly used to convey emotion [6], so is not surprising that affect display in socially interactive robotics similarly concentrates on facial expression (e.g., [3] [15] [12] [17]). As for audition, prosody of speech is used in affect display. Likewise, this means has also seen investigation within socially interactive robotics (e.g., [2] [18]).

2.2 Affective Touch and Human-Animal Interaction

One modality for affect display that has received much less attention than vision and audition, however, is that of touch [11]. The sense of touch is rather unique: the skin is the largest organ in the human body, the first sense organ to develop, and it plays a major role in early development [14]. Furthermore, touch is proximal; requiring close or direct, physical contact to sense [10].

Affective touch can be defined as touch that communicates or evokes emotion. General studies on interpersonal touch, however, have shown various confounding factors such as gender, familiarity, social status, and culture (e.g., [7] [13] [16] [24]). Additionally, these sorts of studies have been found to cause significant levels of participant discomfort (e.g., [23]). In an attempt to avoid these issues, the Haptic Creature project has chosen to draw from models of interaction, not between humans, but between human and animal.

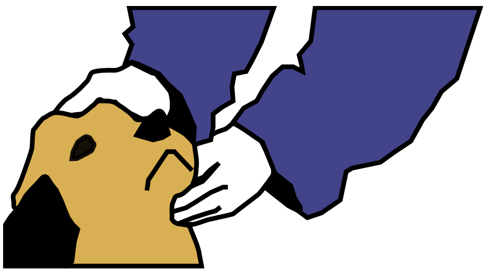

Figure 3. Human interacting with dog through touch.

It is our hope that human-animal touch will be less loaded. Likewise, there already exists a wealth of non-verbal communication—especially through touch (Figure 3)—between human and animal [5] [1]. Also, the long history of human-animal bonds [19] [20] is in keeping with one of the research goals to investigate the influence of affective touch on companionship.

2.3 Differentiation

When filtered through the various research areas presented above, there are several projects that overlap with the Haptic Creature. Most notable are the small set of social robots combining touch interaction and animal-like form: Shibata's baby seal, Paro [21]; Stiehl's teddy bear, the Huggable [22]; and Sony's dog, Aibo [9]. This section covers some of the more significant differentiating factors in relation to these three robots. The rationales behind these factors are given more detail in Section 3.1.

Perhaps the primary differentiation of the Haptic Creature project is its strong concentration on the modality of touch for affect display. The Huggable is the only other device possessing full-body sensing; Paro and Aibo both have only limited interaction points for touch input. Moreover, each of these three projects focuses much less on touch for affect display originating from robot itself; rather, they rely more on visual and auditory expression.

A second differentiating aspect of our project is the level of zoomorphism. The Huggable, Paro, and Aibo all, to varying degrees, have clearly defined features and overall shape. While our goal is that the Haptic Creature be recognizable as animal-like, it is consciously designed to have a more amorphous appearance.

3 THE HAPTIC CREATURE

The Haptic Creature (Figures 1 & 4) is a robotic device that mimics a small lap animal, such as a pet cat or dog. It is composed of five major components: a body, two ear-like appendages, a breathing mechanism, a purring mechanism, and a warming element.[2] The creature interacts with the world primarily through the modality of touch[3] and regulates its emotional state based on this interaction. For example, a human sitting with the creature on her lap gently strokes it. The Haptic Creature may consider this a pleasing interaction, thereby updating its emotional state to reflect happiness. In turn, the creature then renders this by brisk, rhythmic breathing (causing its ribcage to press and release against the human's hand); stiffening its ears; and a gentle purring vibration.

Figure 4. Wizard of Oz prototype. (Photo: Martin Dee)

This section provides further details of the Haptic Creature. It includes coverage of design considerations, phases of development, and an architectural overview of the creature.

3.1 Design Considerations

There are three major design considerations for the Haptic Creature. The first is that the interaction centers around the modality of touch. We are concerned with affect display through touch. As a result, all communication of emotional state from the creature is haptic. Similarly, all sensing by the robot is touch-based. The second consideration deals with providing an organic interaction whereby the sensing and, especially, the affect display seem as a coordinate whole. We are trying to avoid the robot being perceived simply as a "bag of tricks:" a random and unrelated set of actuations. The final design consideration is in the level of zoomorphism. Our approach is to borrow from human-animal interaction; however, we are not attempting to construct a lifelike replica of an existing animal. The creature's form

[2] A non-functioning tail simply conceals cables to the creature from the host computer.

[3] Sensing by the creature is exclusively through touch. The intent is the same for actuation; however, the nature of some interactions—e.g., stiffing of ears—unavoidably produces visual elements as well.

is intentionally minimalistic. Likewise, its interactions should not be limited to that of a single species.

3.2 Development Phases

Development of the Haptic Creature is being conducted in three stages: a Wizard of Oz prototype, an automated prototype, and a final device. This section presents these stages in turn.

3.2.1 Wizard of Oz Prototype

The initial phase of development has already been completed. It was a Wizard of Oz prototype (Figure 4), with all interaction controlled by a human operator. The majority of its effectors are controlled pneumatically, and all sensing is through visual observation of the operator. This version allowed us the ability to quickly explore the idea of affect display through touch within the context of human-animal interaction. Full details of its construction and related user study were presented in [25].

3.2.2 Automated Prototype

The current stage of development is an automated prototype. This version furthers concepts explored with the initial prototype while obviating the need for human operation. The current version of the automated prototype is similar in outward form to the Wizard of Oz prototype (Figure 4). It will sense touch across its entire body (including ears), and effectors will be manipulated via servos and motors (Figure 5). This stage is being used for rapid implementation and testing of software, hardware, and interaction techniques. Automation techniques are being tested and enhanced through successive iterations to evolve into a more robust device (Section 4.2).

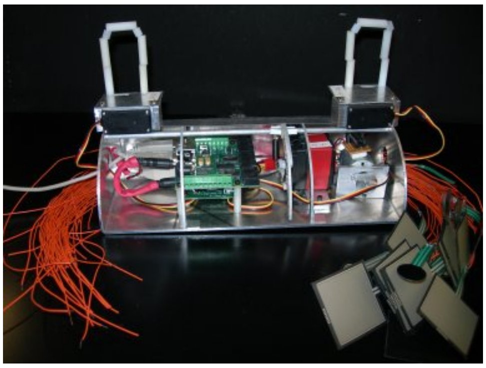

Figure 5. Internals of Haptic Creature showing chassis containing electronics and mechanical components used for sensing and actuation.

3.2.3 Final Creature

After multiple iterations of the automated prototype, a final Haptic Creature will be constructed. The goal is that a majority of the software architecture will be reused; however, more robust hardware elements may be introduced at this stage.

3.3 Architecture

A high-level overview of the Haptic Creature architecture is shown in Figure 6. This section provides a description of the five major components depicted: low-level sensing, gesture recognizer, emoter, physical renderer, and low-level actuation.

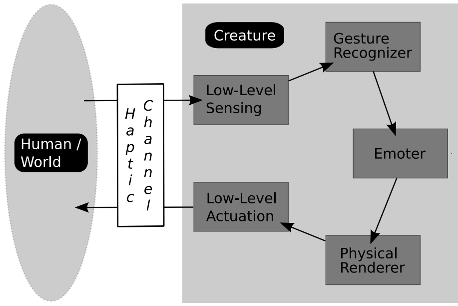

Figure 6. Overview of the Haptic Creature architecture. Human (left) interacts with the Haptic Creature (right) solely through touch. This input passes through the various components of the creature, eventually resulting in an appropriate haptic response to the human.

3.3.1 Low-Level Sensing

This component handles the aspects of the platform that deal with sensing information from the real world. It consists of physical sensing hardware as well as the programmatic aspects that read the data these sensors provide. This component does little interpretation of the data, save perhaps simple filtering and normalization. One example would be a force-sensing resistor that modifies its value based on pressure.

3.3.2 Gesture Recognizer

This component takes information from the *low-level sensing* component and constructs an initial model of the physical data. Its function is to manage the variety of sensor information so as to provide a cohesive view. One example would be an array of pressure sensors that, when monitored, allow determination of direction and speed of movement along with pressure intensity.

This component, in turn, builds a higher-order model of the input data. An example would be distinguishing between a hard stroke and a soft pet. Both require monitoring the direction, speed, and pressure intensity across a range of sensors; however, this component also interprets these values such that an evaluation of the intention of the user can be determined.

3.3.3 Emoter

This component represents the underlying emotional state of the platform. This state is affected either externally through information from the *gesture recognizer* or by means of its own internal mechanisms (e.g., temporal considerations). One example would be a soft pet elicits a *pleasured* state in the device while gradually decaying into a *neutral* state shortly after this interaction ceases. This component itself has no knowledge of the *recognizer* and only cursory knowledge of the *renderer* (necessary for change notification). This allows the model to focus on the domain-specific information of the system without being directly concerned with how it is getting its information or how its state is being presented.

3.3.4 Physical Renderer

This component is in charge of the higher-order, physical manifestation of the internal state of the platform. The component listens for changes in the *emoter* component, then translates the results into an orchestrated manipulation of the effectors. One example might be that when the platform moves into a *pleasured* state its breathing response adjusts to very soft, rhythmic in/out motions while it produces a similar "purr" that can be felt.

3.3.5 Low-Level Actuation

This component is tightly coupled with the *physical renderer* component. It is charged with directly interfacing with the platform's effectors. It does little interpretation of the information, save perhaps adjusting normalized data appropriately for individual hardware devices. One example would be setting the position of a motor.

4 USER STUDIES

The main goal of the Haptic Creature project is to investigate the use of affective touch in socially interactive robotics. We are especially interested in the display, recognition, and influence of this form of touch. To that end, we are developing a suite of studies that examine the interaction between humans and the Haptic Creature. An overview of these studies is presented in this section.

4.1 Preliminary Investigation

This first study has already been completed. It was a preliminary exploration of affective touch that employed our Wizard of Oz prototype (Section 3.2.1). The major aspect of the study had participants physically interact with the Haptic Creature. They were asked to perform specific haptic interactions—e.g., "gently pet"—and the creature then rendered a corresponding emotional response—e.g., "happy". Participants were asked to identify each emotional response from the creature, as well as state any positive or negative shift in their own emotional state from each interaction.

The general outcome arrived at from our study was that emotion can be communicated through primarily haptic means, and that this communication affects the recipient. The study also bolstered our case for the use of human-animal interaction models as a means to explore affective touch. Details of the study were presented in [25].

4.2 Interaction Decomposition

The cyclic interaction between a human and the Haptic Creature is decomposed in Figure 7. Throughout the current development of the automated prototype (Section 3.2.2) various studies will be conducted that concentrate on the direct interaction between human and creature.

The interaction is divided into its component parts, so the studies themselves become additive. We begin by isolating on a specific cell—e.g., studying the variety of gestures a human uses in the display of affective touch (cell 1)—then a subsequent study examines the interaction across two cells—e.g., the output of affective touch from the human, and the ability of the creature to correctly recognize it (cells 1→2). The goal is to characterize low-level aspects of the interaction, then use these to construct higher-order models, eventually ending with an understanding of the entire interaction cycle.

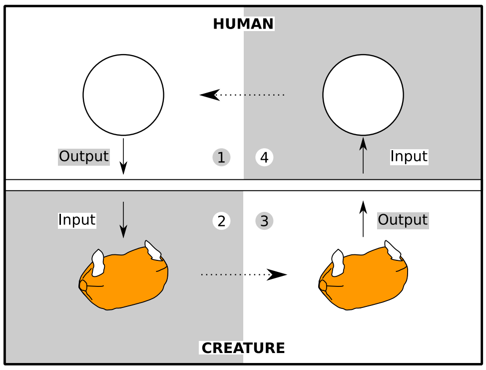

Figure 7. Interaction loop between human and Haptic Creature. Solid lines between cells represent a display of affect touch. Dashed lines denote an internal update of emotional state as a result of the interaction.

