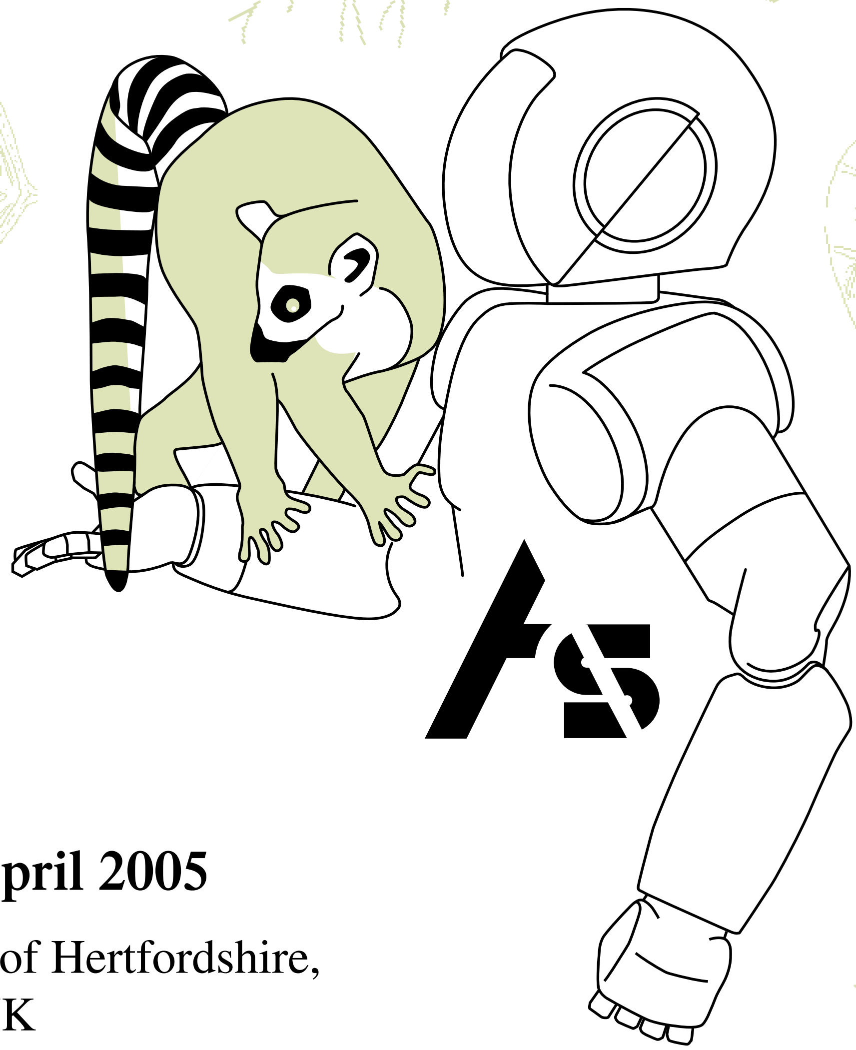
AISB'05: Social Intelligence and Interaction
in Animals, Robots and Agents

Proceedings of the Symposium on Robotics, Mechatronics and Animatronics in the Creative and Entertainment Industries and Arts



12 - 15 April 2005

University of Hertfordshire,
Hatfield, UK

SSAISB 2005 Convention

AISB UH EPSRC Engineering and Physical Sciences Research Council

AISB'05 Convention

Social Intelligence and Interaction in Animals, Robots and Agents

12-15 April 2005
University of Hertfordshire, Hatfield, UK

Proceedings of the Symposium on

Robotics, Mechatronics and Animatronics in the Creative and Entertainment Industries and Arts

(aka the Creative Robotics Symposium)

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Second International Symposium on the Emergence and Evolution of Linguistic Communication (EELC'05)
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Third International Symposium on Imitation in Animals and Artifacts
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Robotics, Mechatronics and Animatronics in the Creative and Entertainment Industries and Arts
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Robot Companions: Hard Problems and Open Challenges in Robot-Human Interaction
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Conversational Informatics for Supporting Social Intelligence and Interaction - Situational and Environmental Information Enforcing Involvement in Conversation
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Next Generation approaches to Machine Consciousness: Imagination, Development, Intersubjectivity, and Embodiment
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Normative Multi-Agent Systems
1 902956 47 6

Socially Inspired Computing Joint Symposium (Memetic theory in artificial systems & societies, Emerging Artificial Societies, and Engineering with Social Metaphors)
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The AISB'05 Convention
Social Intelligence and Interaction in Animals, Robots and Agents

Above all, the human animal is social. For an artificially intelligent system, how could it be otherwise?

We stated in our Call for Participation "The AISB'05 convention with the theme *Social Intelligence and Interaction in Animals, Robots and Agents* aims to facilitate the synthesis of new ideas, encourage new insights as well as novel applications, mediate new collaborations, and provide a context for lively and stimulating discussions in this exciting, truly interdisciplinary, and quickly growing research area that touches upon many deep issues regarding the nature of intelligence in human and other animals, and its potential application to robots and other artefacts".

Why is the theme of Social Intelligence and Interaction interesting to an Artificial Intelligence and Robotics community? We know that intelligence in humans and other animals has many facets and is expressed in a variety of ways in how the individual in its lifetime - or a population on an evolutionary timescale - deals with, adapts to, and co-evolves with the environment. Traditionally, social or emotional intelligence have been considered different from a more problem-solving, often called "rational", oriented view of human intelligence. However, more and more evidence from a variety of different research fields highlights the important role of social, emotional intelligence and interaction across all facets of intelligence in humans.

The Convention theme *Social Intelligence and Interaction in Animals, Robots and Agents* reflects a current trend towards increasingly interdisciplinary approaches that are pushing the boundaries of traditional science and are necessary in order to answer deep questions regarding the social nature of intelligence in humans and other animals, as well as to address the challenge of synthesizing computational agents or robotic artifacts that show aspects of biological social intelligence. Exciting new developments are emerging from collaborations among computer scientists, roboticists, psychologists, sociologists, cognitive scientists, primatologists, ethologists and researchers from other disciplines, e.g. leading to increasingly sophisticated simulation models of socially intelligent agents, or to a new generation of robots that are able to learn from and socially interact with each other or with people. Such interdisciplinary work advances our understanding of social intelligence in nature, and leads to new theories, models, architectures and designs in the domain of Artificial Intelligence and other sciences of the artificial.

New advancements in computer and robotic technology facilitate the emergence of multi-modal "natural" interfaces between computers or robots and people, including embodied conversational agents or robotic pets/assistants/companions that we are increasingly sharing our home and work space with. People tend to create certain relationships with such socially intelligent artifacts, and are even willing to accept them as helpers in healthcare, therapy or rehabilitation. Thus, socially intelligent artifacts are becoming part of our lives, including many desirable as well as possibly undesirable effects, and Artificial Intelligence and Cognitive Science research can play an important role in addressing many of the huge scientific challenges involved. Keeping an open mind towards other disciplines, embracing work from a variety of disciplines studying humans as well as non-human animals, might help us to create artifacts that might not only do their job, but that do their job right.

Thus, the convention hopes to provide a home for state-of-the-art research as well as a discussion forum for innovative ideas and approaches, pushing the frontiers of what is possible and/or desirable in this exciting, growing area.

The feedback to the initial Call for Symposia Proposals was overwhelming. Ten symposia were accepted (ranging from one-day to three-day events), organized by UK, European as well as international experts in the field of Social Intelligence and Interaction.

- Second International Symposium on the Emergence and Evolution of Linguistic Communication (EELC'05)
- Agents that Want and Like: Motivational and Emotional Roots of Cognition and Action
- Third International Symposium on Imitation in Animals and Artifacts
- Robotics, Mechatronics and Animatronics in the Creative and Entertainment Industries and Arts
- Robot Companions: Hard Problems and Open Challenges in Robot-Human Interaction
- Conversational Informatics for Supporting Social Intelligence and Interaction - Situational and Environmental Information Enforcing Involvement in Conversation
- Next Generation Approaches to Machine Consciousness: Imagination, Development, Intersubjectivity, and Embodiment
- Normative Multi-Agent Systems
- Socially Inspired Computing Joint Symposium (consisting of three themes: Memetic Theory in Artificial Systems & Societies, Emerging Artificial Societies, and Engineering with Social Metaphors)
- Virtual Social Agents Joint Symposium (consisting of three themes: Social Presence Cues for Virtual Humanoids, Empathic Interaction with Synthetic Characters, Mind-minding Agents)

I would like to thank the symposium organizers for their efforts in helping to put together an excellent scientific programme.

In order to complement the programme, five speakers known for pioneering work relevant to the convention theme accepted invitations to present plenary lectures at the convention: Prof. Nigel Gilbert (University of Surrey, UK), Prof. Hiroshi Ishiguro (Osaka University, Japan), Dr. Alison Jolly (University of Sussex, UK), Prof. Luc Steels (VUB, Belgium and Sony, France), and Prof. Jacqueline Nadel (National Centre of Scientific Research, France).

A number of people and groups helped to make this convention possible. First, I would like to thank SSAISB for the opportunity to host the convention under the special theme of *Social Intelligence and Interaction in Animals, Robots and Agents*. The AISB'05 convention is supported in part by a UK EPSRC grant to Prof. Kerstin Dautenhahn and Prof. C. L. Nehaniv. Further support was provided by Prof. Jill Hewitt and the School of Computer Science, as well as the Adaptive Systems Research Group at University of Hertfordshire. I would like to thank the Convention's Vice Chair Prof. Chrystopher L. Nehaniv for his invaluable continuous support during the planning and organization of the convention. Many thanks to the local organizing committee including Dr. René te Boekhorst, Dr. Lola Cañamero and Dr. Daniel Polani. I would like to single out two people who took over major roles in the local organization: Firstly, Johanna Hunt, Research Assistant in the School of Computer Science, who efficiently dealt primarily with the registration process, the AISB'05 website, and the coordination of ten proceedings. The number of convention registrants as well as different symposia by far exceeded our expectations and made this a major effort. Secondly, Bob Guscott, Research Administrator in the Adaptive Systems Research Group, competently and with great enthusiasm dealt with arrangements ranging from room bookings, catering, the organization of the banquet, and many other important elements in the convention. Thanks to Sue Attwood for the beautiful frontcover design. Also, a number of student helpers supported the convention. A great team made this convention possible!

I wish all participants of the AISB’05 convention an enjoyable and very productive time. On returning home, I hope you will take with you some new ideas or inspirations regarding our common goal of understanding social intelligence, and synthesizing artificially intelligent robots and agents. Progress in the field depends on scientific exchange, dialogue and critical evaluations by our peers and the research community, including senior members as well as students who bring in fresh viewpoints. For social animals such as humans, the construction of scientific knowledge can't be otherwise.

Beppu, Japan.

Dedication:

I am very confident that the future will bring us increasingly many instances of socially intelligent agents. I am similarly confident that we will see more and more socially intelligent robots sharing our lives. However, I would like to dedicate this convention to those people who fight for the survival of socially intelligent animals and their fellow creatures. What would 'life as it could be' be without 'life as we know it'?

Kerstin Dautenhahn

Professor of Artificial Intelligence,
General Chair, AISB'05 Convention *Social Intelligence and Interaction in Animals, Robots and Agents*

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Symposium Preface
Robotics, Mechatronics and Animatronics in the Creative and Entertainment Industries and Arts

SYMPOSIUM OVERVIEW

The Robotics, Mechatronics and Animatronics in the Creative and Entertainment Industries and the Arts Symposium *aka the Creative Robotics Symposium* is the first research related event to be supported by the EPSRC funded Creative Robotics Research Network (CRRN).

Established in September 2004, the CRRN is currently building a network of members from academia, industry and the arts who share a passion in the creative potential of robotics related technologies. The network's launch event, held jointly with the RoboFesta-UK Educational Robotics Network Fourth Annual Meeting at the Open University, in November, 2004, provided a glimpse into the world of Creative Robotics that will be developed more fully in this Symposium.

The original call for papers for what we have come to refer to as *aka the Creative Robotics Symposium* sought to attract presenters from outside the arena of academic robotics research, as well as from within it:

“Robotics, mechatronics and animatronics are playing increasingly prominent roles in the arts, creative enterprises and entertainment sectors - from theatre sets and film studios to contemporary kinetic sculpture and from advanced marketing displays to theme parks.