4.3 Companionship

Once development of the Haptic Creature is complete (Section 3.2.3), a final user study will be conducted. The goal of this study is to gain a deeper understanding of the role affective touch plays in companionship. Its focus is less on the form of interaction and more on the effects. That is to say, the manner in which the interaction is conducted is the focus of the previous studies, while the emotional result of the interactions is what this study encompasses. It will likely take the form of longitudinal tests, where participants will interact with the Haptic Creature over an extended period.

5 CONCLUSION

In this paper we have presented an overview of the Haptic Creature project, whose goal is to investigate the display, recognition, and influence of affective touch in human-robot interaction. In an attempt to avoid various issues in studies on interpersonal touch, our project draws insight from models of human-animal interaction. We have presented details of the Haptic Creature, an animal-like robot we are developing to interact exclusively through touch. We also presented an overview of user studies employing the Haptic Creature.

5.1 Grace Note

As noted in Section 2.2, studies on the general nature of interpersonal touch have at times proven difficult. Likewise, human-animal studies can require considerable effort in the control of factors. Though our research examines affective touch in the context of interaction between human and robot, there is hope that some insights gained may be applicable to interpersonal or human-animal interaction. As one example, our Haptic Creature may be employed in preliminary hypothesis testing or pilot studies of interpersonal or human-animal interaction (cf. Section 3.1 of [8]).

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Utilizing Physical Objects and Metaphors for Human Robot Interaction

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Abstract. Mouse, keyboard and graphical user interfaces are commonly used in the field of human-robot interaction (HRI) for robot control. Although these traditional user interfaces (UI) are being accepted as the standard for the majority of computational tasks, their generic nature and interaction styles may not offer ideal mapping to various robotic tasks, such as locomotion and navigation. In our research we intend to explore alternative UIs that could take advantage of human innate skills of physical object manipulation and spatial perception, and overcome some of the problems associated with traditional UIs. We suggest the use of tangible user interfaces (TUIs) for HRI applications, leveraging on existing and well-learned physical metaphors for interaction with robots, and exploring new ways to tangibly control one-to-many robot group interaction tasks. In this paper we will describe our current research efforts and findings, and outline our proposed research plans.

1 INTRODUCTION

Robots are digitally controlled physical entities that exist in both the virtual realm and the physical world. They are capable of interpreting bits and bytes and converting them into physical outputs to interact with their surroundings, and are also capable of sampling and sensing physical phenomena and translating it into digital information. As technology accelerates, advanced functionalities have been added to current robots that not only enhanced their abilities to interact with a wide range of physical objects, but also grant them the ability to communicate with humans.

In the past, researchers devoted much effort into robot development, and the problem of how to enhance human operators' situation awareness [11] when controlling robots has often been overlooked. This problem magnifies especially when a human operator needs to remotely operate one or multiple robots that have low autonomy and high intervention ratio [7]. The problem can be addressed by a set of design guidelines based on empirical studies [7, 15]. Although the guidelines are valuable for improving the operators' awareness of robots and their surroundings, they may not be well supported by the traditional user interface, that is, the mouse, keyboard and graphical user interface (GUI) paradigm which are still widely used in the field of HRI (from here on we will refer to the traditional user interface as the traditional UI).

Although the traditional UI is used abundantly in human computer interaction (HCI) tasks it may not fit well with certain HRI tasks. Firstly, the mouse, keyboard, and graphical user interfaces separate user input from computer output, uncoupling action and perception space, and potentially breaking the flow of users' cognitive engagement when performing certain tasks. [22] For instance, when typing on a keyboard, most people need to look at both the keyboard and the computer screen to ensure they entered the correct letter. In terms of telerobotics, the human operators have to solely rely on the image and sensor data transmitted back by the robot to determine their next operation. Constantly switching attentions back and forth between the input device and the data display screen is not ideal especially when the robot is in critical conditions. Secondly, the motor skills required for manipulating a mouse and typing on a keyboard are not intuitive to learn. A sufficient amount of time is required for people to memorize the layout of the keyboard and repeatedly practice in order to type without looking at the keys. When it comes to robot control, the longer it takes a human operator to master certain motor skills, the greater the cost (time, money and labor) of training will be. Also, the amount of attention the operator needs to spend on the input device is likely to be higher, which may hinder the overall performance. Thirdly, the two-dimensional traditional UI limits people's spatial abilities when interacting with three dimensional objects. It can be difficult to control a robot that is capable of moving in three dimensions, for example an unmanned aerial vehicle (UAV) using the traditional UI. [16] In order to effectively and efficiently interact with robots, we suggest exploring an alternative set of UIs to overcome the aforementioned problems, leveraging on physical and tangible interaction metaphors and techniques.

2 RELATED WORK

We suggest looking for alternative solutions to the traditional UI for human robot interaction by examining tangible user interfaces (TUIs). TUIs couple digital information and function with physical objects [9] allowing a virtual entity in the digital realm to be manipulated through a physical medium. TUIs make effective use of the affordances [3] of physical objects which may allow us to fuse user input and robotic functional output together. For instance, the shape, size and weight along with other physical properties of an object imply the way we interact with it. If we can appropriately map the physical properties (such as physical constraints) of a robot to the physical properties of an object, then the potential functionalities and mechanism of a robot can be directly revealed to the operator. Moreover, the spatial orientation and the position of a physical object in relation to its surroundings can expose additional information and provide interaction insight and task awareness to the manipulator.

Research [5, 13] have shown that "very young infants are able to perceive the affordances provided by the physical layout of surfaces in their environment, including those that support locomotion, those that afford falling, and those that afford collision". Moreover, by 5½ months of age, infants are able to perceive the affordances for action of everyday objects. They can discriminate between the correct and incorrect use of common objects in the context of everyday actions. [12] Thus, we can take the advantage of our innate skills at observing and learning how to interact with physical objects in interface design, which may reduce the number of new motor skills an operator needs to acquire.

When remotely navigating a robot, maintaining good spatial awareness [11] is crucial to the human operator. Robotic locomotion and navigation tasks are well-explored research problems in HRI, with special attention given to effective coordination of robotic group in navigation tasks. For example, Kaminka et al. [6] suggested a GUI interface which they call "relation tool" for visualizing the relative position of each robot within a tightly-coordinated robot team. We are exploring new interactive styles that exploit the effectiveness of already established techniques, such as Kaminka's, using a set of physical objects and tools as robotic interaction mediators. For instance, a physical object can be transformed into a tool for navigating a robot, and the orientation and position of the object in the physical space can be utilized to provide spatial information about the robot. Furthermore, our innate abilities allow us to interact with physical objects easily. There is no specific knowledge or memorization required for us to move, manipulate, assemble and disassemble simple physical objects pointing to the great potential of applying TUIs in HRI.

Although the notion of tangible user interface has become the buzzword in the field of Human-Computer Interaction (HCI), only very few researchers related TUIs to HRI. To the best of our knowledge, the first research project that implies the use of TUIs in HRI is done by Raffle et al. in their toy application – Topobo [10]. Topobo is a constructional toy application that allows kids to assemble static and motorized plastic components to dynamically created biomorphic forms. Not only Topobo allows creative constructions, it can also replay the motions applied by users on the motorized components to animate the user creation. Another research which we think should be considered the first attempt in the field of HRI was conducted by Quigley et al [16] who utilize a physical object for controlling a mini-unmanned aerial vehicle (UAV), using a UAV shaped physical icon for controlling the roll and pitch angle of a simulated UAV. For multi-robot control, Lapides et al. [18] have recently presented a three dimensional TUI – "The 3D Tractus" that enables a single user to monitor and control a team of independent robots in 3D spatial tasks.

3 FIRST ATTEMPTS

In order to explore the possibility of applying TUIs to robotic control, we have designed and conducted a user study comparing the usability of generic tangible user interfaces – based on the Nintendo Wii Remote (Wiimote) and Nunchuk [17] with a generic input device – keypad in terms of speed and accuracy in two different tasks. The study includes a high-level navigation task (Figure 1) and a low-level posture control task (Figure 2), and the study result were presented in details in [2].

One of the important advantages naturally embedded in TUIs is the physical affordance that they provide. For the navigation task that we conducted in our study, we provided two Wiimotes to the study participants for controlling a Sony AIBO robot dog [21] through an obstacle course. We have used a zoomorphic-based interaction theme: a horseback riding metaphor to explain the mechanism of controlling the AIBO using a pair of Wiimotes. The participants were asked to think of the Wiimotes as a rein on the neck of the AIBO. By pulling the left Wiimote backwards, the AIBO will rotate to the left. Reversely, pulling the right Wiimote will make the AIBO to rotate to the right. Our study demonstrated that this metaphor helped participants to quickly master the navigation task.

For the posture task, the participants were asked to command the AIBO to perform a series of postures displayed on a computer monitor (Figure 2). Both of the Wiimote & Nunchuk and keypad interface utilize an asymmetric bimanual [19] interaction style.

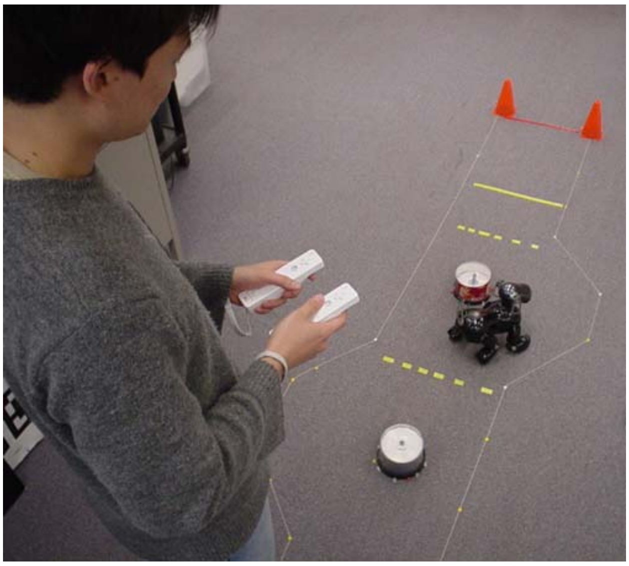

Figure 1. The user is navigating an AIBO robot dog through an obstacle course using two Wiimotes.

Figure 2. The user is controlling the AIBO to perform a posture using one Wiimote and one Nunchuk on each arm.

Due to the nature of the tasks, the Wiimote & Nunchuk gesture-to-action mappings deployed in each task differ from each other in terms of "degree of integration" and "degree of compatibility". [14] The interface mapping for the navigation task has a less than one degree of integration and a low degree of compatibility, where the interface mapping for the posture task has a close to perfect degree of integration and a high degree of compatibility.

The result of the comparative study has shown that the Wiimote and Nunchuk interface allowed the participants to finish both tasks faster, and with fewer errors than the keypad interface. Also, the majority of the participants have reported that they prefer to use the Wiimote and Wiimote & Nunchuk interface for both tasks.

This experiment suggests that using intuitive TUI-based gesture-to-robot action mapping helps the participants to reduce their cognitive load when controlling robots. This implies that operators may spend more time on high-level task planning among other tasks.

4 RICONS FOR ROBOTIC GROUP CONTROL

Our next step is to find a specific set of tools and interaction metaphors to design a tangible user interface for remote control of multiple robots. We intend to explore the possibilities of using small set of physical objects which resemble the shape of real robots as Ricons (robotic icons, based on Ishii & Ullmer's "Phicons" [9]) to provide a physical handle to an operator for interacting with multiple robots remotely.