“This Symposium seeks to bring together academic researchers, industry representatives and arts practitioners to explore the expressive potential of 'creative robotics' technologies in both small works and in the wider context of the creative and entertainment industries.

“In particular, the Symposium will provide an opportunity for robotics researchers to describe creative applications of their research effort as well as discussing technical issues and approaches...”

As we had hoped, the call was open enough to solicit papers from authors from a wide range of backgrounds: industry, academia and the arts are all represented in the pages that follow. The programme itself ranges from the history of Cybernetic Sculpture, to recent robot artworks, via robotics outreach projects and what may turn out to be the first forays into a philosophy of Creative Robotics. Our thanks go in advance to all the presenters and delegates who we are sure will make this first research meeting of the CRRN an event to be remembered (and hopefully for all the right reasons!)

Thanks must also go to the Programme Committee, who themselves represent a varied cross section of the UK robotics community. Faced with an uncertain brief, their invaluable feedback was much appreciated by all concerned:

Martin Smith, Philip Breedon, Jeremy L Wyatt, John Q. Gan, Robert Richardson, Barry Smith, Alex Zivanovic, Dongbing Gu, Andy Gracie, Jon Bird and Mike Reddy.

And so to the Symposium papers themselves, and a good place to start the story of Creative Robotics….

Tony Hirst & Ashley Green, Open University, 3rd February, 2005
www.creativerobotics.org.uk

SAM, The Senster and The Bandit: Early Cybernetic Sculptures by Edward Ihnatowicz

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Abstract

Edward Ihnatowicz (1926-1988) built one of the world's first computer-controlled robotic sculptures, the Senster, in 1968-70. This paper describes that ground-breaking work and examines some of his other cybernetic sculptures, SAM and The Bandit. It also describes how his ideas developed.

1 Introduction

Edward Ihnatowicz was born in Poland in 1926, leaving in 1939 as a war refugee, eventually arriving in Britain in 1943. He studied sculpture at the Ruskin School of Art in Oxford from 1945 to 1949, when he was also interested in electronics:

"I built myself an oscilloscope out of bits from an old radar set, things like this. But, at some point, feeling introspective and conscientious, I said `I've got to concentrate on my drawing and painting, throw away all my electronics, to dedicate myself to my art'. The stupidest thing I've ever done. I had to start again from scratch ten years later." (Reffin Smith, 1984)

He was doing well working in a furniture design company when, in 1962, he left the business and his home to live in an unconverted garage and return to making art. He slept in a sleeping bag on a bed surrounded by a stove, kiln, crucible, welding and assorted workshop machinery. He was now nearly forty years old and felt that his art had not matured with him, leaving him very dissatisfied. He mostly produced conventional portrait busts but he also made a number of sculptures out of parts of old motor cars and even sold a couple. He did not regard them as "serious" sculpture, but he enjoyed making them, and as he came to believe, doing something that he found enjoyable was essential. He had always enjoyed working with machines so continued dismantling cars. In doing so, he realised that the shapes of the highly engineered components of the cars he was taking apart were more satisfactory from the aesthetic point of view than his abstract sculpture, through having *"more conviction and an air of purposefulness and suitability for the tasks for which they were intended; and also that those tasks invariably involved some form of physical motion or transmission of forces."* (From Ihnatowicz's private papers)

Clearly, movement held a great fascination for him and his experience of dismantling cars taught him about ways of generating interesting motion. In particular, he stripped a hydraulic braking system from a car and reconstructed it. He was impressed by the power, smoothness and precision with which it could be made to move heavy objects. He realised that this was a good way of producing very subtle and well-controlled motion and the oil could be delivered to any number of actuators through flexible piping, but to do this required an ability to control precisely the amount of oil being fed to a hydraulic piston. Foot pedals clearly had to be replaced by a motorised pump and the flow controlled by valves. Some method of automatically controlling the valves was required and, even more importantly, an ability to define precisely the motion to be produced. He first attempted to make hydraulic pistons, with little success. After a long search, he found some pistons, together with some servo valves, in a batch of government surplus materials. Neither he nor the dealer were aware of the function of the servo valves and in researching their use, he found out about the whole area of control engineering which he realised would be central to the work he was interested in.

"I can be very precise about when I discovered technology - it was when I discovered what servo systems were about. I realised that when I was doing sculpture I was intrigued or frustrated, because I was much more interested in motion, I was trying to make my figures look as if they were about to take

off and start doing something. We respond to people's movements to a much greater extent than we are aware of." (Reffin Smith, 1984)

He was always very interested in photography and film-making and would often use an 8mm camera to record motion. One day he shot a sequence of a lioness in a zoo. The big cat was just sitting perfectly still staring into space, and then briefly turned to look at the camera and then turned back again. He thought, "if you went into an art gallery and there was a piece that just turned to look at you as you came in…" That was the event that provided the inspiration for his work.

2 SAM

SAM (Sound Activated Mobile) was exhibited at the *Cybernetic Serendipity* exhibition, which was held initially at the Institute of Contemporary Art (ICA) in London in 1968 and later toured Canada and the US ending at the Exploratorium in San Fransisco. It was Ihnatowicz's first attempt at an articulated structure capable of being controlled by an electronic system (he regarded it as *"the first genuine piece of sculpture I had produced"*) and it moved directly and recognizably in response to what was going on around it.

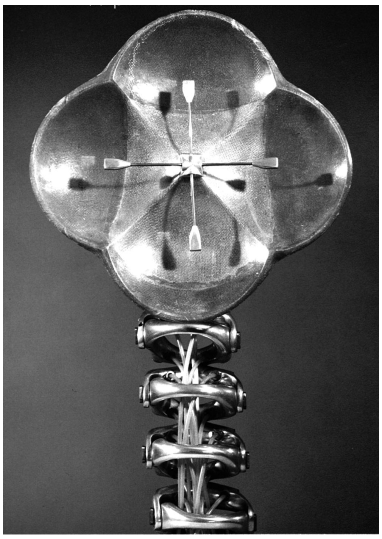

Figure 1: SAM

SAM consisted of a spine-like assembly of aluminium castings somewhat reminiscent of vertebrae (see Figure 1), surmounted by a flower-like fibreglass parabolic sound reflector with an array of four small microphones mounted immediately in front of it. Each vertebra of the spine contained very small hydraulic pistons, which enabled the part to twist in the horizontal plane and to pitch up and down. Each of the pistons had a small range of motion, but was linked to all the others of its type, so that only two servo-valves were used: one to control all the horizontal acting pistons, and one for all the vertical ones. The result was that the whole column could twist from side to side and lean forwards and backwards.

The microphones were arranged in two pairs, one vertically and one horizontally. For each pair, an analogue circuit was used to measure the phase difference between the sound signals on the microphones (effectively measuring the difference in time of a sound arriving at the microphones, and thus the direction of the sound). This output of this circuit was used to control the hydraulic servo valves so that the head turned to face the sound source. This circuit was given to Ihnatowicz by John Billingsley, a friend from Cambridge University and a co-exhibitor at the exhibition. The circuit worked to a certain extent, but by no means perfectly (sound localisation of human voices is still an active research area).

The resultant behaviour, that of following the movement of people as they walked around its plinth, fascinated many observers. Also, since the sculpture was sensitive to quiet but sustained noise, rather than shrieks, a great many people spent hours in front of SAM trying to produce the right level of sound to attract its attention (Reichardt, 1972).

After SAM and Cybernetic Serendipity, Ihnatowicz returned to investigating control engineering, where he was fascinated by analogue computers (constructed of electronic circuits based around operational amplifiers, configured to carry out operations on analogue voltages). He bought an army-surplus oscilloscope, constructed a simple analogue computer and could make the spot on the screen move in what he considered were elegant ways. He also learned how to make his own hydraulic actuators and found out about the various methods of honing, grinding, hardening and sealing, eventually constructing a simple servo-system which would move a lever in strict accordance with the pattern displayed on the oscilloscope. Although the various waveforms produced by the computer were pleasing, and the physical motion of the lever encouraging, he wanted a more precise way of describing the motions to be produced in terms of velocities and accelerations and time intervals. He also wanted to understand better how we and other animals move and, to this end, he contacted some people working with powered prosthetics, having learned that they were analysing movements of human arms during the performance of various tasks. He was amazed to discover that the motion of a human elbow when performing a well-rehearsed movement from one point to another exhibited an almost constant acceleration and deceleration, the sort of motion that he could simulate exactly on his analogue computer.

He also noticed that these people were using digital logic circuits to sequence and control their simulators, and so he taught himself about digital computing. He eventually constructed a small logic network, which, together with a pair of digital-to-analogue converters, enabled his hydraulic lever to perform a great variety of movements.

3 The Senster

Ihnatowicz realised that the shapes which he produced for SAM's neck looked somewhat bone-like, though he had not tried to imitate any natural forms. He was intrigued to discover that an almost identical shape existed in nature in the joint of the claw of the lobster. It was not only the similarity of shape which was intriguing; its operation was like that of his joint: a simple pivoting action, which he had never seem before in nature. Most animals, even those with exo-skeletons, have more complex joints which, like our shoulders, can rotate in several planes at the same time. In the lobster all the joints are simple pivots, but in spite of this apparent limitation and in spite of having only six of them in any leg, that leg can perform all the required motions with perfect ease. Ihnatowicz started sketching ideas for a full-size sculpture based on such a leg (see Figure 2).

Figure 2: Concept Sketch of The Senster

He was constructing a model of such a leg (using miniature hydraulic actuators) when a friend of his introduced him to James Gardener, the exhibition designer. Gardener was responsible for the Evoluon, which was the electronics giant, Philips' new (1966) showpiece permanent technological exhibition (since converted to a conference centre) in Eindhoven, in the Netherlands. Gardener introduced Ihnatowicz to Philips in 1967 and persuaded them to commission him to produce a large moving sculpture, which Gardener eventually named The Senster.

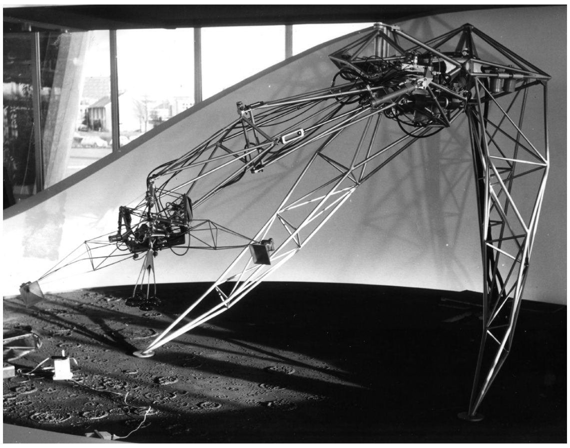

Figure 3: The Senster

The Senster (see Figure 3) was probably the world's first computer controlled robotic sculpture which reacted to its audience and was a huge undertaking which took Ihnatowicz several years to complete (the contract was signed in May 1968 and the Senster went on display in September 1970) but which enabled him to put many of the ideas he had been toying with into practice. It took the general form of a great lobster's claw with the pincer replaced by a moving array of microphones like SAM's, except that the whole thing was now run by a digital computer, had proper industrial actuators and servo-valves and he had a professional engineers from Philips and Mullard to help with the electronics.

He had, by that time, established a close relationship with a number of people in the Department of Mechanical Engineering of University College London (UCL) where he went frequently for advice. For the last year of working on the Senster (from July 1969), he moved there completely. A technician at UCL welded together the huge structure of the Senster and it dominated a laboratory in the basement (for some years after, there was a chunk of concrete missing from the ceiling as a result of a glitch in testing). After the system was tested, it was dismantled and shipped to Eindhoven (in June 1970), where it was installed in the Evoluon. It was unveiled in September of that year and Ihnatowicz stayed in Eindhoven until December. He spent about half of that time sitting in the exhibition hall programming the Senster and observing the interaction between it and the spectators. He came to the conclusion that the shape and the general appearance of the structure were of very little significance compared to its behaviour, and especially to its ability to respond to the public. People seemed very willing to imbue it with some form of animal-like intelligence and the general atmosphere around it was very much like that in the zoo.

Relations between Ihnatowicz and Philips appear to have been difficult because, except for a visit to the official opening of the Evoluon, he was not in contact with them again until the Senster was dismantled, despite offering his services, particularly with regard to programming.

The Senster was large: 15 feet (5m) long and 8 feet (2.4m) tall "at the shoulder" and has been described as resembling a giraffe or dinosaur. It was made of welded steel tubes, with no attempt to disguise its mechanical features. There were six joints along the arm, actuated by powerful, quick and quiet hydraulic rams. Two more custom-made hydraulic actuators were mounted on the head to move the microphone array. The microphones were arranged in pairs (much like in SAM) but the sound localisation was carried out in software by a process of cross-correlating the inputs on each pair of microphones (a much more sophisticated and reliable technique than that of SAM's). The actuators in the head moved the microphones very quickly in the calculated direction of the sound, in a movement reminiscent of an animal flicking its head. The rest of the body would then follow in stages, making the whole structure appear to home-in on the sound if it persisted. Loud noises would make it shy away. In addition, two Doppler radar units were mounted on the head of the robot, which could detect the motion of the visitors. Sudden movements "frightened" the Senster, causing it to withdraw. The complicated acoustics of the hall and the completely unpredictable behaviour of the public made the Senster's movements seem a lot more sophisticated than they actually were.

"In the quiet of the early morning the machine would be found with its head down, listening to the faint noise of its own hydraulic pumps. Then if a girl walked by the head would follow her, looking at her legs. Ihnatowicz describes his own first stomach-turning experience of the machine when he had just got it working: he unconsciously cleared his throat, and the head came right up to him as if to ask, 'Are you all right?' He also noticed a curious aspect of the effect the Senster had on people. When he was testing it he gave it various random patterns of motion to go through. Children who saw it operating in this mode found it very frightening, but no one was ever frightened when it was working in the museum with its proper software, responding to sounds and movement." (Michie and Johnston, 1984)

It soon became obvious that it was that behaviour and not anything in its appearance which was responsible for the impact which the Senster undoubtedly had on the audience.

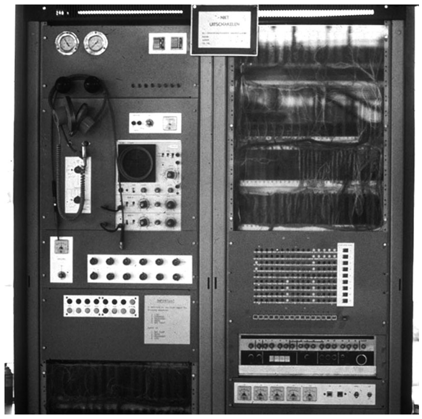

Figure 4: Senster's Computer and Control Electronics

The computer used to control The Senster was a Philips P9201 with 8k core memory (see Figure 4), which used punched paper tape to load the program. This computer was a clone of the more common Honeywell 416, and was valued at £8500 in 1969 (according to a shipping invoice), equivalent to about US $500,000 in current terms. Fortunately, a code listing is still in existence, but is hard to decipher (it is, of course, written in assembly language).

Several racks of custom electronics interfaced the computer to the Senster. Again, it is fortunate that most of the circuit diagrams survive. There were eight hydraulic actuators in total (including the two in the head) and they were controlled in pairs, so, essentially, there was one standard output circuit repeated four times. The following description is for one such circuit.

The output from the computer was latched as sixteen data bits (the input could also be set via manual switches, for testing). All 16 bits were also taken to light bulbs for debugging purposes. The 16 bits were split into two sets of five bits, which represented the next required position for an actuator, thus each joint had 32 (2^5) discrete positions. This was a very low position resolution but was overcome by the use of a circuit called the predictor. Each set of five bits was passed to a digital to analogue converter and thence to the predictor.

The predictor was a sophisticated arrangement of op-amps, which operated as a second-order low-pass filter, with a roll-off frequency set by a circuit called the acceleration splitter, fed by three spare bits from the latch, via another digital to analogue converter. This circuit distributed an analogue voltage, with a resolution of 8 (2^3), to the predictor circuits, which altered their roll-off frequencies. It basically set the time by which all the joints had to reach the next set positions, so that they all arrived at the same time, to make the movement look natural. There were two separate acceleration splitters: one for the hydraulics which moved the microphones and another for the joints in the rest of the structure, thus the microphones could flick quickly, while the main structure moved at a more sedate pace.

The predictor smoothed the analogue voltage output so that it followed a spline-like curve. (The computer was not fast or powerful enough to do this in real-time, hence the use of analogue circuits.) The output from the predictor circuit was fed to a closed-loop hydraulic servo system, so that the actuators followed the analogue voltage in a proportional way. The predictor was one of the critical parts of the Senster's control system because it contributed much of what made the movement look very natural and is examined in more detail below.

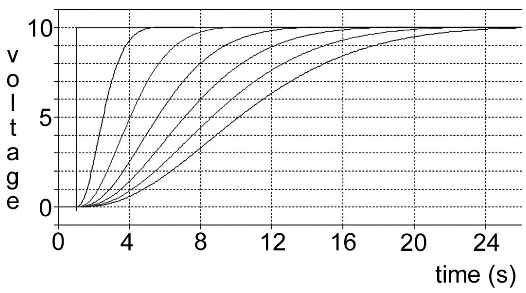

Figure 5: Predictor output for different values output by the Accelerator (position is proportional to voltage)

Fortunately, the circuit diagram for the predictor survives and I was able to simulate its operation (using SPICE, a standard circuit simulation software package). Figure 5 shows the effect of the circuit. At time = 1s, the output from the computer goes through a step change from 0 to 10V. The predictor filters out the high frequency components, so that the robot starts and stops smoothly. The different splines illustrate the effect of changing the value output by the acceleration splitter.

The shape of the spline curve is defined by its first order derivative, in this case, equivalent to the velocity of the joint, and this is shown in Figure 6a.

Ihnatowicz *"tried to make its movements efficient. In the process of doing that, [he] discovered that animals, when they perform competent movements, are extremely efficient, and [his]machine looked animal like, even though [he] didn't try to copy animal movement."* (Reichardt, 1972)

The most efficient (least expenditure of energy) motion can be shown mathematically to be when the velocity has a parabolic profile. The actual shape produced by the predictor is not this ideal: it is asymmetrical (the peak velocity occurs before the half-way point) and tails off gradually. Later studies of human motion showed that this is very similar to what happens in biological systems. Figure 6b is a graph of normalized velocity against normalized time of a tracked human arm (Atkeson and Hollerbach, 1985) and it compares extremely well with the output of the predictor. This behaviour of the predictor is, in the author's opinion, a key reason why the movement of the Senster was regarded as looking natural.

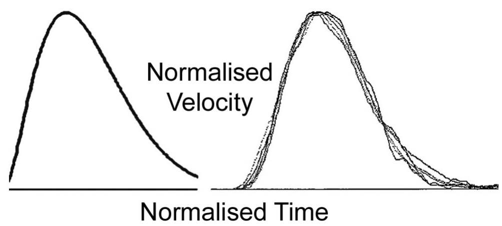

Figure 6: a: Velocity profile from Predictor circuit; b: Velocity profile of human movement (from Atkeson and Hollerbach, 1985)

Philips dismantled The Senster around December 1973, giving the reason *"the unfavorable publicity"* they had been receiving. According to Ihnatowicz, *"The bad publicity was due to the fact the machine was not in fact performing as intended, its programme having been severely degraded in order not to cause too much excitement and noise."* (unpublished letter). It is not known what happened to the computer, but the electronic system was given away to local electronics enthusiasts, and the mechanical structure was given to a Dutch firm of subcontractors who had done some structural work on the Senster. One of their employees realised the historical significance of the artwork and they eventually set it up in front of their premises, where it remains to this day (see Figure 7). Philips appear to have destroyed their records of the project, as the only items in their archive relating to it are a few publicity photographs. It is, perhaps, surprising considering that they had invested such a large sum of money in the project (the system was insured for £50,000, the equivalent of around US $4.5m in current value, when it was shipped from London to Eindhoven in 1970).

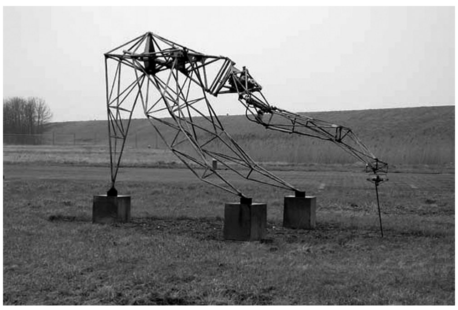

Figure 4: The Senster as it is now

On his return from Holland, Ihnatowicz was invited to join the staff of the Mechanical Engineering Department of University College, London as a research assistant.

Observing the Senster, and knowing just how simple the controlling program was, he *"felt like a fraud and resolved that any future monster of mine would be more genuinely intelligent."* (private papers). He found it disconcerting *that "people kept referring to it as an intelligent thing, but there wasn't an iota of intelligence in it: it was a completely pre-programmed responding system."* (Reffin Smith, 1984)

He believed that he could make his next machine more intelligent by simply consulting the right people in the Artificial Intelligence fraternity about the correct programs to use in these circumstances. He soon discovered that *"those involved with AI concerned themselves with completely different problems, or at least that their methods, and especially the criteria they applied, had very little relevance to my problems"* (private papers). He decided to do some research of his own but after a long time, realised he was not getting anywhere.

He arrived at two conclusions: one, that mechanical movement was not only the common element in all such experiments but also the only means by which we could establish the presence of any would-be mental activity, and two, that while the concept of intelligence remained as elusive as ever, the notion of perception seemed as important and perhaps more manageable. Perception, like mechanical motion, must, of necessity, constitute a part of any form of behaviour and can be thought of as the mechanism by which the sensory data arriving from the eyes or ears or any other type of sensor is organised into a form suitable for producing an appropriate response. That response, in the simple systems he was looking at, was invariably some form of motion, so that the immediate problem seemed to be to discover a method of describing the two sets of phenomena: visual patterns, say, and physical movement, in such a way that their correspondence, which was a physical fact in the outside world, could be reflected inside the system.

4 The Bandit

He felt that he needed to understand more about the nature of mechanical information and decided to concentrate on that. He helped in the supervision of a PhD student to whom he suggested a project to develop a hydraulically-operated mechanical lever, equipped with pressure sensors and connected to a computer, with which it would be possible to move or exert pressure against a variety of objects and in this manner discover something about their mechanical characteristics.

Being connected to a computer, the arm was capable of operating in two modes: in the position mode it would move to a specified position with a prescribed velocity, largely without regard to any encountered resistance and in pressure mode it would exert a specified pressure against whatever object it encountered. If the specified pressure was zero it would become completely passive and compliant.

In 1973 the Computer Art Society staged an exhibition on the fringes of the Edinburgh Festival and asked him to contribute a piece of work. The arm was all that he felt he could show, so together with the student he turned it into an exhibit. The arm was made to operate in both position and pressure mode and people were invited to move it in any way they liked. When compliant, the computer would store the movements the spectators made and then play them back in position mode. The different ways in which people reacted when the arm suddenly took over were analysed by a statistical program which was capable of distinguishing between sexes and of classifying people according to their temperament. The results were printed on a tele-printer and were surprisingly accurate. It was called The Bandit, after the One-Arm-Bandits of Las Vegas, which it vaguely resembled.

The Bandit was, however, a little off the point as far as his main interest was concerned. He was forming an idea that perception ought to relate to objects rather than events; that it ought to enable the system to distinguish between itself and the outside world. He felt that a very important distinction should be made between what could be called non-dimensional sensing, that is, awareness of changes in some stimulus like pressure, noise or light which have a magnitude but no direction; and the type of perception which could enable the system or animal to determine the shape, size, position or direction of motion of other objects as well as of itself. The Bandit, having only one actuator, could deal only with magnitudes and so another moveable segment was added to it, similarly instrumented and forming, in effect, an elbow.