4.1 DESIGNING RICONS

First of all, an appropriate Ricon should provide a tight spatial mapping [4] between itself and a real robot. As mentioned earlier, the shape, size and weight of a Ricon should reflect the physical properties of the robot it represents. Also, it is important and beneficial if we can utilize the physical constraints of the Ricons to prevent navigation accidents from happening. One obvious example is that each Ricon occupies a portion of the physical space. Thus, two Ricons can never "collide into" each other. This physical constraint can be immediately perceived by the operator if two robots are about to collide. Secondly, by manipulating a Ricon directly, the human operator should be able to adjust the position and orientation of a single or group of robots. For instance, when a robot or a group of robots needs specific attention, the operator can use a Ricon to give specific movement orders to one or multiple robots that are of the same type. The operator can simply move a Ricon or rotate it on a 2D surface to move or rotate a robot in the 3D space. Thirdly, the operator can use Ricons to configure different group formations of multiple robots. Multiple Ricons can be placed at different locations on a 2D region to represent the team formation of multiple robots.

To aid the human operator with sensory data and live video feedback from the robot, we want to utilize a digital tabletop for displaying such information. As Yanco et al. suggested in their research [8], to increase the operator's situation awareness in HRI interface design, we need to 1) fuse all related information onto the same display window, 2) provide spatial information in regard to the environment that the robot is within. To follow this guideline, we intend to project sensory data and live streaming video of each robot onto the digital table. In addition, to support the operator with spatial information, we can project a digital map (if available) of the remote region that the robots are working at on the table as well.

In order to closely combine the digital information with the Ricons together, we intend to put the Ricons on top of the digital table and use a vision tracking system to keep tracking of their locations on the table. By accurately locating the whereabouts of the Ricons, we can "superimpose" the Robotic status associated with each Ricon beside it. In addition, if we can access the location of each robot in the real world using vision or GPS tracking, then by scaling the digital map properly, we can use the Ricons to pin-point each robot on the map and control them in the real world by simply moving the Ricons TUI-representations on the table. This hybrid interface will not only allow I/O unification on the same surface, but also provides the ability to the operator to interact with digital and physical entities at the same time.

To simulate a robot collaboration task in a lab setting, we intend to use five to eight AIBOs as the robotic platform for performing a set of collaborative tasks. For instance, the robots will be placed in a particular formation to carry or pull a heavy object together from one place to another. (Figure 3)

Figure 3. A conceptual design of a simple collaborative task among AIBOs carrying an object from one location to another.

Figure 3 demonstrates one possible example of group collaboration tasks among the AIBOs. For completing tasks like this, the AIBOs have to maintain a particular group formation while moving towards their destination. If any member of the AIBO group falls behind the others, they may drop the object they carry, which in turn, fail the task.

4.2 SYSTEM IMPLEMENTATION

We intend to use small dog-shaped toys as Ricons TUIs for controlling the real AIBOs. By placing reflective markers on top of these toys, we will be able to use the Vicon MX system [23] to keep track of the Ricons' locations on a SMART board [20]. (Figure 4) As the users move the Ricons around on the board, the information provided by each robot will be displayed and follow along with the Ricons.

In order to access the location of each AIBO in the real world, we will use another set of our lab's Vicon MX cameras to keep track of the AIBOs at a remote place (a different location from the Vicon & SMART board setup to simulate a remote robot control environment). As AIBOs move around the real world, their status and locations will be gathered and updated on the SMART board.

Since we are designing a group interface for controlling multiple robots, we are considering a layer of specific physical tools on top of the Ricons to address some of the group task aspects. In order to allow multiple robots to march in a particular formation, we intend to utilize different types of physical "ties" to accomplish this task. We define a tie as a rigid band that bounds multiple Ricons together in a pre-defined shape. For instance, reflecting on the triangle used for Pool or Billiard balls, we may build a triangle shaped tie to band multiple Ricons together in a triangle formation. By pushing the tie, we can navigate a group of Ricons to a desired location in a triangle formation easily. We

Figure 4. The user is holding two physical objects to interact with the virtual entities displayed on the SMART board. The board is surrounded with six Vicon motion tracking cameras for locating the reflective markers attached on top the objects to approximate their positions on the table.

may also build various ties in different shapes for accomplishing different tasks. On the other hand, by simply taking off a tie from a group of robots would break their group relationship. We hope this simple physical "binding" and "unbinding" metaphor would help users to organize multi-robot group behaviors easily.

5 CONCLUSION

We believe low-level robotic control tasks can benefit from the physical interaction style afforded by TUIs. The idea of using Ricons as physical handles for controlling real robots can hide tedious low-level robotic control mechanism from the end user. Moreover, the users are not required to learn new motor skills to control complex robots. By leveraging the advantage of TUIs, we can reduce the cognitive load of the human operator and allow them to spend more time on high-level task planning.

Although the human operator can directly manipulate real robots using Ricons, they can not visualize the internal state of the robots from observing the Ricons. To augment the Ricons with the information in regard to the internal status of the robots, we will use a digital table for displaying such information to aid the operator in remote control tasks. By fusing the system input and output within the perceptions of the users, we hope to reduce confusions in regard to inadequate situation awareness problem found in previous research [11].

During the development of our proposed project, we intend to explore possible physical metaphors to extend the users' ability to interact with the system based on previous knowledge. For instance, the "tie" example that we explain in Section takes advantage of people's knowledge about physical objects to easily group or separate multiple robots.

Although TUIs can provide many advantages over traditional UIs, they may be more prone to unintended usage due to their physical nature. For instance, since Ricons can be easily moved around on the table surface, users may accidentally knock them off from their supposed positions while manipulating other Ricons. Thus, we need to consider how to apply physical constraints to the system to prevent undesirable actions.

In summary, we propose to utilize both tangible user interfaces and a digital table to allow an operator to remotely navigate multiple robots. This hybrid interface will allow human operators to control individual robot behaviors and uniform group behaviors easily through the use of physical *Ricons*. No specific training will be required to operate a large robotic group with this interface. We hope our future work on the proposed system will provide new insight on human robot interface design using TUIs, especially for one to many robot navigation tasks.

6 FUTURE TUI DESIGN FOR HRI TASKS

Nature and our rich interaction with physical objects should inspire future research into designing and developing TUIs for HRI tasks. Specifically, in order to make TUIs more intuitive and accessible to non-expert users for controlling zoomorphic or anthropomorphic robots, we should consider utilizing the physical metaphors that are commonly observed in human-animal interaction for this propose. We believe that direct physical interaction techniques with robots will emerge from observing the extremely rich interaction techniques used by humans for domesticating animals, very similar to the reins we used in our AIBO navigation task. For example, we have seen collaborative hunting techniques using golden eagles, fishing techniques using cormorants, and the vast spectrum of existing interaction techniques between humans and dogs.

Animals are tamed and domesticated by humans for various proposes, examples range from providing labor, raising as food sources all the way up to forming intimate sociable relationships. In the case of training and utilizing animals as laborers, people use physical objects such as whip and rein to directly apply forces on the animals to reinforce their commands. These instruments, although very physical and aggressive in nature, provide instantaneous control and feedback for both the animal and the operator and, while ethically questionable, are very efficient. We believe this simple physical control mechanism can be very efficient for various collocated robotic interfaces. For instance, the BigDog robot [1] build by Boston Dynamics is a carrier robot acts like a mule for transporting supplies on a battlefield. Such robots may need to deal with various interaction layers, some of them maybe as simple, physical and direct as a kick or whip.

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An Inferential Dynamics Approach to Personality and Emotion Driven Behavior Determination for Virtual Animals

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Abstract. The problem considered is how to provide virtual animals, living in an online virtual world, with internal personality and emotion structures that will lead them to display behaviors perceived as naturalistic and emotionally compelling by humans controlling avatars that interact with the virtual animals. A novel approach is proposed, in which both spontaneous and goal-driven animal behaviors are governed by a set of probabilistic logic implications, which are forward and backward chained together, both to directly guide action selection, and to adjust the values of internal emotion indicators. The approach has been prototyped in an preliminary version of a system that controls virtual animals in Second Life, and is expected to be included in a commercial virtual-animals product later in 2008.

1 INTRODUCTION

We consider the problem of creating virtual animals, resident in a 3D virtual world such as Second Life, which not only learn and adapt their behavior based on training and experience, but also possess distinctive personalities and fluid emotional responses, sufficient to intrigue and emotionally engage the humans who interact with them (by means of their avatars). The approach we describe here is based on a tight integration of emotion and personality with other aspects of "virtual animal psyche," within an integrative Virtual Animal Brain (VAB) architecture. At present a prototype of this architecture has been constructed and is the subject of testing and experimentation; the ultimate goal of the project within which it has been created is the launch of a commercial virtual animal product within Second Life and potentially other virtual worlds as well.

The approach taken here is novel in several respects, most notably in its integration of logical and dynamical methods. In the VAB, an animal's behavior is controlled by a combination of procedures (represented internally in a dag form, co rresponding to human-readable scripts in a LISP-like language), and probabilistic-logical implications. There are methods for converting back and forth between these procedural and declarative representations as necessary. Currently, learned behaviors such as "tricks" are represented procedurally, whereas relationships between personality traits, emotions and behaviors are represented declaratively as implications. The learning aspect of the VAB has been described in detail elsewhere [1]; so here, after a brief review of the VAB overall, we focus on explicating how the system of implications is used to regulate emotion and behavior. Iterated forward and backward chaining probabilistic inference, using these implications, play the role of "update equations" updating the states of internal emotional variables and behavioral propensities. These equations modify behaviors, which in turn lead to shifts in emotional state directly, which affect the outputs of the implications, thus leading to an overall nonlinear dynamic coupling the animal's mind with its behaviors.

This approach is somewhat complex, but the end result of this complexity is a richness of emotion and personality driven behavior that seems (based on our own experimentation) to be more difficult to achieve with simpler and more straightforward approaches. Our preliminary experimentation suggests that animals governed by the approach presented here may be interesting and appealing to interact with; but the final test, of course, will be after product release occurs.

It's worth noting that the approach is also highly configurable, as the basic logical implications on which it is based may be easily customized by nontechnical individuals. This gives rise to the possibility (which will likely not be realized in our initial product releases) that eventually end-users may be able to enter new implications textually or graphically, thus configuring the personality and emotional makeup of animals that serve as their pets or relate to them in other ways. Finally, there are ample possibilities for further extensions, such as using advanced probabilistic logic to learn new emotion/personality/behavior implications via experience, generalization, analogy and so forth.

Positioning the current approach in terms of the literature on emotional expression in virtual agents, we may describe it as combining the best aspects of the categorial [2] and dimensional [3] approaches, as well as going beyond both to provide a more nuanced way of inferentially interfacing emotion with behavior, personality, memory, learning and so forth. In the typical categorial approach, an agent is assigned a subset of a certain set of predefined emotions; whereas in the typical dimensional approach, agent emotions are expressed as linear combinations of a certain set of basic emotions. Put simplistically, the categorial approach is logical whereas the dimensional approach is quantitative; whereas by utilizing the language of probabilistic logic, we make the logical quantitative, thus achieving both the clear distinctions and amenability to inference of the categorial approach and the continuous variability of the dimensional approach.

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2 THE NOVAMENTE COGNITION ENGINE

The VAB is a simplified, specialized version of a broader AI architecture called the Novamente Cognition Engine (NCE) [4,5], which is aimed beyond the domain of virtual animals, toward powerful artificial general intelligence [6,7].

One may conceptualize the NCE in the context of the overall task of creating a powerful AGI system, which we decompose into four aspects (which of course are not entirely distinct, but still are usefully distinguished):

1. Cognitive architecture (the overall design of an AGI system: what parts does it have, how do they connect to each other)
2. Knowledge representation (how does the system internally store declarative, procedural and episodic knowledge; and how does it create its own representation for knowledge of these sorts in new domains it encounters)
3. Learning (how does it learn new knowledge of the types mentioned above; and how does it learn how to learn, and so on)
4. Teaching methodology (how is it coupled with other systems so as to enable it to gain new knowledge about itself, the world and others)

We now briefly review how these four aspects are handled in the NCE. For a more in-depth discussion of the NCE the reader is referred to [4,5].