The new device was re-orientated so that the tip moved horizontally, parallel to the surface of a table, which could be placed beneath it. He devised an experiment in which the arm could be made to run along a piece of metal placed on the table and the computer could record such runs and deduce the angle at which the piece had been placed from the relative velocities of the two rotating joints. The point of interest here was that the arm was not given any positional information, merely a value of acceleration, and positional information was what came back to it.

Further research into robotics was thwarted by a lack of funding. Ihnatowicz left UCL in 1986 to set up his own company: IMA (Industrial Microcomputer Applications). He installed an Io Research Pluto system featuring Designer Paint and Designer 3D. The package was mainly used for modeling, illustration and animation. He got some commissions, particularly for advertising and portraits. He also produced control programs for small computers in engineering and small scale factory automation.

He was unable to complete any more cybernetic sculptures before his death of a heart attack in October 1988.

4 Conclusion

Ihnatowicz was remarkable in not only being a artist, but also a talented self-taught engineer. Much of his work was exploring concepts in artificial intelligence, particularly with the link between perception and intelligence. His work is still very much relevant in the field of robotics and AI, and now that computers are orders of magnitude more powerful than those available to him, it is perhaps timely that some of his ideas are revisited. In particular his argument that

"in order for any system, natural or artificial, to be able to deduce anything at all about any object simply by looking at it, it must first be able, or must have been able in the past, to interact with it in some mechanical way. Moreover, only those aspects of the object which can be modified by such actions can ever be successfully interpreted." (private papers).

Acknowledgements

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The Development and Effectiveness of the CYCLER Educational Presentation Robots

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Abstract

This paper describes the design, development and operation of three state-of-the-art presentation robots being used to present an educational programme to schoolchildren in the UK. The three identical robots were designed to simulate intelligent behaviour in order to appeal to primary and special needs pupils and to grab and hold their attention. The robots present the educational material autonomously except that question and answer sessions are triggered by a handler to synchronise the interaction with the children. The paper describes the functional, behavioural and appearance aspects of the design and includes a summary of the effectiveness of ten years use in thousands of schools with hundreds of thousands of children.

1 Introduction

The environment protection charity Waste Watch has been operating a waste reduction scheme the “ReCyclerbility Education Outreach Programme” in UK schools for the last ten years. The aim of the programme is to encourage children, their teachers, schools and parents to reduce the amount of waste that is dumped in landfill sites in the UK. This is achieved by using three robots, each with an education officer from Waste Watch, that go into primary schools in England, Scotland and Wales providing free interactive educational presentations. The normal age of the children in the audience is from 4 years to 11 years old (key stage 1 and 2) but there is no age limit for special needs schoolchildren.

The use of robots in classrooms to engage and sustain the interest of the pupils and educate them has been described in Bruder and Wedeward (2003) and Smith (2000). The use of robots to assist the rehabilitation of autistic children in special schools has been described in Werry et al (2000). However the use of robots to provide the actual educational message is unusual. In this case the robots and their handlers present the pupils with shows promoting the message of recycling, reducing the use of, and reusing waste packaging and products. Each robot handler is a qualified education officer, often a former primary school teacher. The education message is sustained with the use of activity books, which provide further practical information, educational puzzles and exercises.

It was found at an early stage in the programme that having a robot presenting the message interactively with a human was far more effective at keeping the children’s attention and enthusiasm than employing a teacher on their own. A further ten years experience has confirmed this. This idea had been used successfully in the USA and Waste Watch adopted the approach in the UK. They wanted three robots, one each for the north, south and central area of the UK mainland. They produced an outline specification for the required robots and submitted it to a number of universities and companies for competitive tender. The contract for the design, building and maintenance was awarded to the authors. The programme is funded by Biffa Waste Services via the “Biffaward” scheme under the government’s landfill tax credit regulations. The robots are designed to elicit an emotional response from the children through the creation of a childlike appearance, voice tone and behaviour. These have been developed over the years in response to the children’s reactions. The robots are designed to be entertaining, interactive and largely autonomous. One of the robots is shown in figure 1. For about

90% of the duration of the performance the robots are under software control (with randomised movements) and the remainder of the time the robots are under human control.

Figure 1. Cycler the "Rapping Robot".

2 Robot design specification

Three robots that met most of the requirements had been imported from the USA in 1994 but were aging and proving too unreliable, causing school visits to be cancelled. The unreliability was giving rise to high maintenance costs. Three new machines, built to a higher specification, were required. The new robot design required that its appearance and behaviour be appealing, engaging, happy, friendly and childlike. The behaviour of the robots was to be such that they appeared to have minds of their own and be capable of apparently independent even "naughty" behaviour. The three Cycler robots were to talk and sing the message in a "rapping" style on cue and be able ask questions and respond with a yes or no response immediately after a child gave a correct or wrong answer to a question posed by the robot. Each robot would be likely to go into three schools a day, five days a week throughout the school year giving 500 presentations to 100,000 pupils per year. A single breakdown would result in several cancellations, as rapid servicing was impractical due to the cost and distances involved. Any such breakdown would cause disappointment to hundreds or even thousands of children. The typical and maximum number of children attending a show would be 200 and 250 respectively. The robots would be subject to a lot of heavy handling and vibration when travelling on rough roads and when being hauled up and down stairs and lifted in and out of cars. The dimensions were to be approximately 1.2 metres tall, 470mm wide and 470mm deep. The life of the rechargeable batteries was to be six hours minimum. The Cyclers were to be able to interact with the audience, and the handler was to be in full view throughout the interactive presentation. Only a single handler for each robot was economically viable and any human control had to be virtually invisible to the audience. The robots needed to be designed, built and in service in a few months at minimal cost.

3 Robot design implementation.

To keep the cost low and respect the mission of recycling, the middle and lower half of the robot design was retained. The visible part of Cycler's mid section is made from used plastic drinks bottles to show that the robot is at least partly constructed from re-cycled materials. However a smoother, more rounded, light coloured, smart, uncluttered finish was adopted to give a more modern, high quality and realistic look and feel to the robots. As the robots were being developed for teaching it was felt important that they should look alive and not have a distracting appearance. The robots were not to be perceived by the children as toys but as representing "someone" who should be listened to and could command quietness and stillness in the children at the appropriate time. Cycler had to be believable in that it had to look, behave and sound like an intelligent robot. The external design was created to incorporate some features from robots that might have been seen by the current generation of primary school children and features from other robots with an appearance that is friendly, appealing and believable. These robots were from television, film, and toys such as Metal Mickey, Pino, R2-D2, C-3PO, Honda's P1, 2 and 3 series, Asimo, Buzz Lightyear, Robocop, Twiki, and Marvin. We excluded designs that had cartoon influences, as we wanted the robot image to appear believable and alive. We also wanted to avoid the appearance, described by Mori (1982), of being in the "Uncanny Valley" region where robots can look frightening or unsettling. This was partly achieved in the external appearance and partly though avoiding the possibility of the robot making jerky sudden movements that look mechanical rather than human. Smith (2005) gives some more detailed information on giving a robot human lifelike motion and Norman

(2004) provides some insights into designing artefacts that appeal to a wide audience.
To gain maximum reliability, the internal working and upper body, head and arms were re-designed from scratch. The arms lift forwards rotating at the shoulder. Mechanical links from each shoulder to each forearm are provided so that when the upper arms are rotated forward at the shoulders the elbows bend giving two degrees of freedom from each motor. Thus the arms can move from hanging vertical by the robot's sides to the hands waving at eye level position. Both positions are shown in Figure 1.

The new Cyclers contain five micro controllers; to decode the radio receiver signals, control the sequences of eye illumination, eye movement (panning), head movement (panning and tilting), arm movement (shoulders and elbows), and control the MP3 player. The microcontroller in the transmitter decodes key presses and sends high-level commands to another microcontroller that encodes them for transmission to the robot over the radio link. The microcontrollers in Cycler are in a hierarchical fault tolerant net. Transmitted radio data packets are decoded and commands are sent to a top-level microcontroller that routes commands to the MP3 controller and the two main sub processors controlling the head and body. The body microcontroller has a further sub processor that controls the arms. The top-level microcontroller can, if necessary, reset any of its sub processors. Each of these processors runs a "behaviour" in the background that is interrupted when a particular action is required.

Each robot's voice is recoded as a sequence of MP3 sound files. Red LEDs forming the robot's lips light up in time with the voice when talking and singing. The handler can start and stop the MP3 player quickly using the buttons on a small keypad, which is concealed in the palm of their hand. The buttons on the keypad can be operated with one or two fingers without being noticed. The keypad is connected to a small specially made VHF radio transmitter. Thus the robots can be operated to effectively interact with the audience. By stopping and starting the sound files at the appropriate instants, Cycler can respond to answers given by the audience. The buttons are multifunctional to minimise their number and hence the size and visibility of the keypad. A micro controller interprets the button presses. Thus in one mode the buttons control the movement of the robot (move forward, backward, turn left or right, turn on the spot), in another mode the same buttons control the movement of the arms (wave the left arm or right arm or both), in a third the movement of the head (pan or tilt), and in a fourth they operate the MP3 player. Four visual feedback LEDs, on each shoulder of the robot, serve to remind the operator what mode of operation the robot is in.

An amplifier and two 18 Watt speakers are built into the robot. A ring of six blue LEDs forms each eye. The eyes pan and the head pans and tilts. The head panning rate is not constant but software controlled to give a more human like and expressive rotation. The movements are achieved using a 5V servo motor for the eyes, two propulsion motors running on 12V or 24V depending on the required speed, two 12V arm motors and two 12V head motors for panning and nodding. The arm, head and eye movements, when not being controlled manually, are under the control of an "inbuilt personality programme", Buckley (2004). Under this programme the arms, head and eyes follow a randomised pre-recorded choreographed sequence. Thus the movements are lifelike and do not repeat during a show. The personality programme allows the handler to have both hands in full view, enhancing the illusion of the robot being "intelligent". Thus it is extremely hard to deduce how the robot is controlled even by careful study of the robot's behaviour and by watching the operator's hands.

If the transmitter is not used for several minutes it will switch off to save battery power. When the transmit signal stops the top-level micro controller in the robot puts the robot into sleep mode until valid commands are received. This stops all movement for safety and extends the robot's battery life, Smith (2004).

4 Safety

An important consideration is safety, as the robots are used as close to the children as possible, and the risk of injury to a child in the event of loss of control should be negligible. There is a finite risk of a Cycler falling on to a child so Cycler was designed to be lightweight (less than 35kg), stable i.e. have a low centre of gravity with four widely spaced wheels, and be low powered. The robot speed is limited to walking pace and the arm, head and eye motors will stall rather than inflict injury. The robot can move forwards, backwards and turn on the spot but again for safety reasons these actions are only at the command of the handler. There are two speeds; only low speed is used when children are near. In low speed mode, where half the battery voltage is applied to the propulsion motors, the robots are easily stopped by most obstacles. The joints in the hands are not powered. An emergency cut off button is mounted on each shoulder. A radio failsafe system checks the received signal for invalid commands and stops all movement if the received signal is interrupted or corrupted by interference. The elbows bend but only up to ninety degrees to avoid trapping fingers. All exposed bodywork is thin section plastic or fibreglass, which bends fairly easily. The body is held on to the chassis by mountings that will break off or bend and absorb energy rather than injure a child. The body is smooth and rounded with no sharp edges. The handler is required to keep in reach of the emergency stop buttons at all times the robot is switched on or when a child is near.

5 Simulating intelligent behaviour

The way in which the robot is perceived is critical to the ability of the robot to encourage the children to sit still, listen and learn. Because the robot has to interact in a natural way with the children it has to be social. Synchronised lip "movement" accompanies talking and singing, and the head, arms and eyes can move at the same time under manual or "personality" program control. Thus the robot seems to be behaving intelligently all the time and the pre-programmed sequences are not noticed. The simulation of naughty or slightly out-of-control behaviour apparently has the effect that children identify the relationship between handler and robot with the relationship between the child's parents and the child itself. Because the robot asks the audience and the handler questions to extract answers to which the robot can reply, the robot appears to be engaging in sophisticated conversation with the audience and the handler. The randomised sequence of head panning and tilting simulates the robot looking at each member of the audience and making eye contact. The blend of human control, randomised choreographed movement and responsive question and answer behaviour gives a good simulation of intelligent behaviour. Since Cycler's "personality program" movements are rarely repeated, the impression that the robot is real is enhanced. The voice tone is positive, exciting and interesting with some authority, which helps keep the children paying attention. The combined effect is that the children apparently perceive that the robot as being intelligent and as having an engaging personality.