The NCE's high-level cognitive architecture is motivated by human cognitive science and is roughly analogous to Stan Franklin's LIDA architecture [8]. It consists of a division into a number of interconnected functional units corresponding to different specialized capabilities such as perception, motor control and language, and also an "attentional focus" unit corresponding to intensive integrative processing. A diagrammatic depiction is given in [4].

Within each functional unit, knowledge representation is enabled via an AtomTable software object that contains nodes and links (collectively called Atoms) of various types representing declarative, procedural and episodic knowledge both symbolically and subsymbolically. Each unit also contains a collection of MindAgent objects implementing cognitive, perception or action processes that act on this AtomTable, and/or interact with the outside world.

One of the most important types of Atoms is the PredicateNode, which represents a logical predicate evaluated on certain inputs. Emotions, which will play a significant role in our discussion here, are represented as 0-ary predicates, which have a truth value at each time calculated via fixed internal code representing the "biological" grounding of the emotion. Emotion predicates may also be updated via application of logical rules, as will be described below. These logical rules take the role of ImplicationLinks (representing probabilistic logical implications) joining combinations of PredicateNodes to each other, where combinations of PredicateNodes are represented in terms of AndLinks, OrLinks and NotLinks joining PredicateNodes.

In addition to a number of specialized learning algorithms associated with particular functional units, the NCE is endowed with two powerful learning mechanisms embedded in MindAgents: the MOSES probabilistic-program-evolution module (based on [9]), and the Probabilistic Logic Networks module for probabilistic logical inference [10,11]. These are used both to learn procedural and declarative knowledge, and to regulate the attention of the MindAgents as they shift from one focus to another, using an economic attention-allocation mechanism that leads to subtle nonlinear dynamics and associated emergent complexity including spontaneous creative emergence of new concepts, plans, procedures, etc.

Finally, regarding teaching methodology, we advocate a virtually-embodied approach which integrates linguistic with nonlinguistic instruction, and also autonomous learning via spontaneous exploration of the virtual world. And this is where the subject of the present paper comes in: personality and emotion, via their impact on behavior, are key to establishing appropriate interactions with other agents, so as to encourage an embodied AI system's ongoing learning as growth (as well as achieving other goals such as making the AI system more appealing for humans to interact with).

3 AN ARCHITECTURE FOR INTELLIGENT VIRTUAL ANIMALS

Figure 1. Screenshot of a virtual animal in Second Life, controlled by the NCE-based AGI architecture described in this section.

In this section we briefly describe our current, preliminary experimental work using a simplified version of the Novamente Cognition Engine (the so-called "Virtual Animal Brain" or VAB) to control virtual animals in the Second Life virtual world. Figure 1 above shows an example virtual animal controlled by the VAB, interacting with a human-controlled avatar in the context of learning to play soccer. Figure 2 gives a high-level architecture diagram for the VAB, which is a simplification of the overall NCE architecture as diagrammed in [4].

The capabilities of the VAB-controlled virtual animals, in their current form, include

- Spontaneous exploration of the environment
- Automated enactment of a set of simple predefined behaviors
- Flexible trainability: i.e., (less efficient) learning of behaviors invented by teachers on the fly
- Communication with the animals, for training of new behaviors and a few additional purposes, occurs in a special subset of English called ACL (Animal Command Language)

- Individuality: each animal has its own distinct personality
- Spontaneous learning of new behaviors, without need for explicit training
- Capabilities intended to be added in future VAB versions include
- Recognition of novel categories of objects, and integration of object recognition into learning
- Generalization based on prior learning, so as to be able to transfer old tricks to new contexts
- Use of computational linguistics to achieve a more flexible conversational facility

The VAB architecture is not particular to Second Life, but up till now has been guided somewhat by the particular limitations of Second Life. In particular, Second Life does not conveniently lend itself to highly detailed perceptual and motoric interaction, so we have not dealt with issues related to these in the current version of the VAB. However, we have dealt with some of these issues in a prior version of the VAB, which was connected to the AGISim framework, a wrapper for the open-source game engine CrystalSpace [12].

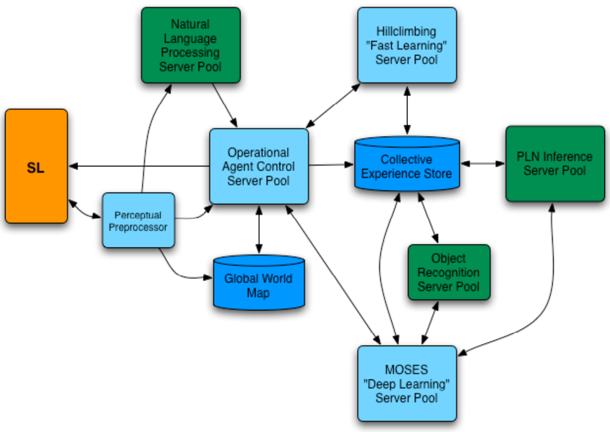

Figure 2. High-level diagram depicting VAB software architecture. The NLP, object recognition and PLN components are missing from the architecture that will initially be commercially deployed but are present in Novamente LLC's internal research codebase.

Instruction of VAB-controlled agents takes place according to a methodology we call IRC learning and is described in detail in [3], involving three interacting aspects:

- *Imitative* learning: The teacher acts out a behavior, showing the student by example what he wants the student to do
- *Reinforcement* learning: The student tries to do the behavior himself, and the teacher gives him feedback on how well he did
- *Corrective* learning: As the student attempts the behavior, the teacher actively corrects (i.e. changes) the student's actions, guiding him toward correct performance

The combination of these three sorts of instruction appears to us critical, for learning of complex embodied behaviors and also, further along, for language learning. Current experimentation with the IRC methodology has been interesting and successful, resulting in a framework allowing human-controlled avatars to teach VAB-controlled agents a variety of behaviors such as fetching objects, delivering objects, going to desired locations, doing dances, and so forth. Further detail is given in [3]; our present treatment is focused on the emotion and personality aspects of the system.

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4 MODELING EMOTION AND PERSONALITY

Psychological theories of emotion are numerous and diverse, and it seems likely that many of the available theories capture relevant aspects of the emotion phenomenon as it occurs in humans and other animals. The NCE architecture itself is flexible enough to support a variety of approaches to AI emotion; a theoretical analysis of related issues is given in [12]. For the purpose of the VAB project, however, we have opted for a relatively simplistic approach, drawing directly on the ontology of emotions supplied in [14]. Based on a deep and rigorous analysis of the logical structure of emotional experience, [14] propose an emotional ontology that is well summarized in Figure 3:

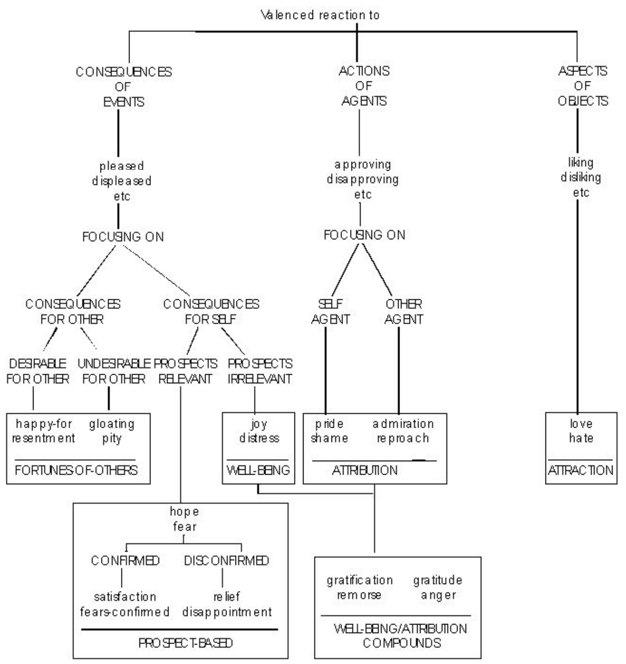

Figure 3. Ortony et al's logic-based ontology of emotions [14]

We have implemented this emotion theory within the VAB via the simple mechanism of associating a PredicateNode with each emotion in the ontology. While this may seem overly simplistic, it's not as bad as it initially seems. As argued in [13], there is not necessarily a dichotomy between localized and distributed representations of knowledge. A PredicateNode associated with an emotion like anger must be considered not in isolation, but rather as a trigger of, and indicator of, broader patterns of activity within the NCE's knowledge base.

Next, regarding animal personality, we have taken a pragmatic approach, including a number of personality parameters drawn directly from the cognitive theory of emotions –

- ill-will, which determines how much resentment/ gloating the pet indulges in
- morality, which determines how much pride/shame/ admiration/reproach the pet indulges in (this is related to obedience)
- goal-orientation, which determines how much joy/distress the pet indulges in, i.e. how much does it care if it gets what it wants or not
- other-orientation, which determines how much the pet indulges in emotions related to others (e.g. happiness-for, admiration/reproach, resentment/gloating)

-- and also a number of personality parameters drawn from qualitative analysis of the psychology of dogs (being the animals we're initially exploring): aggressiveness, curiosity, playfulness, friendliness, fearfulness and obedience. There is also a personality parameter called "emotional expressiveness," which governs how intensely an animal needs to be experiencing an emotion in order to express it externally.

Each animal is assigned a number corresponding to each personality parameter, and the set of these numbers is a crude characterization of the animal's personality. Of course, the actual personality of the animal is more complex than a set of numbers, and consists of a set of complex emergent patterns that are induced by these numbers in the context of the animal's cognitive structures and dynamics and the environment in which it is embedded.

5 INFERENTIAL DYNAMICS FOR EMOTION AND PERSONALITY DRIVEN BEHAVIOR DETERMINATION

Now we describe the scheme via which animal emotions are updated, and used to drive behavior, in the VAB architecture. In short, a collection of probabilistic logic implications are encoded relating emotional states, personality traits and behaviors. Emotional state adjustment and emotion and personality driven behavior determination are then guided by chaining of these implications. In the current, prototype version the implications ("rules") have been hard-coded, but, the overall VAB architecture supports the learning of such rules based on experience and on combination and generalization of pre-programmed rules; and, future work will explore this direction.

The full rule-base used to guide spontaneous behaviors and emotions in the current system version is too large to present here, but we will give a few evocative examples. First, though, we must give a few comments on rule notation. Firstly, the notation ==> in a rule indicates a PredictiveImplication relationship. Rules are assumed to have truth value strengths drawn from a discrete set of values

{0, VERY LOW, LOW, MIDDLE, HIGH, VERY HIGH, 1}

In the following list, all rules should be assumed to have a truth value of HIGH unless something else is explicitly indicated

Also, predicates (including emotions, personality values and others) are assumed to be scalable according to a scaling function called scale(), which takes two arguments: scale(x,c), where both x and c should live in [0,1]. The behavior of this is as follows:

If c=1, then $\text{scale}(x,c) = x^r$
If c=0, then $\text{scale}(x,c) = x$
If c=-1, then $\text{scale}(x,c) = x^{1/r}$

(As a default one may choose, say, r=5 for the scaling parameter.) For fixed x, scale(x,c) increases as c increases. The reason to use this function is because if x is trapped in [0,1], one can't scale it by multiplying it by a constant. So we need to scale x nonlinearly, in a way that making c bigger generally makes x bigger. A simple first choice of scaling function is

$\text{scale}(x,c) = x^{c*r}$, for c>0
$\text{scale}(x,c) = x^{|c|\,/\,r}$, for c<0

For simplicity of notation, scaling by c will be denoted ^^c . For instance

$.5^{\wedge\wedge c} = \text{scale}(.5,c)$
$\text{AggressivenessP}^{\wedge\wedge .8}$. = scale(AggressivenessP,.8)

Without scaling, it seems that rules with more factors on the lhs will generally be less often invoked because their lhs has the product of a larger number of terms, all less than 1. So we have introduced a default scaling, so that in a rule with k terms, all terms are scaled by ^^(-k/r), for example.