The creative elements in the design are substantial although not always obvious.

6 Children's reaction

The children's reaction has been very positive. They accept the robots in minutes. They apparently react as honoured, privileged people in the presence of a celebrity. "Guess who came to my school today" is a common reaction. Children sometimes tell the robots jokes and stories and talk to the robots as if they understand. Even relatively young children are sufficiently captivated by Cycler's presentation to sit still and quiet on wooden floors for the whole of a 45-minute to one hour-long presentation. The question and answer sessions induce very natural interaction between the children and robots. Many children want to touch the robots and run after them waving goodbye when they leave. Rarely can any sign of boredom in the children be detected. Very occasionally a robot frightens one of the younger children even though care has been taken to give the robots a non-threatening appearance. These occasions only tend to apply to children of a particularly nervous disposition. In these rare cases the handler or a schoolteacher will usher the child towards the back of the audience. Almost invariably Cycler elicits excited emotional responses in the children.

Cycler seems to be effective at drawing responses from relatively withdrawn children including those with special needs. The robots are particularly effective at maintaining the children's attention and interest. Being able to simulate human lip, eye, arm and head movement and having a childlike appearance are important aspects of human robot communication. Being able to make children laugh at childlike, slightly naughty, behaviour induces an almost universal feeling of identifying with the robot, inducing feelings of friendliness and empathy. The combination of appearance, behaviour and the friendly, cheerful positive but childlike voice tone gives an appealing impression that children quickly relate to. The children readily project emotions on to the robots.

A side effect of the Cycler outreach programme is that the children are presented with a much more positive image of robots than the dystopian futures shown in roughly half the popular science fiction stories.

7 Experience and Effectiveness

Waste Watch started the Cycler programme in April 1994 and expanded it nationally in 1997. To date the Cycler presentations have been given in over 4200 schools and in front of about 750,000 children. The programme has steadily grown to the current rate of activity of 500 presentations and 100,000 children per year, Jansen (2004). A Cycler visit is so popular that bookings often have to be made six months in advance. A typical comment from a teacher following a visit is; "For a group of children with severe learning difficulties who find concentrating for any length of time difficult, Cycler really captured their attention and imagination". Waste Watch monitor the effectiveness of the programme closely. Their surveys have found that schools have achieved waste reductions averaging 47% with a few schools achieving a 90% reduction, Jenkinson (2003). This is largely as a result of the children being persuaded by Cycler's message.

8 Publicity

The idea of using a robot to present the environmental message is not only effective at securing the children's interest and attention but has the effect of generating additional interest and publicity for the programme. This has helped widen the audience for the message in the press, radio and television. The new robots were launched by a former Minister for the Environment at the House of Commons in March 2003, they appeared on the BBC2 peak viewing time show Techno Games and on Blue Peter. Typical newspaper coverage for a school term is a Cycler feature with a photograph in 40 articles with a combined circulation of 2,250,000 copies. Such a high level of media and public interest would almost certainly not have been achieved without the use of robots.

9 Other design and operation influences

There are some difficulties associated with designing robots for use in close proximity to children. The children, who are normally aged from 4 years to 11 years, generally sit on the floor a metre or so in front of the robot, and at the end of each show gather around the robot. Any radio controlled mobile machine is not immune from unexpected movement due to radio frequency interference hence electromagnetic compatibility EMC and portable appliance testing PAT regulations apply. In these circumstances, health and safety regulations, public liability, negligence, contractual, and insurance issues are non trivial. Some development time also had to be devoted to financing, non-disclosure agreements, copyright, intellectual property rights, a warranty, a servicing contract and a maintenance agreement.

10 Conclusions

The use of the Cycler robots in schools to engage the interest and attention of primary school children has been proven to be effective over a period of ten years in thousands of schools and with hundreds of thousands of children. The message presented by the robots has been shown to be effective in that the schools visited have achieved an average reduction in the production of waste by 47%. Cycler grabs the attention of typically 200 primary school children for up to an hour at a time, and keeps them sitting still and quietly by using a mixture of randomised behaviour, choreographed, lifelike "personality" movements and some movements and speech triggered by the handler. The message is conveyed by the robot and handler more effectively than with a teacher alone. The package of creative design elements that gives the robots a friendly appearance, the appealing behaviour and the assertive but engaging voice tone combine to make a very effective teaching aid. The children generally show uninhibited affection towards the robots. The experience gained over the years includes the following; robots that are designed to appeal to humans and children in particular should be short (as tall robots are threatening and physically relatively unstable), smooth textured, light in colour, light in weight and low speed to minimise momentum, not eerily lifelike, have human proportioned features, have a symmetrical appearance (as human beauty and good looks are associated with symmetry of physical features), have large appealing eyes, have a youthful, soft, musical voice without any monotones, and a warm smile. Such machines should also have human like body proportions and limb speeds and accelerations (as might be associated with fit, energetic, healthy, childlike but gentle and graceful people).

There are features we would have added if the resources had been available and they include expressive eyelashes, more expressive eyes perhaps with a hint of dilated pupils and a more expressive mouth.

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Robot Thought – A Dialogue Event for Family Audiences

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Abstract

An original and highly successful public engagement event format has been devised for encouraging family audiences to consider and convey their opinions on issues associated with robotics technology. The format uses the traditional approach of an entertaining science "show" to appeal to young and old alike. The show is broken down into a series of short dramatic vignettes to highlight important practical, personal and social issues relating to robotics. During each vignette a particular concept or issue is presented to the audience, who are then encouraged to express their opinions and concerns about issues, and debate the implications of robotics on future society. This paper describes the key features of the event format, with particular reference to the successful pilot performances held during October 2004.

1 Introduction

Robotics is a subject that is capable of drawing the public into engagement with many aspects of science, technology, engineering and mathematics. The University of the West of England's Intelligent Autonomous Systems (IAS) laboratory[1] has one of the largest and best regarded mobile robotics research portfolios in the UK and a long history of finding ways of taking their expertise to non-specialist audiences through demonstration lectures and events. This project involves a partnership between the IAS laboratory and the Graphic Science Unit[2], innovative science communication specialists based at the University of the West of England, who have an international reputation for devising interesting ways of engaging public audiences with science and engineering.

A major market has recently been established for robots designed for recreational purposes. One of the best known examples is Sony's robotic dog, the Aibo. These have increased public interest in robotics, and an opportunity exists to build on this foundation to draw the public into considering both the engineering challenges and ethical issues that are raised by work in the field. These two topics are strongly linked because the public tend to overestimate the technical capabilities of existing robots, and consequently have concerns about them that are based more on science fiction than science fact.

Robot Thought is an innovative event format that highlights issues pertinent to current research in robotics. Some of these issues are technical, [e.g. "How do you create robots capable of navigating in complex environments?"]; others are ethical [e.g. "Who would be responsible for the behaviour of an autonomous robot?" or "If robots had emotions would we have to treat them differently?"].

1.1 Rationale

Successful public engagement with robotics research requires two-way communication, offering the facility for public audiences to convey their own

[1] http://www.ias.uwe.ac.uk/
[2] http://www.uwe.ac.uk/fas/graphicscience/

attitudes and opinions, as well as the opportunity for the researchers to demonstrate their work (Jenkin 2000). Inclusivity is further encouraged through careful design of the public event format, combining both entertainment and educational aspects of the topic. These were the key motivating factors in the design of the *Robot Thought* format.

Student retention within science subjects, particularly the physical sciences, has dramatically decreased in recent years. The recent student-led review of the national science curriculum (commissioned by Planet Science in 2002) concluded that having a discussion or debate was the most effective way of learning, whilst 57% of students surveyed agreed that introducing discussions about philosophy and ethics would definitely make GCSE science subjects more attractive as a subject. This event format is therefore specifically designed to raise issues within robotics research, and encourage consideration and discussion of those issues within the audience. *Robot Thought* therefore encourages greater interest in science and engineering amongst young people attending the performances.

Certain constraints were placed on the event structure in order to maximise transferability and flexibility. These included:

- No requirement for specialist staging, for example sets, lights, etc
- All effects are deliverable through a laptop and a data projector
- No requirement for professional actors

Robot Thought is therefore capable of being mounted by individuals and organisations for whom the event would be attractive, but who do not necessarily have access to theatre expertise and equipment [for example University departments or robotics R&D specialists]. This maximises the possible dissemination routes and allows the event format to be adapted to be suitable for as wide a range of locations and audiences as possible.

1.2 Target Audience

The target audience is primarily family groups, consisting of both adults and young children (typically aged 4–12). The event format was effective across a considerable spectrum of audiences, principally because the dramatic vignettes engage the audience at a number of different levels, and the level and focus of the discussion can be adjusted to suit the background of the audience.

The interactive nature of *Robot Thought* makes it most suitable for relatively small groups (up to ~100 people), where each audience member has the opportunity to feel directly involved in the performance. It is adaptable to a wide variety of venues, from science centres to University open days to shopping malls.

2 Event Design

The project team encompassed a variety of expertise relevant to the project, including robotics researchers, professional science communicators, and a representative from the pilot venue, At-Bristol. Each of these team members was thoroughly consulted during the design process in order to produce the most effective event format possible. For example, the input of the local venue representative provided invaluable knowledge regarding likely audience sizes, ages and backgrounds, and ensured that the show would suit the chosen venue, and engage the target audience as much as possible.

2.1 Audience Pre-Research

The target audience for *Robot Thought* was thoroughly researched at the beginning of the project. This ensured that the event format was tailored specifically for the target audience of family groups. A brief description of the audience pre-research is included below; the full report is available at:

www.uwe.ac.uk/fas/graphicscience/projects/robots.htm

There were four key data sources for the audience pre-research:

1. Visitor demographics from At-Bristol
2. Analysis of visitor responses to the *Hot Topics* exhibits – a suite of computer-based exhibits related to robotics issues that have been a popular feature of Explore At-Bristol since the centre opened in 2000. They were designed by the Graphic Science Unit at UWE, and provide visitors with the opportunity to compare their responses to other visitors of the same age and gender.
3. Interviews with visitors to At-Bristol – structured questionnaire-based interviews were conducted during school holidays and over a weekend in order to obtain similar audiences to that expected during the timing of the pilot performances. A two-tier approach was used to differentiate the audience: adults were interviewed by an adult using a written questionnaire, whilst children were interviewed by a child (the 8-yr-old son of the evaluator) using a tape recorder.
4. Structured group discussions with school children – a selection of robots were taken into a primary school and used to prompt students' debate (years 3-6) about the nature and parameters of robotics.

2.1.1 Summary of Key Pre-Research Findings

- The audience within Explore At-Bristol out of term time is largely made up of mothers or grandparents with children.
- There is a pervasive and well developed scepticism about the potential abilities of future robots.
- When thinking about close-up interactions with robots, most adults limit the useful role of robots to housework and occasionally other menial tasks. Children tend to focus more on leisure pursuits.
- There is a widespread ignorance about the current state of robotics technology. Most adults and children do not realise that robots are already involved in complex and challenging tasks, particularly in space and conflict zones.
- Almost nobody in the adult sample believed that robots would ever achieve a level of intelligence and agency comparable with humans. Younger children, on the other hand, were equally confident that they would.
- Children's views of robots are heavily determined by their physical appearance and their conformity to pre-existing visual stereotypes.
- Some children can differentiate robots by their ability to perform complex tasks, such as walking and talking.
- Only a very few younger children have any grasp of the concept of autonomous robots.
- A robot ranking game might be an accessible and appropriate way to introduce children to the concepts this project seeks to raise.

2.2 Presenters

A deliberate decision was taken not to use professional actors in the performance of *Robot Thought* to ensure maximum transferability to other venues. The presenters for the pilot events were experienced at communicating scientific concepts to the target audience through a performance medium: science shows. They were specifically NOT familiar with robotics. The key characteristics of the presenters were their enthusiasm, ability to react and respond to the audience's opinions, understanding of their audience, and ability to comprehend and explain the necessary concepts of robotics technology. There are many such presenters throughout the UK that would be capable of presenting *Robot Thought*, which should assist with dissemination of the event format.

2.2.1 Presenter Training

The presenters were sent briefing materials in advance of the performances. This pack included articles and websites aimed at the general public, and provided further background to the issues and topics raised within each of the performance vignettes. The presenters also visited the IAS lab at UWE in order to, firstly, gain an appreciation of the current state-of-the-art in robotics research and, secondly, so that *Robot Thought* would be directly informed by the particular themes of research in the IAS lab. These themes include biologically-inspired robotics and swarm intelligence.

A day-long training session was conducted by the project team immediately prior to the performances, with four key components:

1. *Overview of venue* and discussion with At-Bristol staff – this prepared the presenters for the venue and facilities they would have access to, and allowed transfer of expertise regarding audiences and other logistics.
2. *Pre-research briefing* – A summary of the audience pre-research findings was given in order to inform the presenters of likely issues and attitudes.
3. *Robotics briefing* – The presenters were provided with a short tutorial in the relevant topics and issues in robotics, and given the opportunity to ask questions of the robotics experts in the project team.
4. *Rehearsals* – The science communication experts within the project team facilitated the rehearsals, with the emphasis on conceptual understanding of the issues to be discussed within each vignette, rather than learning a specific script.

2.3 Show Content

The show consisted of five short dramatic vignettes. Each vignette was based around a critical theme in robotics as identified by the project team, and deemed to be of interest by the audience pre-research. The topics of the five vignettes were:

1. What is a robot?
2. Why aren't robots more advanced?
3. What do we want to use robots for?
4. State of current research: UWE example
5. What do we want for the future of robotics?

Further details of each of the vignettes, including a description of the content and explanation for its inclusion, are briefly outlined in the Appendix.

2.4 Evaluation

The pilot performances of *Robot Thought* were evaluated in two main ways:

- *Observations* – All of the performances were observed by an evaluator, who took extensive contemporaneous notes on the size, composition and reactions of the audience.
- *Questionnaire-based survey* – The attitudes of adult members of the audience towards the show were investigated using a survey consisting of a series of closed questions.

One performance was also recorded on video for documentation purposes.

The full evaluation report, including a copy of the survey questions, is available online at:
www.uwe.ac.uk/fas/graphicscience/projects/robots.htm

3 Pilot Performances

3.1 Venue

The pilot performances were held at At-Bristol, a world class science centre located in Bristol. The performance space was situated directly on the exhibition floor at Explore At-Bristol, surrounded by other exhibits and demonstrations. Computer projection facilities, microphones and a speaker system were in use during the pilot performances, but no specialist dramatic equipment (lighting, sound effects) were used.

3.2 Publicity

Good publicity is crucial for any outreach activity, to ensure that the event reaches its maximum possible audience. In the case of the pilot performances this included press releases, inclusion in At-Bristol's "What's On" flyer (circulation: 40,000 within the South West region); article in the Bristol Observer (free local newspaper distributed to 180,000 homes within Bristol), announcements and notices within At-Bristol on the day.

3.3 Timing

Six performances of *Robot Thought* were presented over the course of three days. The timing of the pilot performances was specifically chosen to coincide with the October half-term holiday. In half-term the numbers of family audiences visiting At-Bristol is significantly greater than during term time. The events were held at 1pm and 3pm during the afternoon, again to coincide with the largest concentration of visitors.

3.4 Audience

Table 1 sets out the number of people in the audience at the beginning of each of the performances. The audiences were observed to consist almost entirely of adults and children; very few teenagers watched any of the shows

There was a certain amount of coming and going during each performance. In general the audience size declined by approximately 10% during the first ten minutes and then gradually grew until by the end of the performance it significantly exceeded the figures quoted in Table 1. In particular, Shows 4 and 6 were observed to have well over 100 people in attendance part way through each show.

Table 1 – Preliminary audience sizes for each *Robot Thought* performance

	Adults	*Children*	*Total*
Show 1	26	21	47
Show 2	24	28	52
Show 3	27	28	55
Show 4	38	30	68
Show 5	23	31	54
Show 6	24	32	56
Total	*162*	*170*	*332*

Audience members were most likely to leave at the break between different vignettes, particularly at the end of the robot parade. It was observed that most families who left before the end of the show did so at the insistence of parents. This was more noticeable during the 3pm shows, where travel home (and traffic avoidance) seemed to be an issue. There were no observed instances of children leading their parents away from the show.

With one or two exceptions, children were well behaved throughout the performances and seemed focussed on the show. Questions from the presenters were always met with a rush of raised hands, even when the child in question had no idea what they would say. There was very little interaction between children during the performances, and where they were talking to each other it was usually a disagreement over something in the show.

There was fierce competition to be picked by the presenters as a volunteer and occasionally some disappointment among those audience members who were not chosen.

3.5 Survey results

A total of fourteen adults were surveyed after the performances. The sample was roughly gender balanced (6 male, 8 female) and was entirely white. 10 out of 14 members of the sample were aged between 36 and 45, all of whom were accompanied by children. Only one member of the sample was visiting At-Bristol without children. Occupations were mostly professional plus three full time homemakers, a dinner lady and an au-pair. Respondents were selected at random.

12 out of 13 respondents agreed with the survey question "Are you interested in science?". This figure is higher than usually reported from national surveys (at around 70% according to the *Science and the Public* report), and may be a product of the immediate environment (i.e. the type of person

likely to remain behind after a show), representative of those who attend science centres in general, or a correlation with the higher than average socio-economic demographics of the sample group.

Respondents were given a series of statements about the show and asked to rank their attitude on a scale of 1 to 5, where 1 is strongly agree, and 5 is strongly disagree. The results of this survey are summarised in Table 2.

Table 2 – Survey Results

Statement	✓	-	✗
I enjoyed the show	14	0	0
I would recommend this show to a friend	14	0	0
I would like to see the show again	9	1	4
I was interested to hear about robots	12	2	0
I learned about robots	14	0	0
It made me think about robots	12	2	0
I have not thought much about robots before	5	6	3
I am concerned about ethical issues arising from robot technology	8	4	2
I felt able to express my own views	9	4	1
I would like more opportunity to express my own views	4	4	6
✓ = 1 or 2: 'strongly agree' or 'agree' – = 3: neutral ✗ = 4 or 5: 'disagree' or 'strongly disagree'			

Across the board, all reactions were very positive. The show was reckoned to be enjoyable, interesting, educational and thought provoking. All the respondents surveyed strongly agreed that they both enjoyed the show and would recommend it to a friend. There was even interest amongst those surveyed in seeing the show again

Overall, there was agreement with the statement "I am concerned about ethical issues arising from robot technology". Just over half of the sample (8) agreed with this statement, with only two disagreements.

The majority of people surveyed (9) agreed that they felt able to express their own views within the existing show format, but few (4) were interested in having a greater opportunity for that expression. In fact, six respondents actually disagreed with the statement "I would like more opportunity to express my own views". This relatively even distribution of attitudes could reflect the composition of the audience. The *Science and the Public* report has identified the Confident Believers as an attitudinal cluster who can be found among this demographic, and who do not see themselves as lacking in representation or opportunities to voice their opinions. On the other hand, there are a substantial number who are concerned about the future of robotics and who might welcome further opportunities to consider issues akin to those raised in this project. At any rate, these responses would seem to indicate that the majority of the adult audience were satisfied with the time available for discussing personal views.

4 Conclusions

An inventive and exciting event format has been devised to engage family audiences with issues in robotics research. Six pilot performances of the event were held over three days, with tremendous popularity and extremely positive feedback from the audiences.

The event format has been specifically designed to be transferable to a wide variety of venues and audiences.

4.1.1 Key success criteria:

A number of criteria were identified during the pilot performances of *Robot Thought* which significantly contributed to the success of the performances:

- *venue layout* – the space needs to be large enough to perform interactive activities, with the audience close enough to feel involved in the show
- *timing* – needs to coincide with times of high footfall
- *audience targeting* – bi-level content to engage both adults and children
- *entertainment* – toys, visible props, noise, cheering, audience voting, etc.
- *presenters* – enthusiastic, scientific background (but not necessarily in robotics), ability to react to audience
- *real research* – interactive demonstrations, video of real robots in action, and if possible, live demonstration of real research robots
- *issues* – ask audience for their opinions

5 Future Directions

There is strong interest in further performances of *Robot Thought*, from both the science communication and robotics research communities. Supplementary events have already been performed in association with the South West regional branch of the BA (the British Association for the Advancement of Science), and the show is booked to perform at the Cheltenham Festival of Science in June 2005. Funding is currently being sought by the project team to extend the programme to venues across the UK.

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A Appendix 1 – Show Content

This appendix provides further details for each of the five dramatic vignettes within *Robot Thought*. The aim is to deliver both an overview of the content as well as the reasoning behind its inclusion. In this manner there should be sufficient information for interested parties to run their own events within a similar format, yet still be able to alter the content to suit their own audience, background or interest.

A.1 What is a robot?

A.1.1 Robot Toys

As the audience gathered, a range of toys were distributed amongst the children. The toys were specifically chosen to cover the range of characteristics identified during the pre-research as being necessary for a robot: motion, thinking, sounds, runs on batteries and so on. Each toy covered one or more of these characteristics, but the range of toys was selected such that none of the characteristics was covered by every toy. For example, some toys were humanoid in appearance whilst others looked like animals or abstract shapes, and a wind-up alarm clock was included so that not all the toys ran on batteries. The selection was also deliberately focused on *toys* (rather than other potential robotic items) so as to appeal to the younger members of the audience and create a cohesive, recognisable set.

The toys used in the pilot performance were:

- *Robosapien* – remote-controlled traditional looking (humanoid) robot which moved, made sounds, and could be programmed to perform set tasks.
- *Singing lion* – a stuffed toy that either sang or spoke to the user when his ear was pressed. The conversation was fixed, but on first hearing it was believable that the toy was responding to the child's answers.
- *Remote-controlled car* – a car that moved according to remote instructions.
- *Crying doll* – a realistic baby doll that cried until it was picked up, and snored when it was laid down.
- *Transformer* – a plastic toy that could be converted from a truck into a human shape. Included some sounds.
- *Wind-up alarm clock* – a clock that could be made to ring at a set time, and operated without batteries or electronics.
- *Purring cat* – a furry cat that reacted to being touched by purring and moving.

The toys were described by the presenters as being 'possible robots' and the children were encouraged to have a look at their particular toy and decide whether or not they thought it was a robot. They were also prompted to think about what makes something a robot, and encouraged to pass the toys around amongst the audience.

A.1.2 Robot Characteristics

The show started with the audience being asked to look at the toys and suggest what characteristics make up a robot. This section was kept interactive by asking individuals to type in their particular characteristic, which were displayed on-screen to the audience in real time. One presenter was on hand at the laptop during this process to assist younger members. During this period the other presenter individually pointed out the toys in the audience and asked the children to explain what their toy did. As the characteristics were entered on screen the audience was asked to consider whether each of the toys did or did not have those characteristics.

A.1.3 Robot Parade

When the list of characteristics was complete, the children holding the toys were invited to stand in a line. A 'clapometer' competition was run to ascertain which of the toys was 'most' robotic, with the level of cheering and clapping for a particular toy used to determine rankings. Care was taken to ensure that none of the toys was described as an actual robot – the discussion was about whether individual toys were more or less robotic than others.

Once the toys were ranked, the top three were placed on a podium that was visible to the audience throughout the rest of the show.

A.1.4 Robot / Nobot

The presenters discussed the characteristics obtained from the audience, and then asked the audience to consider a series of five images. The audience cheered "yes" if they thought that image represented a robot, and "no" if they thought it was a "nobot". Again, the images were carefully chosen to represent a range of popular robots, including those from film (Daleks, Terminator), a toy robot, real life (the Mars rover), and a person (partly a joke for the adults).

A.2 Why aren't robots more advanced?

A.2.1 Technical Difficulties

The robot / nobot section prompted a discussion about why the robots we see in the movies don't yet exist in real life. The presenters explained that technical difficulties with the software are responsible: although the hardware and mechatronics exists, complete artificial intelligence is still not possible.