For clarity, in the following list of rules, we've used suffixes to depict certain types of entities: P for personality traits, E for emotions, C for contexts and S for schemata (the latter being the lingo for "executable procedures" within the NCE). In the case of schemata an additional shorthanding is in place, e.g. barkS is used as a shorthand for (Execution bark) where bark is a SchemaNode. Also, the notation TE<expression>($X) is shorthand for

ThereExists $X
    Evaluation <expression> $X

i.e. an existential quantification relationship.

Example rules from the rule-base are as follows:

- angerToward($X) ==> angry
- loveToward($X) ==> love
- hateToward($X) ==> hate
- fearToward($X) ==> fear
- TEgratitudeToward($X) ==> gratitude
- angerToward($X) ==> ~friend($X) <LOW>
- TE(near($X) & novelty($X)) ==> novelty
- TEloveToward($X) & sleepy ==> gotoS($X)
- TE(loveToward($X) & near($X)) & sleepy ==> sleepS
- gratitudeToward($X) ==> lick($X)
- atHomeC & sleepyB ==> Ex sleepS <.7>

- gotoS($X) ==> near($X) <.6>
- gotoS($X) ==> near($X) <.6>
- AggressivenessP & angryE & barkS => happyE
- AggressivenessP & angryE & barkS ==> proudE
- AggressivenessP & angerToward($X) ==> barkAtS($X) <VH>
- AggressivenessP & angerToward($X) ==> barkAtS($X) <VH>
- AggressivenessP & angerToward($X) ==> nipS($X) <MID>
- AggressivenessP & near($X) & ~friend($X) ==> angerToward($X)
- AggressivenessP & near($X) & enemy($X) ==> angerToward($X) <VH>
- AggressivenessP & near_my_food($X) & ~friend($X) ==> angryToward($X) <VL>
- AggressivenessP & near_my_food($X) ==> angryToward($X)
- AggressivenessP & angerToward($X) & ~friend($X) ==> hate($X)
- AggressivenessP & OtherOrientationP & ownerNear($X) & enemy($X) ==> angerToward($X)
- AggressivenessP & near($X) & enemy($X) & homeC ==> angerToward($X)
- AggressivenessP & ~happyE & ~angryE ==> boredE
- AggressivenessP & jealousE ==> angryE
- AggressivenessP & boredE ==> angryE <LOW>

Spontaneous activity of a virtual animal, governed by the above equations, is determined based on the modeling of habitual activity as the carrying out of actions that the pet has previously carried out in similar contexts. For each schema S, there is a certain number of implications pointing into (Ex S), and each of these implications leads to a certain value for the truth value of (Ex S). These values may be merged together using (some version of) the revision rule.

However, a complication arises here, which is the appearance of emotion values like happyE on the rhs of some implications, and on the lhs of some others. This requires some simple backward chaining inference in order to evaluate some of the (Ex S).

A similar approach applies to the generation of goal-driven activity based on rules such as the above. As an example, suppose we have a goal G that involves a single emotion/mood E, such as excitement. Then there are two steps:

1. Make a list of schemata S whose execution is known to fairly directly affect E
2. For these schemata, estimate the probability of achievement of G if S were activated in the current context

For Step 1, we can look for

- Schemata on the lhs of implications with E on the rhs
- One more level: schemata on the lhs of implications with X on the rhs, so that X is on the lhs of some implication with E on the rhs

Perusing the above rules, one notes a similarity to the dimensional approach to emotional characterization [3], which is that the emotional state of an agent is being described here as a numerical vector whose entries are the probabilistic truth values of emotion predicates. However, the dynamics of these truth values are being adjusted via probabilistic-logical rules which are more naturally interpreted in a logical framework than a vector-space framework, even though they can in many cases be interpreted as nonlinear transforms on vector space. (Specifically, if one makes independence assumptions translating & into multiplication, then each logical rule becomes a nonlinear transform; but if one uses more sophisticated inference and evaluates conjunctions more accurately based on background knowledge and experience, then the vector space mapping becomes more complex and only holds up if one moves to a higher-dimensional space whose coordinates are logical combinations of behavior/emotion/personality predicates.)

7 RESULTS & FUTURE WORK

We have described an approach to emotion and personality driven behavior determination for virtual animals. The approach has a relatively simple initial incarnation, which has been implemented as described above. And our preliminary experimentation suggests that the initial version is quite sufficient to give rise to a variety of interesting behaviors. One may configure the parameters to create dogs with a variety of personality types; for instance, to give just a few examples, we created

- Diablo: an aggressive dog.
- Maxie: a curious and fearless dog
- Bob: a purely fearful dog
- Princess: A fearful but also curious dog
- Sleepy: A very calm dog

Examples of scenarios enacted using these dogs include some involving attack:

- An avatar attacks Diablo. He bites back immediately.
- An avatar attacks Maxie. She runs away. He attacks again, then Maxie bites back.
- An avatar attacks Bob. He runs away. He attacks again. Bob runs away again.

and some involving a new object (say, a stick or a ball) placed into the vicinity of the dog:

- Maxie is having fun with her owner, but immediately leaves and runs across the scene investigate the object.
- Princess does not leave her owner to investigate the object, but when the owner walks near to the object, Princess does investigate it.
- Sleepy does not investigate the object at all, but simply stays near the owner. The owner picks up and throws the object but Sleepy still doesn't bother to investigate, simply rubbing against the owner's leg instead.

The variations in behavioral response demonstrated in these examples emanate directly and simply from the personality parameters associated with the separate dogs.

The approach described here also presents a broad scope of possibilities for future growth. Most notably, since the behavior and emotion determination rules are expressed in the form of probabilistic-logic implications, it will be natural to augment the initial architecture via

- introducing automated mining of rules based on a database of the system's experience (the principle being that rules which the system has implicitly followed in the past, may be explicitly mined as probabilistic implications and then used as explicit behavior determination rules; this process has a deep foundation in cognitive systems theory and is related to the "cognitive equation" articulated in [15]).
- utilizing probabilistic logic to derive new rules from existing ones, based on logic rules described in [11] such as deduction, induction, abduction, analogy and so forth.

We suspect that these enhancements will lead to substantially richer behaviors and emotional dynamics,

Finally there arises the issue of validation. The real test of all these ideas, of course, will be when the animals are released in Second Life and other virtual worlds for interaction with end-users. But it is also of interest to design more objective metrics for assessing the quality of behavioral/emotional dynamics, and this will be one of our foci in our ongoing work.

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The huggable robot Probo: design of the robotic head

Kristof Goris and **Jelle Saldien** and **Bram Vanderborght** and **Dirk Lefeber**[1]

Abstract. Probo is a social robot intended to be used with children in a hospital environment to provide them with information, moral support and to comfort them in a possible difficult time. This paper reports on the early stages in the development of the expressive huggable robot Probo with potential applications for Human-Robot Interaction (HRI) and Robot-Assisted Therapy (RAT). Drawing on research in social communication, the robot head, capable of displaying basic emotions, is designed and compared with other social robot heads such as Kismet, Eddie and iCat. Some design criteria and their influence on the actual design are highlighted. This leads to a 17 Degrees of Freedom (DOF) modular non-anthropomorphic soft actuated robotic head.

1 INTRODUCTION

1.1 Research Motivation

Recently, more and more robots are created with intention to interact and communicate with humans while following social rules. The field of social robots and safe Human-Robot Interaction (HRI) opens new areas of applications like: healthcare, caretaking, assistance, edutainment and entertainment. For example, a social robot could be used in Robot-Assisted Therapy (RAT). In RAT a robot with specific characteristics becomes a fundamental part of a person's treatment. RAT will improve the physical, social, emotional, and/or cognitive condition of a patient, as well as provide educational and motivational effectiveness for participants. Currently, RAT is established with social robots like Intelligent System's robot seal PARO [21] [22] , Sony's dog robot AIBO [24], Philips' cat robot iCat [25] and Omron's NECORO [14].

Hospitalized children form a target group that needs some special attention. They need to be distracted from the scary and at the same time 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, hospital environment, medical investigations [11]. Currently, there are already several projects that aim to use Information and Communication Technologies (ICT) like the internet and webcams to allow hospitalized children to stay in contact with their parents, to virtually attend lectures at school, etc. [9]. However, these 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. People need a reference point to refer their communication to [7]. From this perspective, we started with the development of a social robot named Probo. This paper is organized as follows: section one describes the research motivation and the project, section two describes the mechanical design of the robotic head considering some specific design criteria, in section three the electronics and Graphical User Interface (GUI) are described, section four shows some design evaluations and finally, section five concludes this paper.

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1.2 Project Overview

The development of the huggable robot Probo is one part of the ANTY project [20]. The main objective of the ANTY project is to offer solutions to some specific needs of hospitalized children.

Another aspect of the ANTY-project is the creation of a multidisciplinary 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: HRI and RAT, will be investigated.

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

1.3 The Huggable Social Robot Probo

Probo (Figure 1) resembles an imaginary animal based on the ancient mammoths. The main aspects are a huggable appearance, an attractive trunk or proboscis, and an interactive belly-screen. The internal mechanics of the robot will be covered with foam and a removable fur-jacket, in such a way that Probo looks and feels like a stuffed animal.

To communicate, our robot requires the ability to express emotions. In order to do so, a fully actuated head, for facial expressions, and a specific language are being developed. The robot Probo will speak to the children using nonsense affective speech, which will be a cross-cultural and understandable language for most of the children regardless of their own native language [29].

At first the robot is controlled by an operator and functions as an interface performing preprogrammed scenarios and reacting on basic input stimuli. The input stimuli come from low-level perceptions, that are derived from vision analysis, audio analysis and touch analysis. Those stimuli will influence the attention and emotion system, used to set the robot's point of attention, current mood and corresponding facial expression. The vision analysis includes the detection of faces, objects and facial features such as facial expressions. Audio analysis includes detecting the direction and intensity of sounds and the recognition of emotions in speech. The touch analysis will be used to detect where the robot is being touched and the different types of affective touch such as tickling, poking, slapping, petting, etc.

Figure 1. A conceptual view of the huggable social robot Probo.

2 MECHANICAL DESIGN

2.1 Design Criteria

2.1.1 Facial Action Coding System

Facial expression is a major modality in human face-to-face communication [16]. If we want to use Probo for displaying facial expressions and emotions, it will need several degrees of freedom (DOF) in its head. Most DOF of the face are based on the Action Units (AU) defined by the Facial Action Coding System (FACS) developed by Ekman et al. [8]. AU express a motion of mimic muscles as 44 kinds of basic operations, with 14 AU to express the 6 basic emotions: anger, fear, disgust, sadness, happiness, and surprise. The number of DOF in Probo's head is compared to other prominent robot heads like: Kismet [6], Leonardo [5], iCat [25], iCub [2], Roman [13], Robota [3], Eddie [23], Aryan [19], Saya [12], WE-4RII [1] and androids of the Intelligent Robotics Laboratory directed by Ishiguro [17]. Most of those robotic use eyes, eyelids, eyebrows and a mouth to conform with the AU. In contrast with other robotic heads, a special feature, namely the trunk, is added to possibly intensify certain emotional expressions and to increase interactivity. Table 1 shows the DOF of Probo's robot head compared to some other non-android robot heads.

Table 1. DOF and ranges of the actuated joints of Probo's head in comparison with other prominent non-humanoid robot. heads

	Kismet	Eddie	iCat	Probo		
(DOF)					**Range [°]**	
Eyes	(3)	(3)	(3)	**(3)**	**Pan** **Tilt**	**100** **80**
Eyelids	(2)	(4)	(2)	**(2)**		**150**
Brows	(4)	(4)	(2)	**(4)**		**45(cf exp)**
Ears	(4)	(4)		**(2)**		**90**
Yaw	(1)	(1)		**(1)**	**Yaw**	**45**
Lips	(4)	(4)	(4)	**(2)**	**Lipcorners**	**60**
Special features		Crown (1)		**Trunk (3)**		**(cf exp)**

2.1.2 Uncanny Valley

Since our robot has to be seen as an imaginary creature, it has no resemblances with existing animals or humans. In this way we avoid Mori's theory of the uncanny valley that states that as a robot increases in humanness, there is a point where the robot is not fully similar to humans but the balance between humanness and machine-likeness is uncomfortable for a user [28].

2.1.3 Intrinsic Safety

Most of the robots are actuated by electric drives as these actuators are widely available and their control aspects are well-known. Because of the high rotational speed of the shaft and the low torque of an electrical motor, a transmission unit is often required. Due to the high reflected inertia of the transmission unit, the joint must be seen as rigid. This is in contrast with our goal to create a huggable robot that has to feel complaint. The use of the soft actuation principle together with well thought through designs concerning the robot's filling and huggable fur, are both essential to create Probo's soft touch feeling.

Compliant actuation is an innovative actuation principle in the world of robotics. Pneumatic muscles (e.g. PPAM [27]), MACCEPA [26] and voice coil actuators [15] are some examples of soft actuators. While the stiffness of the actuated joint can be changed with [26] and [27], it is not required in our application. Thus, compliance is introduced using an easier way, namely 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. Precision positioning is complex in comparison with classic high positioning actuators typically used in industrial applications but the intrinsic safety introduced in the system is of major importance in HRI.

2.1.4 Environment

Although Probo will look and behave like a huggable pal for hospitalized children, it implements some important design restrictions. Strict rules concerning hygiene, mobility, noise, usage of electronic devices, etc. are being used in hospital environments. As the robot will be devoted to children, it has to be intrinsicly safe, strong and light weighting while still being huggable. These demands imply restrictions on used materials, actuation mechanisms and overall control strategies.

2.1.5 Modular System Architecture

On top of the restrictions above, the prototype designer has to keep in mind the need of a modular mechanical system architecture to simplify assemblance and maintenance. This approach leads to an effective development and realization of a robot prototype and requires the use of transferable mechanic and electronic components. By lack of commercially available standard mechanic and electronic modules e.g. eyes, eyebrows, trunk, etc. one must design prototype depended modules. To reduce development and production time, the different modules are designed using commercially available of the shelve components as much as possible.

In the next paragraphs the different modules with the AU needed to express facial expressions and the basic emotions are described. Each module can easily be replaced without effecting the other ones.

2.2 Eyes & Eyebrows

Besides the role of the eyes to show some facial expressions, there are two additional reasons to equip a social robot with actuated eyes.

1. Eye-gaze based interaction: The phenomenon that occurs when two people cross their gaze is called eye contact, and it enables communication [4]. The same phenomenon between robot and child will be used to encourage HRI. People use eye-gaze to determine what interests eachother. By focussing the robot's gaze to a visual target, the person interacting with the robot can use the robot's gaze as an indicator of the robot's intentions. This greatly facilitates the interpretation and readability of the robot's behavior, as the robot reacts specifically to what it is looking at [18].
2. Active vision: When a robot is intended to interact with people, it requires an active vision system that can fulfill both a perceptual and a communicative function. An active vision system is able to interact with its environment by altering its viewpoint rather than passively observing it. For that reason, the designed eyes are hollow and can contain small cameras. As its cameras can move, the range of the visual scene is not restricted to that of the static view.

Although the aim of a pet-type robot, the design of our robot eyes is based on that of human anthropomorphic data. The imitation of anthropomorphic eyes gives the impression of being natural. In many species, the eyes and its appendages are inset in the portion of the skull known as the orbits or eye sockets. The movements of different body parts are controlled by striated muscles acting around some joints. The movements of the eye are no exception. When the muscles exert different tensions, a torque is exerted on the globe causing it to turn. This is an almost pure rotation, having only about one millimeter of translation [10]. So we can consider that the eye rotates around a single point in its center.

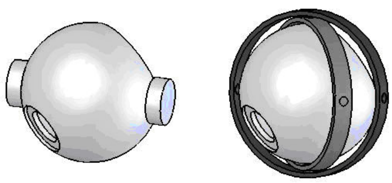

Figure 2. Different possibilities to support a sphere.

Two possible eye-supports are shown in Figure 2. The former holds the eye-ball between Teflon parts with the same spherical curvature as the eye-ball. That way the eye has three DOF just like in a spherical joint, and allows smooth rotations around the center of the sphere due to the low friction. Not one mechanical part intersects the eye-ball, so the eyes can bulge out of the head. The latter concept consists of two rings and two axes. One rotation axis passes through the center point of the eye and holds the eye in the inner ring to allow the eye to rotate relatively to the inner ring. A second rotation axis passes through the inner and outer ring, allowing the inner ring (holding the eye) to rotate with respect to the outer ring. While panning the eye, the inner ring comes out of the plane of the other ring disallowing the eye to bulge out as far as in the former support. Most of the other mentioned robot heads uses the second support type or a variant on it. This often leads to visible mechanical parts and to Mori's theory of uncanny valley. Therefor the first support type is used with Probo.

The five DOF eyes module exists of two hollow eyeballs supported in an orbit as shown in Figure 3. Conform the chosen DOF based on the AU mentioned earlier; the eyes can pan separately and tilt together, each eye can be covered by an upper eyelid and the eyelids can blink separately. The eyebrows module fits on top of the eyes module. Each eyebrow has two DOF meaning that both the vertical position and the angle of each eyebrow can be set independently. Nine commercially available hobbyist servomotors together with a Bowden cable mechanism are used to power the eyes, eyelids and eyebrows. Axial springs and the use of flexible cables both introduce compliance. Position measurement is established by the embedded controllers in the servomotor. Using flexible Bowden cables creates the opportunity to group and isolate the different servos and to place them anywhere in the robot. That way heat and noise dissipation can be controlled and the head can be held light-weighted, both resulting in a safe design.

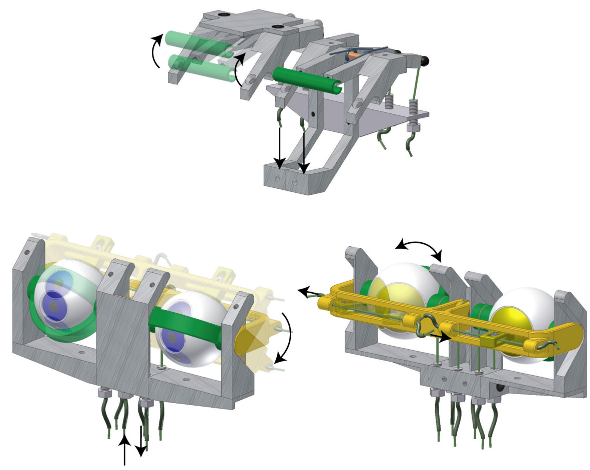

Figure 3. CAD and working principle of eyes and eyebrows of Probo.

2.3 Trunk

According to the results of a small survey amongst children aged 10-13, the proboscis or trunk of the robot seems to be the most intriguing element. It is used to grab and maintain the child's attention. When the child's attention is focussed on the trunk, the child's face fits within the range of the on board eye cameras. This way the child's attention can be guided towards the face of the robot enabling face to face communication.

The three DOF trunk as shown in Figure 4 consists of a foam core with segmented extension discs. Axial to the centerline, three flexible cables are guided through the discs. These cables are fixed to the front disc. Each cable can be wind up on a pulley, resulting in a motion of the entire trunk. The motion of the trunk depends, among other things, on: the number of discs, the dimensions of the discs and the core, the flexibility of the cables and the composition of the foam. The compliance of the trunk is secured by using the foam and the flexible cables. This way the light weight and flexible trunk will not harm the child during HRI.

Three maxon brushless motors are used to actuate the trunk. Each motor is coupled with a worm worm-wheel gear train to reduce the rotational speed and to increase the output torque. A worm drive is used because of its self locking capability. The direction of transmission (input shaft vs. output shaft) is not reversible, due to the greater friction between the worm and worm-wheel. That way the position

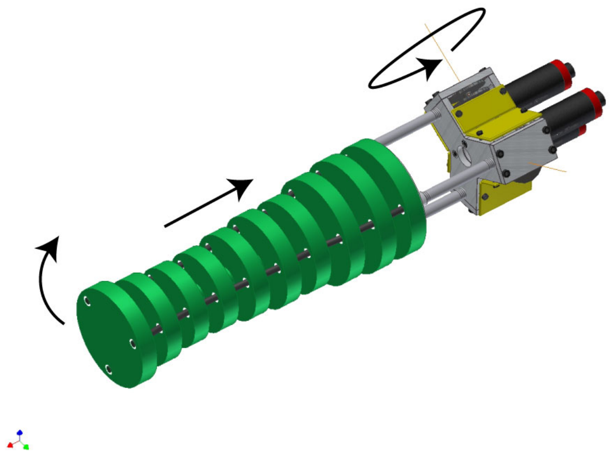

Figure 4. CAD and working principle of the trunk of Probo.

of the trunk will not change after being set and no motor current will be dissipated, resulting in a energy efficient design. Optical encoders are used to calculate the angular displacement of the pulleys and thus an estimation of the trunk position can than be made.

2.4 Mouth & Ears

To reinforce the impression that Probo is a living creature, lip movements and speech are generated. To apply emotions to Probo's speech communication, Probo will use a nonsense affective speech [29]. Probo's mouth has an upper lip and a lower lip. The middle of the upper lip is attached to the trunk. The middle of the lower lip can move vertically so that the mouth can jaw. Both lips come together in the mouth's corners. These mouth corners are actuated. The mechanism used for actuating the mouth corners is the same as that used in the ears module and is shown in Figure 5.

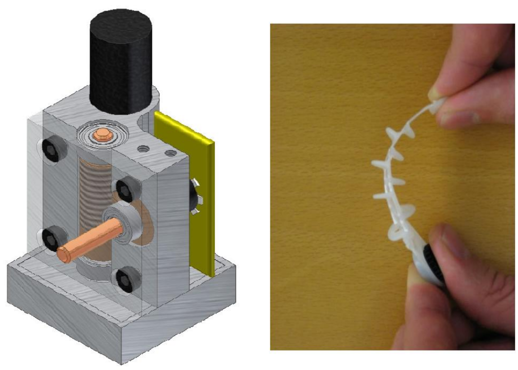

Figure 5. Mechanism to actuate ears and mouth corners.

The mechanism consist of a brushed Maxon motor with a planetary gear train. The first gear train is followed by a second one which is a worm drive. The advantages of this drive are the same as mentioned above. Position measurement is done by an absolute position sensor fixed on the output shaft on which either an ear or a mouth corner is attached. Jawing is established by movement of the middle of the lower lip. An axial spring in the lower lip and a well through thought design of the actuated parts as shown in Figure 5 secure the compliance. Compliance is introduced by the shape of the ear and mouth corners and by the use of flexible materials. The actuated part is flexible in a certain direction, and stiff in the tangent direction. In comparison with [5],[13] and [18], Probo has less DOF in the mouth. In fact this is no restriction to express the basic emotions.

Each ear has one DOF. The movement of our robotic ear is a rotation which consits of two combined rotations. The first rotation turns the entire ear while the second rotation twists the ear axially. That way the ear's opening is pointed to the front when the robot is attended and the opening is pointed to the ground when the ear lies flat to the back.

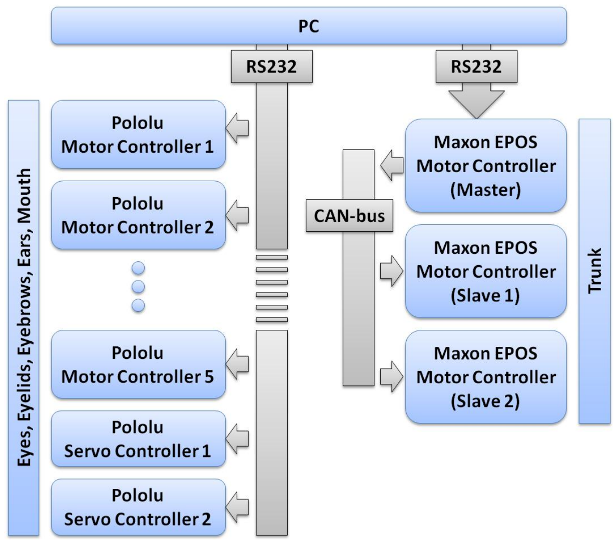

Figure 6. Architecture of the motor controllers.