A.2.2 Human Intelligence

A visual demonstration enhanced this concept: A volunteer was asked to walk over to a pile of crisp packets, select one that they liked, walk back to the front of the performance area, open the packet of crisps and eat one (after checking with an adult that it was OK). Of course the children had no problems with this exercise – they have proper intelligence.

A.2.3 Robot Intelligence

The volunteer was then told that they had been transported into the future, where they could have their very own robot (one of the presenters with antennae on). They were given a 'communication device' (a microphone) and told that their robot could now perform the crisps task. The difficulty of breaking down the instructions into simple steps clearly highlighted to the audience the futility of having a perfect working robot without intelligence: the simple instruction of 'walk' had to be clearly explained, and much entertainment and humour was gained from the robot misunderstanding instructions, resulting in him stepping on the crisp packets or scattering them all over the floor when he did finally open them.

A.3 What do we want to use robots for?

The audience were asked to consider the future, and think about what they would do with a robot, assuming that the intelligence issue was overcome. The most common response was either 'homework' or 'housework', depending on the age of the respondent. If necessary, the presenters prompted certain professions, such as doctor, soldier, cleaner, partner. Each of these professions was chosen to highlight certain ethical issues related to the future of robotics, such as 'Who is responsible for what a robot does?' or 'Will robots have rights?'. This was particularly poignant during the soldier profession, when the robot had a toy water pistol, and the other presenter asked whose fault it would be if the robot sprayed everyone with the water pistol?! The overwhelming response from the audience was that it would be the controller's fault.

A.4 State of current research

Having set the scene with future applications, the audience were then introduced to an example of current research that is attempting to solve the intelligence problem: swarm intelligence and emergent behaviour. This is a topic under investigation by the robotics experts on the project team, and one which lends itself well to both demonstrations and audience involvement.

A.4.1 Interactive Demonstration

A simple – and very successful – demonstration of swarm intelligence was obtained using members of the audience. Ten volunteers were chosen (and given flashing headsets to indicate they were robots). The volunteers were given three simple rules:

1. Always walk in straight lines using "robot" (small) steps.
2. If you reach the edge of the performance area then just turn around and keep walking straight.
3. If you bump into another "robot", link arms.

After a period of time where the volunteers wandered about the performance space, the above three simple rules resulted in all the volunteer robots having linked arms, and concentrated in one corner of the performance space. The presenters asked both the volunteers and the audience whether they had been instructed to all link arms together and collect in one area – to which the answer was of course no.

The presenters then explained that through having enough robots following very simple rules it was possible for much more intelligent behaviour to emerge.

A.4.2 Research Video

The audience was shown a video of real research performed at the University of the West of England, Bristol. The video started with ten robots situated in a large arena, with black and white Frisbees spaced throughout the arena in a grid-like pattern. It was explained that each robot followed simple rules:

1. Always walk in a straight line
2. If you reach the edge of the performance area then just turn around and keep walking straight in a random initial direction.
3. If you find a Frisbee, pick it up.
4. If you are already holding a Frisbee when you find another one of the same colour then drop your current Frisbee.
5. If you find a Frisbee of a different colour to the one you are holding then turn around and keep walking straight in a random initial direction.

As the (speeded up) video played, the Frisbees were seen to move from a grid pattern into a more random pattern, and then into two distinct piles of separate black and white Frisbees.

A.4.3 Linux Bots

A highlight of the show was the inclusion of 'real' robots for the audience to look at and see in operation. Two Linux Bots, developed at UWE (see Figure 1), were chosen for this purpose as they are sturdy and reliable, and can demonstrate 'interesting' behaviour within a short space of time.

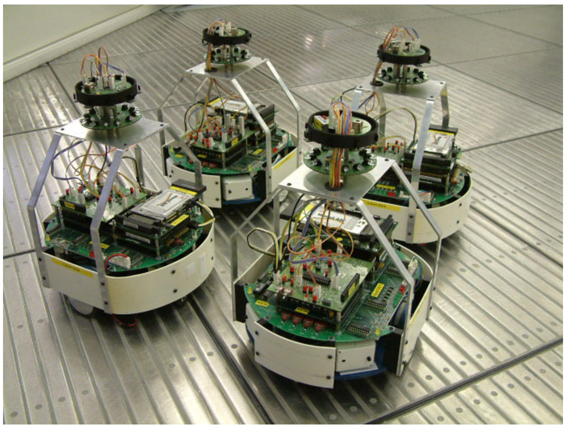

Figure 1: The IAS lab Linux Bots

The Linux Bots were held by the presenters and shown around the audience so that each person had a chance to see them up close. Although this was a relatively time-consuming process there was little fidgeting during this period as the audience seemed spellbound!

A robot arena was set up within the performance space by the members of the audience holding sections of white card. The Linux Bots have infrared sensors at their feet, which work best with white surfaces.

The Linux Bots were placed inside the impromptu arena and the avoidance programme switched on. A "Blue Peter" moment of tension occurred before the robots started working… The Linux Bots move on small wheels, and are programmed such that when they encounter an obstacle they stop and move again in a random initial direction. It was usually clear to the audience that the robots were avoiding the walls and each other, and the presenters emphasised the fact that they were controlling themselves and making their own decisions – there was no-one backstage operating a remote control. The presenters then demonstrated the operation of the avoidance programme by placing their hand near the front of the robots – which of course stopped, and moved off in a different direction. Well-behaved audiences were then invited to try this for themselves, although care was taken to ensure that no one actually went into the arena or touched the Linux Bots.

A.4.4 Podium Changeover

The audience were reminded of the original 'most robotic' toys that remained on the podium positions, and were asked whether they thought the Linux Bots deserved first place. The response was overwhelmingly 'yes', at which point the toys were demoted and the Linux Bots placed on 1st position.

A.5 The future of robotics

The final section of the show was a reminder that the future of robotics relies on the decisions of ordinary people – like the people in the audience. Possible applications of robotics were demonstrated visually on-screen (e.g. finding landmines, dealing with nuclear radiation, deep sea diving, outer space, nanobots) and briefly discussed. This vignette was aimed more at the older members of the audience, but was kept short and snappy to ensure that the children did not lose interest. The audience was encouraged to think about each form of technology and comment on whether they would like to see it used.

The final message of the performance was: "Robots will be what WE make of them" – a deliberately inclusive message designed to place ownership of the decisions and future directions of robotics with the audience.

A Lifelike Robotic Policeman with Realistic Motion and Speech

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Abstract

This paper describes a completed project to produce a lifelike robotic figure of a policeman. The semi-autonomous robotic figure was designed to demonstrate to politicians, the news media and public an issue that the project's sponsors wanted to be more widely recognised. The figure appears to answer questions in an intelligent and humorous way using engaging body language with movements that emphasise the presented message in a positive manner. The lifelike apparently intelligent behaviour is achieved using a randomised series of background body movements and voiced speech that can be triggered and synchronised from a palm-sized keypad held by an operator. This paper describes the design requirement, implementation, method of construction, performance and effectiveness of the figure. The paper describes how the figure was given a lifelike appearance with realistic head, eye and lip movements.

1 Introduction

Most newspaper and magazines editors are more likely to feature news stories that are accompanied by photographs. Thus a photo opportunity or visual event in combination with a press release can be a very effective method of bringing issues to the attention of the press and public and cause politicians to respond (Ward, 1992). Robotic, figures and automata have captured the public's imagination and attention for hundreds, if not thousands, of years (Wood, 2002), although recent interest has increased thanks in part to the popularity of recent TV programmes featuring "robots". Thus Hartnell Creative Communication Ltd., as part of a contract from the Police Federation, decided to use the robotic figure of a policeman to bring to the press, public and MP's attention the message that the police were being hampered in their work by increasing regulation, monitoring and paperwork, forcing them to operate in a robotic or mechanistic fashion. Providing a robotic figure was to give press photographers a theme or angle from which to take interesting and unusual photographs thereby making the message more newsworthy.

The PR company wanted the robotic uniformed policeman to be seated on a bed in an iron barred prison cell and be interviewed by MPs on the Police Federation's stand at each of the party political conferences at the end of summer 2003. After answering scripted questions put by MPs the figure was to plead guilty to the charge of not being able to carry out its public duties and services.

To capture and retain the attention of a passing busy, sophisticated audience the figure had to look realistic and be of good quality but look robotic and not so lifelike that it could have been a human actor. This would have been less "newsworthy" and less interesting to watch with less of an image of robotic behaviour. Thus the movements and appearance of the figure had to emphasise the spoken message voiced by the figure.

2 The design of the figure

The design is a robotic policeman that holds a pen in one hand and an A4 document 'red tape' on its knee with the other hand. The policeman looks up to answer questions, and after answering, looks down again to 'read' the document.

Members of the public and MPs were invited to enter the prison cell and ask questions from one of two scripts, one on anti social behaviour and one on burglaries. The policeman gives a sequence of pre-recorded answers to each question. If the volunteer questioner asks an un-scripted question, the figure gives a generic non-committal answer. The figure's lips move in synchronism with the voiced answers. The body, head and eyes move under autonomous behaviour control programs to give the appearance of intelligence.

In between the scripted replies the figure runs another "personality" program that causes it to move its head and eyes as if it is reading the 'red tape' document, occasionally looking up and around as if it is thinking.

An operator hidden in the audience synchronises the policeman's answers to questions posed by the questioners. The operator presses the relevant button on the handset transmitter of an infra red link to initiate one of the pre-recorded answers and the accompanying sequence of head, eye and lip movements.

3 The construction of the figure

The skin of the head, which is shown in Figure 1, is made from silicone, which allows realistic facial movements; mounted on a fibreglass skull. The microcontrollers, MP3 player, audio amplifier, loudspeakers and power supplies are mounted inside the body. Power is obtained from a mains socket. The operator triggers the figure to respond to the correct script and triggers the figure to synchronise the replies or a generic non-committal answer at the end of each question. When the operator triggers a reply, the microcontroller software initiates the appropriate MP3 sound file and the file that controls the corresponding behaviour motion sequence. The start and end transitions of each motion sequence are blended so that there is no perceptible start or stop to the performance.

The major moves of the head are triggered by the operator. These moves were programmed by moving the head as required and recording the positions. The minor background moves were recorded as part of the "personality programme" and are triggered at random and by the voice. Thus it is not really possible to see how the figure is controlled purely by observation.

The head nods and turns, the eyes scan right and left and the mouth opens and closes. The head and mouth motion is achieved using an electric motor and specially made servo amplifier with position feedback on each axis. A standard servomotor controls the eye motion.

Figure 1: The policeman's head

The head and mouth movements are controlled to produce low acceleration and medium speed to avoid the rapid jerky motion obtained with standard servomotors which change output shaft angular position from end stop to end stop in nominally 0.2s unless constrained to move more slowly. Thus plots of servomotor output shaft angle versus time show curves with a smoothed trapezoidal shape rather than a nominally rectangular shape.

Standard servos tend to be too mechanically noisy have a limited life (just a few days if operated eight hours per day, accelerating and decelerating larger masses). The special low noise, high reliability servos used here were made using motors run under their normal rated voltage and using long life (10 million cycle) position sensing potentiometers. Running the motors on low voltage is a convenient way of achieving a more natural damped and compliant motion.

Human eyes move more rapidly than heads and have a relatively low mass so high quality standard servos were used to control the eye movement. The head's panning axis is not vertical as might be expected but is tilted forward slightly. Thus panning produces horizontal and vertical motion simultaneously, which makes the figure's head movement more appealing. An exaggerated example of this idea is used in the NEC personal robot PaPeRo where the head axis is tilted down at the front by about twenty degrees from the vertical. Thus the toy looks up as it turns its head left or right which gives a submissive, non threatening, friendly, cute, innocent look. The aim is to evoke an unconscious desire to feel protective towards it.

In the Cycler robot the main microcontroller runs the personality program, interprets the signals from the IR-receiver, initiates the appropriate speech file, and initiates the matching action sequence. A secondary microcontroller converts the MP3 lip control track into signals that move the lips in synchronism with the voice. Thus the lip movements are voice operated. This avoids the problem of the lip movement creeping out of synchronism with the voice track as can easily happen with separate sound systems.