3 ELECTRONICS & INTERFACE

As described above, three different kind of motors are used and each type of motor has a different motor driver. The Maxon brushless motors, which are used to actuate the trunk, are driven by Maxon's EPOS Motor Controllers. The Maxon brushed motors, used in the mouth and the ears, are driven by Pololu's Motor Controllers with Feedback and the servo motors, for the eyes and eyebrows, are driven by Pololu's Micro Serial Servo Controllers. Figure 6 shows the architecture.

In this stage of the development, a personal computer (PC) is used to control the different motors. Two serial ports, using the RS232 protocol, are used to communicate with the motor controllers. The first serial port communicates with one of the three Maxon EPOS motor controllers. This controller acts as a master in a master-slave set up with the other two Maxon EPOS motor controllers (slaves). The communication between master and slaves is done with CAN. The second serial port communicates with all Pololu controllers. Despite the use of serial communication and the high number of motor positions and speeds needed to refresh, the refresh time rests less than the mechanical inertia and consequently acceptable.

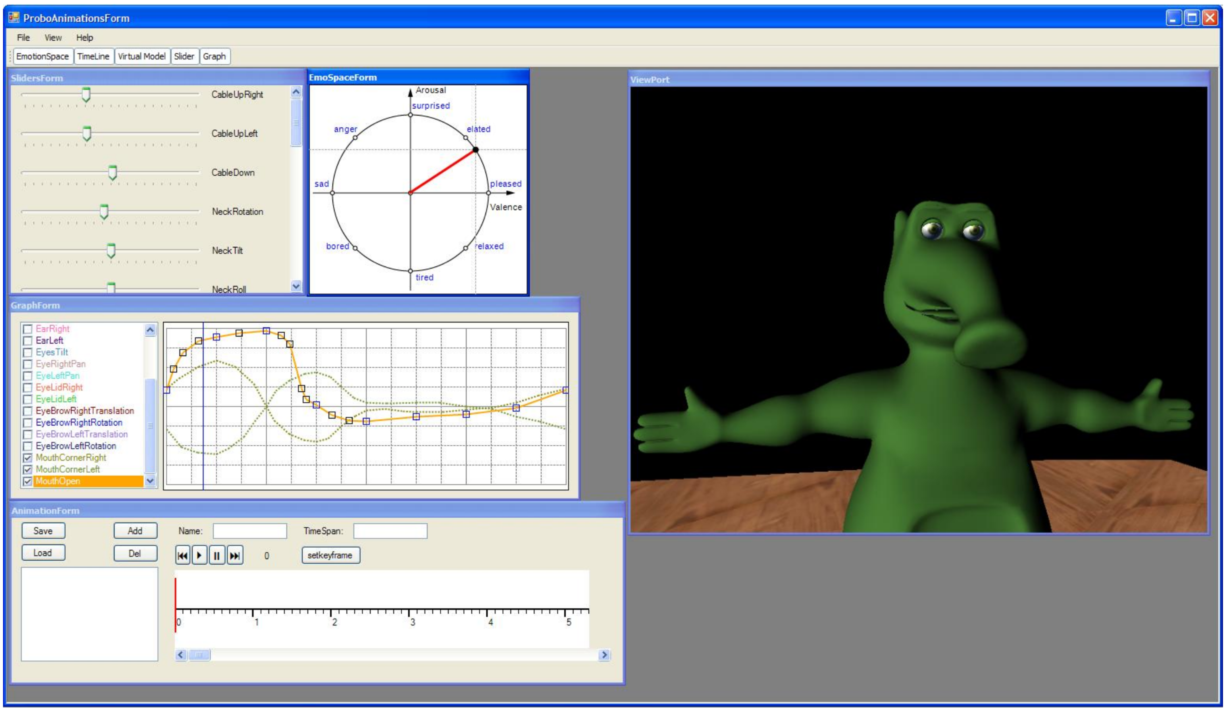

Figure 7. The GUI running on the host PC to control Probo and to create some behaviours. Realtime feedback is given by the virtual Probo.

The control software running on the host PC is written in C# using the .NET framework. By using the Graphical User Interface (GUI), (Figure 7) the software sends the desired motor positions and speeds to the respective motor controllers. By moving sliders, all actuated parts can be moved. Meanwhile, the virtual model on the screen shows the according expression of the face. A time bar with key-points can be used to generate movements from one expression to another.

4 Design Evaluations

Several preliminary experiments and tests were performed during development phase. After conceptual tests CAD drawings of the mechanisms were made in Autodesk Inventor and implemented into a virtual model. The virtual model, generated in Autodesk 3D Studio Max, was used to evaluate virtually the mechanisms and the possibility to express emotions with them (Figure 8).

The looks of the robot and the way it reacts can rather be evaluated subjectively than objectively. In this scope the virtual model based on the real intern mechanical designs will help converting faster to a nice looking and moving prototype in the iterative process of designing. Tests with different mechanisms were done until looks were fine and movements were smooth. Some of these tests were:

- Eyes and eyebrows evalution: the tendon driven eyes, eyelids and eyebrows were tested and some expressions are shown in Figure 10;
- Trunk evalution: during these experiments different trunks were tested. The trunks differ in used materials (foams and flexible cables) and in shape (the number of discs). This iterative process leads to the designed trunk which moves quite smooth and natural. Figure 11 shows the result of such a test.

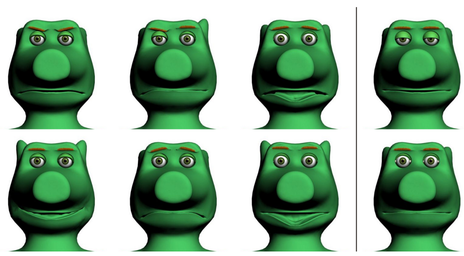

Figure 8. Virtual model expressing the 6 basic emotions: anger, disgust, fear, happiness, sadness and surprised. On the right a sleepy and neutral face.

In this stage of the development, most parts are made out of aluminium because it 's a strong, light weighted and tractable material. Some very specific and complex parts, e.g. the eyeballs and eyelids, are manufactered using advanced rapid prototyping techniques.

5 CONCLUSION & FUTURE WORK

In this paper the design of a new soft actuated, and intrinsic safe, robotic head is highlighted. The head uses a strict set of Action Units (AU) defined by the Facial Action Coding System (FACS) to express the 6 basic emotions; anger, fear, disgust, sadness, happiness, and surprise. The 17 DOF robotic head will be used in the huggable social robot Probo. The eyes, eyelids, eyebrows, mouth, trunk and ears can be moved in order to show some facial expressions. In contrast with other prominent robotic heads, a specific feature, namely the trunk is added. First experiments with some assembled modules, to test motions and ranges, are satisfactory. The GUI, running on a host PC, controls the robotic head and is used to program animations.

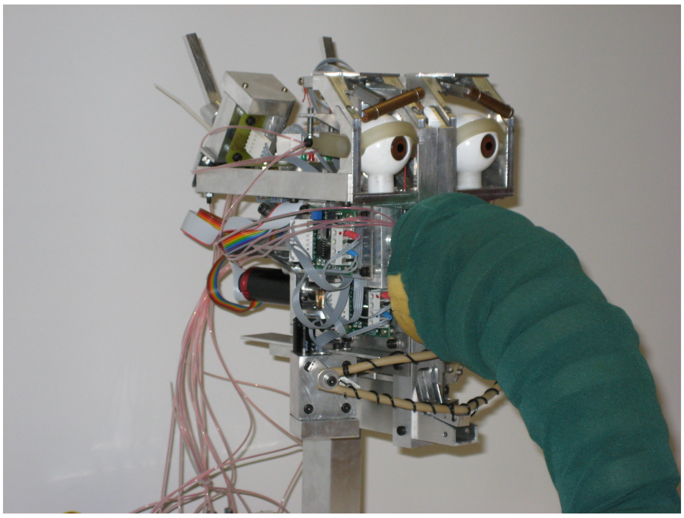

Figure 9. Assembled robotic head of the social robot Probo.

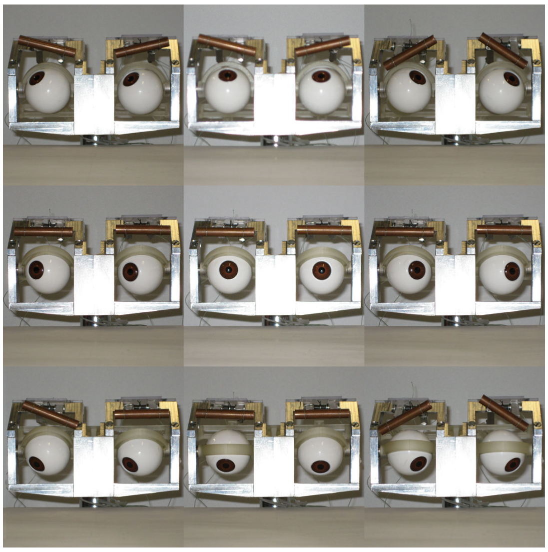

Figure 10. Experimental results of the eyes and eyebrows.

Figure 11. Experimental results of the trunk.

In the near future, three DOF will be added. The head will be supported by an actuated neck module. In this way the entire head can pan, tilt and rotate. A fur jacket will be used to cover the robotic head and to give the robots head a nice, and friendly look. Meanwhile software will be written to generate emotional behaviours.

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Learning to care for a real pet whilst interacting with a virtual one? The educational value of games like Nintendogs

Thomas Chesney[1] and **Shaun Lawson**[2]

Abstract. Publishers and manufacturers of *virtual pet* games and products have also regularly claimed in their marketing literature, that their games and toys have worthwhile educational value - in other words they imply that simply by using their products can people learn to become better pet owners. At present these claims are entirely unfounded. However, if they are true then the impact of their educational value is potentially huge - games like Nintendogs, which, as of January 2008, has sold almost 18 million copies worldwide[2], do indeed have even the slightest educational value then the net improvement to the worldwide understanding of good pet-ownership and animal welfare could be tremendous. This paper outlines a research project aiming to test these claims.

1 INTRODUCTION

Games which exploit traditional features of computer-gameplay for educational benefit – so-called 'serious-games' – have generated widespread interest in recent years [1] and there are many recent examples of games being reported in the literature which have been specifically developed to promote learning of one kind or another in different subject areas and with different age groups (eg [2][3][4]). The majority of such games however have either been developed as research tools, or with their audience restricted in some way and it is still relatively rare to witness mainstream console game titles marketed as being largely educational in their design[3]. The idea that commercially successful games can also incidentally result in learning, or at least in putting across ideas and concepts, however is established to some degree: Squire in [5] gives a good overview of this – and, for instance, reports on the perceived urban-planning learning effects of playing games such as SimCity.

Publishers and manufacturers of *virtual pet* games and products have also regularly claimed in their marketing literature, that their games and toys have worthwhile educational value - in other words they imply that simply by using their products can people learn to become better pet owners. At present these claims are entirely unfounded. However, if they are true then the impact of their educational value is potentially huge - games like Nintendogs, which, as of January 2008, has sold almost 18 million copies worldwide[4], do indeed have even the slightest educational value then the net improvement to the worldwide understanding of good pet-ownership and animal welfare could be tremendous. Additionally, perhaps on a lesser level, parents especially may like to test to see if their children are ready for the responsibility of owning the dog they always wanted.

There is very little previous work which analyses the educational impact of virtual pet games. Related frameworks for evaluating systems are mostly aimed at commercial software and are unable to cope with educational software appropriately [6], let alone a game that might have education benefits. For instance, a usability metric for a commercial application may be that the user must not get lost in a 'sea of information'. For deep learning to occur this may be exactly what is required in an educational package [7]. Many evaluation techniques, such as GOMS suggested by Card *et al*. [8], are designed to be used by HCI professionals and not educators. Evaluation methods that are used for evaluating educational software, such as heuristic evaluation [9], involve evaluation by teachers and not the learners who are ultimately the users of the software, and fail to assess whether actual learning has occurred after use. Other approaches make measurements such as time taken to accomplish a task [10] which relates to learning to use the software rather than learning from using the software.

In this paper we describe our approach to investigating whether common commercially available virtual pet games do indeed provide any beneficial education to children and young people in the care of real animals (specifically dogs) and secondly to determine whether playing such games could influence young people to find out more about caring for their pets than they might learn in the game. We were also interested to discover whether playing virtual pet games have any detrimental effect in younger people's understanding of pet ownership. Our research has the ultimate intention to formulate recommendations to improve such games so that they provide quantifiable improvements in understanding pet ownership and animal welfare.

2 BACKGROUND

A virtual pet is an artificial companion that typically attempts to stimulate human-computer interaction by making the user feel responsible for it. Many virtual pets, visually at least, are often replicas of real animals such as cats and dogs though abstract creatures are not unknown, such as Furby. Millions of consumers worldwide have purchased these products, played with them, interacted with them, invested time in looking after them, and perhaps even become emotionally attached to them. Despite this huge financial and emotional investment by consumers, and an ongoing development and marketing investment by industry (new titles are appearing almost daily), academic interest in such products is virtually nil. This is surprising given the abundant activity in closely related fields such as social robotics [11], emotionally aware and affective computing [12], and the many diverse aspects of believable graphical agents [13][14].

A virtual pet is an artificial companion that attempts to stimulate human-computer interaction by making the user feel responsible for it. The concept gained worldwide popularity (and some notoriety) in the late 1990s when Japanese toy manufacturer Bandai released the handheld computer game, Tamagotchi. There have since have been numerous copycat products, mostly aimed at children, appearing on sale in high street stores for a few tens of UK pounds. Many such derivative games, unlike the Tamagotchi, feature simulations of real companion animals – mainly cats and dogs. Recent examples of these include Anipalz and Password Puppies. In their literature their website, the makers of Anipalz suggest that :

[2] For example, see eview of Nintendo Press release January 2008 at http://www.consoledigest.com/nintendo-announce-wii-and-nintendo-ds-sales-figures.html
[3] A recent exception to this is Dr Kawashima's Brain Training game for the Nintendo DS.
[4] For example, see eview of Nintendo Press release January 2008 at http://www.consoledigest.com/nintendo-announce-wii-and-nintendo-ds-sales-figures.html

"For those of you looking for a real pet, start with these cute little virtual pets that will test…if you can quite cut it as a pet owner."

Games like the Tamagotchi and Anipalz are delivered in a format that requires users to buy a complete electronic device – however there are numerous conventional game products that allow virtual pet software to run on a PC. The Petz series, which includes the games Catz and Dogz (as well as more recent and much more curious titles such Hamsterz and Tigerz), uses animated instances of familiar pet animals as the user's virtual pet. Players (or 'owners'), can choose their pet at the pet shop, look after their health, teach them tricks and so on – exactly as one would with a real pet. The Petz series in this way actually feels more educational when compared with other products. Indeed, Ubisoft's Petz Executive Producer Tony Van, when interviewed about the recent release of the Petz series on the Nintendo DS, stated that:

"one value I always suggest is the player learning how to best take care of their pet, which translates to its use in the real world. This is valuable to both kids and adults, and if it results in one less abused animal in this world, that makes my job even more rewarding"[5]

Such a claim is remarkable – that by playing a computer game which involves caring for a virtual pet, people are able to train themselves to care for, and improve the welfare of, real animals.

Nintendogs, released by the Japanese games company Nintendo in 2005 for its handheld games console the Nintendo DS, is one of the fastest selling games titles of all time and has received consistently high reviews by a video-gaming press usually dominated by adult oriented first-person-shooter and action games enthusiasts. Nintendogs features an animated puppy which owners must feed, water, walk, wash, groom, play with and train. The Nintendogs themselves are animated implementations of real breeds of dog (such as Labradors and Chihuahuas) and move in highly believable animations. Nintendogs is unique in two aspects: firstly, users can actually touch their screen based pet through the use of the DS's touch screen, and secondly users may exploit the wireless network capability of the DS to exchange puppies with each other and allow Nintendogs to visit another device and play with each other.

Figure 1. Can playing a virtual pet game on, for instance, the Nintendo DS improve children's understanding of looking after real dogs?

The typical characteristics of Nintendogs owners are unclear – although it is easy to assume that the game is aimed towards children (Figure 1), some of Nintendo's marketing for the game has clearly been adult oriented. Additionally, Nintendo have claimed[6] that 22% of Nintendogs owners are female compared to only 5% of players of their other early success for the DS platform, Mario Kart DS (a driving game). The games industry still appears to view female gamers as a largely hitherto untapped demographic and whilst early explicit attempts to exploit this potential market were largely seen as unsuccessful, many recent games such as the Sims, Animal Crossing and Nintendogs have shown that certain styles of game-play (for instance, ones that encompass creativity and emotional attachment as well as, or even instead of, tangible goals) are indeed very appealing to female buyers. It is often assumed that the popularity of these games with female players has been accidental – however this view does seem naïve if one considers the careful, often very conservative, but ultimately successful strategies of the two games' publishers Electronic Arts (EA) and Nintendo and the burgeoning academic debate that is informing gender and gaming (e.g. [15]).

Although Nintendo have been careful not to over-hype the educational aspects of Nintendogs, they have reported the results of a, presumably commissioned, review of the game by a relationship psychologist who made the claim that:-

"it (Nintendogs) can not only help develop our attention spans and motor skills, but also improves our ability to solve problems and think creatively …. teaches us how to bond and provides us with a sense of nurture and responsibility ….(and has) emotional effects, helping to raise self-esteem and develop strategic thinking"[7]

Nintendo also teamed up with the charity Dogs Trust in the UK in 2005 during the launch campaign of Nintendogs. In a statement at the time, Dogs Trust marketing manager Adrian Burder stated:

" it's great that there's a game that is not only fun to play, but supports the message that responsible dog ownership means more than giving your dog an occasional stroke."

Once again, the implication of this marketing is that owing a virtual pet improves players' understanding of the implications and requirements of looking after a real one.

Compared to the scarcity of published work in the understanding of the psychological impact of owning virtual pets, there is an abundance of long-standing literature examining the benefits regarding health, social well-being and status afforded by owning real pets (e.g. [16] [17]). In our own work we have already begun to adopt a multi-disciplinary approach to the understanding of virtual pets and companionship [18][19]. In particular we have looked at anthrozoological (human/animal interaction) studies which have attempted to quantify the benefits humans receive from interacting with real pets and companion animals. We have also investigated the role of both age [20] and gender [21] in our studies of virtual pets. We are curious to know whether people interact with virtual pets to gain some, or all, of the same benefits that are achieved by ownership and interaction with real pets, or, conversely, whether people interact with them for reasons that are unconnected – which would be at complete odds with manufacturers' claims. Therefore, we are engaged in an ongoing set of work to compare people's perceived benefits of interaction with both real and virtual pets.

More generally, we believe that there is a set of fundamental, unanswered, questions centered on the commercial interest in virtual pets which is has hitherto been overlooked. Sales figures and the very fact that many virtual pet products are squarely aimed at children and younger people indicates to us that more attention should be paid to the effects, both positive and otherwise, that such products have on their users, owners and players. Subrahmanyam *et al*. [22], in their well known analysis of the on the impact of home

[5] Interview on Gamasutra website at http://www.gamasutra.com/php-bin/news_index.php?story=11736

[6] Fils-Aime, R. Nintendo keynote speech at Montreal International Game Summit, November 2006.

[7] This review was reported in a Nintendo press release, available at: http://www.gamesforhealth.org/news/archives/000086.html.

computer use on the development of children and adolescents, discuss the shift from real life to simulation in the context of virtual pets but merely conclude that systematic research is needed to assess the impact of such technology.

Criterion	Scant evidence of any knowledge	Demonstrates some knowledge but could not be trusted to look after a puppy yet	Demonstrates a reasonable knowledge but would require supervision to look after a puppy	Adequate knowledge of puppy care	Detailed knowledge of puppy care	Comprehensive knowledge of puppy care
Subject is able to prepare for the arrival of a new puppy	Most answers left blank or clearly guessing.	Most obvious questions are answered correctly, but when asked to give lists, only one or two items are given, and more difficult questions are answered incorrectly.	Answers most obvious questions correctly and leaves the others blank. When asked to give lists, typically only one or two items are given.	Has a correct answer for most questions, but when asked to give lists, typically only comes up with one or two ideas.	Has a correct answer for all questions. When asked to give lists, typically comes up with two or three ideas.	Has thought through in depth, a wide range of issues relating to preparation.
Subject is able to care for puppy in the first few days and weeks of its life in its new home	Most answers left blank or gives dangerous answers.	Gives incorrect answers but not dangerous ones.	Could nourish a puppy but not train him.	No answers are incorrect but when asked to give lists, typically only comes up with one or two ideas.	All answers are correct. When asked to give lists, typically comes up with two or three ideas.	All answers correct and demonstrates a deep understanding of puppy care and training.
Subject is able to care for the puppy outside of the home	Most answers left blank or clearly guessing.	Few correct answers but hasn't really thought through all answers.	Some correct answers but hasn't really thought through all answers.	Mostly correct answers but hasn't really thought through all answers.	Could be trusted to take puppy away from home.	Could be trusted to take puppy away from home. Demonstrates thought for the best training for the puppy.
Subject is able to care for the puppy's welfare	All answers incorrect or blank.	Few correct answers.	Most answers correct.	Correct, but brief answers.	Correct answers.	Correct and comprehensive answers.
Subject is comfortable communicating with puppy	All answers incorrect or blank.	Few correct answers.	Most answers correct.	Correct, but brief answers.	Correct answers.	Correct and comprehensive answers.

Table 1 – Rubric (or Criterion Reference Grid; CRG) used to score participants' knowledge of dog ownership.

3 METHODOLOGY

We are currently involved in a study to examine the educational benefits from caring for a virtual pet; specifically, we want to test whether caring for a virtual puppy dog increases knowledge of care for a real one. The games chosen for our investigation are the long running Dogz title currently published by French games company Ubisoft and Nintendogs by the Japanese company Nintendo. Both games run on the Nintendo DS handheld games console. So far we have run a pilot study to test our method.

We have recruited two sets of participants – 20 eighteen year olds to pilot our data collection questionnaire, and 10 participants aged again aged 18/19 to use a DS for six weeks. No subjects in the batch of 10, or their households, had previously owned either a cat or a dog. None of them had previously played the two games used in the study. Our method took a longitudinal approach to examine the educational impact of owning a virtual pet. This entailed firstly assessing each participant's knowledge about acquiring, training and looking after a dog using the questionnaire specially designed, and piloted for this study with the first batch of participants. This was followed by a period of 6 weeks during which half were loaned a copy of either Dogz or Nintendogs, as well as a Nintendo DS, to play with in their own time. The other half were given an alternative game. During this period the first participants were instructed to keep a special diary detailing their interactions with their virtual pet as well as a record of any other ways in which they sought information on pet ownership. At the end of the six week period all participants returned the loaned game and console and were again given the questionnaire based assessment of dog ownership knowledge. Each questionnaire was scored using a rubrics-based approach to assessment. This is shown in Table 1.

5 CONCLUSION

So far, all our work has focused on testing, refining and validating our proposed method for studying the educational impact of owing a virtual pet. When complete, we intend to start data collection with children aged 12-14. This introduces additional hurdles to overcome, which need to be resolved before we can even start to answer the question of whether virtual pets can make users better pet owners.

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