Figure 2: The policeman in its cell with the Liberal Democratic Party Leader, Charles Kennedy.

The movement sequence for each reply is slightly different and the pose of the figure at the start of each reply is usually different. These apparently random sequences add to the realism. The motion programs and sound files are stored in MP3 format on Compact Flash memory cards allowing the performance to be reprogrammed with the aid of an LCD screen and user controls. The software is written in Parallax Control Basic running on Parallax Basic Stamp modules, BS2, BS2sx and compiled Parallax Control Basic running on PIC 16F84s.

The infra-red link is a proprietary 12-channel system from Quasar Electronics with an added (RS232 5V) serial interface constructed with a Parallax BS2 controller. The IR receiver communicates the signals it receives to the figure via a short cable link that has two way handshaking.

The files containing the voice replies and the files containing the lip movement sequences are stored on separate tracks. The lip movement track carries an edited and reshaped volume envelope of the voice track. The start and stop times for the movement of the lips are slightly different for each reply, further adding to the realism. To ensure that a slow speaking or distracted volunteer performer doesn't get out of synchronisation with the figure's responses, each answer is triggered by the operator.

The figure is self contained with the exception of a bass-speaker, which was too large for inclusion, and the IR-receiver which was mounted in a more convenient position in the cell.

4 The performance script

When a member of the public or an MP volunteers to take part in the performance they are given one of two scripts and invited to take a seat with the policeman in the cell (as shown in Figure 2). One script features anti social behaviour and the other features burglaries. The sequences for the two scripts only differ in detail. The script for antisocial behaviour follows to illustrate the performance.

Policeman	(Looks up). Can you make it quick please; I've got a lot of work on.
MP	Hello my name is (state name). I shall be interviewing you about allegations of professional negligence. Do you understand?
Policeman	(Nods). Yes.
MP	I caution you that you do not have to say anything; but it may harm your defence if you do not mention, when questioned, something, which you later rely on in court. Anything you do say may be given in evidence. Are you John William Constable of Anywhere Constabulary?
Policeman	Yes.
MP	On the evening of 18 May this year, a gang of yobs were causing mayhem in Letsby Avenue. We

	called you to attend a number of times. Is this correct?
Policeman	It is.
MP	What were you doing at the time?
Policeman	I was dealing with a shoplifter I had just arrested.
MP	Why didn't you respond immediately?
Policeman	I had to prioritise. No one was hurt and a crime wasn't being committed. I didn't need to respond straight away. I wanted to, but was tied up with three-and-a-half hours of paperwork.
MP	Why didn't you ask a colleague to attend?
Policeman	I didn't have any colleagues to ask. No one was available. Some were on jury protection, there was a drugs raid in progress, we were providing extra officers for airport security, some were attending community meetings, some were on observations and others were dealing with a domestic violence incident.
MP	Surely someone could have attended?
Policeman	Impossible. On top of this we were processing a backlog of prisoners in custody. We were doing criminal records checks, waiting for parents and solicitors, taking statements, fingerprints and DNA samples. It all had to be done.
MP	Because you didn't attend when you were called some people were afraid to go out. The yobs were intimidating and shouting abuse at my elderly neighbours. I'm sure they were drinking and they were skateboarding along the kerb making drivers swerve to avoid them. How do you plead to this charge?
Policeman	I plead guilty to being a prisoner of bureaucracy, not having the information technology that would allow me to complete a form only once, and being professionally frustrated in my efforts to give the public the service it demands.

At apparently random moments the figure makes slight movements under control of the behaviour program. Larger movements tie-in with the script.

5 The performance of the figure

Human head and eye movement is very smooth, in part because the muscle power is well matched to the weight of the head and several feedback loops exist. In order to achieve similar freedom from vibration, backlash and overshoot a relatively low power to weight ratio was used for this humanoid. Compliant mechanical linkages further contribute to the smooth motion. The eye motion is controlled by a standard servomotor. This analogue mechanism sets a particular output shaft angular position that is proportional to the width of the applied signal pulse, provided that the pulse width lies between a nominal 1.5 and 2.5ms. Thus control of the rate of widening and narrowing of the servo control pulse from a nominal 1.5ms to 2.5 ms was incorporated in the software to avoid unnaturally fast or slow speed and acceleration. The standard pulse repetition or frame period of 20ms is used although in practice many servos in this type of application can tolerate periods of between 15ms and 500ms. Other features designed to achieve realistic motion are incorporated in the driving software. A motion that is too slow can look sinister and a movement that is too fast can look too mechanical, surprising or threatening.

6 Creative Factors

Programming engaging body language is not easy as the terms “engaging” and “body language” are hard to define. Engineers are not normally familiar with creative concepts such as “friendly movement” but sharp, darting movements of a person’s head suggests that the person might be under threat and so such motion may be unconsciously unsettling in an observer. Similarly a slow ponderous movement as seen with large animals and screen villains also appears threatening. Humans are analogue machines with infinitely smooth motion. The optimum level of animation is similar that used by skilled television presenters and public speakers, who by use of their body language and speech tone unconsciously create and hold an audience’s attention. These aspects are described in more detail in Mori (1982) the originator of the concept of the “Uncanny Valley”. His concept is that as a robotic figure is made more and more lifelike in its movement and appearance it becomes more appealing until a point is reached where the figure can look like a “moving corpse” and the figure induces a negative reaction in its audience. As the figure is made more lifelike still the reaction becomes positive again as it approaches 100% human in likeness. The dip in the curve of positive human reaction plotted against “similarity to a human”, he called the “Uncanny Valley”. Creative skills are required to design friendly and attractive looking machines that avoid the valley and choreograph believable, engaging, motion; particularly where the number of degrees of freedom is constrained. Where machines and humans interact; attractive things work better (Norman, 2004).

Some body language cues can be quite subtle, and imitating them requires a combination of creative and engineering skills. It is not sufficient for realism or emphasis to merely animate a series of static poses.

7 Reliability

The reliability of these types of figures is of paramount importance as a failed performance would be counter productive to the aim of promoting the message. It is not practical to call out the robot builder to travel across the country quickly to effect repairs or to have an engineer standing by all the time. The skills required to create reliable robotic figures at low cost are acquired by experience; in this case by many years, cumulating in a series of similar figures including a figure of a Celt in the “Tales of Tameside” exhibition in the Town Hall in Ashton-under-Lyne, a Crofter in the Hootenanny Celtic Heritage Museum in Inverness, three schools educational presentation robots (Smith and Buckley, 2005) and others. The policeman operated without any failures at all the season’s party political conferences.

8 Results

Press photographers from a national daily newspaper took photographs of Charles Kennedy, the Liberal Democratic Party Leader, with the policeman apparently inside a police cell on the Police Federation stand at the party's conference in Brighton and at the other conferences. Thus the press release featuring the message was taken up and widely publicised achieving the aim of the sponsors.

9 Conclusions

Constructing a believable, lifelike robotic figure of a human being at low cost with a small number of degrees of freedom requires an unusual combination of engineering and creative skills to conceal the performance limitations, exaggerate the lifelike aspects of the motion and create an engaging performance. Using a robotic figure to attract a sophisticated, busy audience and the national press was successful in that the policeman and story were featured in the UK’s most popular daily newspaper and elsewhere. It is sometimes thought that robots and robotic figures only appeal to children and young people. However it was found that the target audience was sufficiently captivated by the figure and its choreographed movement to stand and listen to the complete performance. Such figures should not be too lifelike or the effect can be eery, unappealing and unsettling.

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iCat: Experimenting with Animabotics

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Abstract

Recently a new type of robot user interface has been discussed (Bartneck and Okada, 2001). This paper argues that a new discipline is needed for successfully developing these robot user interfaces. This discipline derives from the fields of animatronics and robotics, and is named 'animabotics'. After explaining this term, our research platform for studying animabotics is described. The platform consists of a robot character called 'iCat' and a software framework called 'Open Platform for Personal Robots', or just OPPR. Two research cases are described that are based on our research platform.

1 Introduction

In the last decade research laboratories and industrial companies have shown interest in robots that affectively interact with users in their domestic environment. These robots are presented as a friend. In 1996 toymaker Bandai Co (Bandai, 2004) introduced the probably most famous non-robotic example of this concept: the Tamagotchi, an egg-shaped key-chain that simulates a little creature that needs to be fostered by its user. This little toy was a big success as over 40 million pieces were sold worldwide (Tamagotchi Connection, 2004). Soon, robotic follow-ups were developed, such as Tiger Electronics' furry pet Furby (Tiger Electronics, 2004), Sony's AIBO (Sony, 2004) and the research robot Kismet (Breazeal and Scassellati, 1999) that is used for studying social robotics. Most recently, this robotic friend concept has been combined with real domestic functionality and new robots have been developed that are enjoyable to interact with, while performing functional domestic tasks such as guarding and cleaning homes, educating children or controlling domestic devices (e.g. VCR and lights). Bartneck and Okada (Bartneck and Okada, 2001) describe this as a new user interface paradigm: Robotic User Interfaces.

Which discipline should be adopted to develop robotic user interfaces? It is tempting to say that robotics is the right discipline to develop these devices. Robotics has a long history in developing and studying devices that perform actions in the real world. On the other hand, one could also argue that animatronics, a technique frequently used in the entertainment industry, provides the right toolset to develop robotic user interfaces. This paper, however, argues that the right discipline is sitting somewhere between robotics and animatronics. We call this new discipline *animabotics*. Animabotics should support designers in creating autonomous and intelligent robotic user interfaces, while providing tools to make these robots as enjoyable as the ones found in animatronics industry.

This paper describes the new field of animabotics. Section 2 provides background information and explains to term 'animabotics'. Section 3 presents our research platform that is used for studying animabotics. Some final thoughts are presented in section 4.

2 Animabotics

2.1 Robotics and animatronics

The field of robotics originates from the requirement of creating machines that can operate autonomously and "intelligently". Malone (2004) presents an historical overview of developments in the field of robotics. In 1948 W. Grey Walter performed experiments with a robotic 'tortoise', the first autonomous mobile robot. This robot was equipped with sensors and could move towards light sources. The first industrial robot arm was created in 1962. The robot was called *Unimate* and was part of the assembly line at General Motors. While Unimate was fully pre-programmed, the next major developed was to create a robot that could 'think' by itself how to act in some environment. The robot *Shakey*, developed in 1970 at the Stanford Research Institute, was the first robot that used a planning algorithm (STRIPS) to decide what action to take. The next breakthrough in the field of robotics happened during the 1980s, when Rodney Brooks published the subsumption architecture. Instead of planning all actions, Brooks proposed to control autonomous and mobile robots by a set of prioritized stimulus-responds behaviours. Over the years the main research area within the field of robotics was creating control architectures to make autonomous and mobile machines.

While the field of robotics was working on creating autonomous and mobile robots, the entertainment industry had a different goal in mind with robotic devices. During the 1960s Walt Disney opened a new attraction in their theme park 'Disneyland'. This attraction was called the *Enchanted Tiki Room* and was based on the idea of creating real three-dimensional characters (Driscoll, 2004). The Enchanted Tike Room consists of over 200 singing, talking and whistling mechanical birds, flowers and tiki poles. A new technology named *audio-animatronics* was developed to create this attraction. In contrast to the field of robotics, audio-animatronics is not a technology to create autonomous and intelligent devices, but it is a technology to create what Disney calls 'the illusion of life': believable characters (Thomas and Johnson, 1981). During the 1980s and 1990s companies like Jim Henson and Stan Winston Studio developed many animatronics characters for the movie industry. They emphasized the personality of the character: the way it looks, behaves and responds apparently emotionally to things.

2.2 Defining animabotics

Robotic user interfaces as described in the introduction are both robotic and animatronics devices. They should operate autonomously and should appear believable to their users.

This work on autonomous and believable robotic user interfaces that combines results from animatronics and robotics I would like to call *animabotics*. Animabotics combines science, engineering and art with the ultimate goal to construct believable, autonomous and intelligent robotic user interfaces. The way of working is that of synthesis: by building real systems ideas and theories are tested and new food for thought is created that provides input for further new ideas and theories. Animabotics is a creative discipline, as solutions need to be found for new problems that arise when combining robotic and animatronics techniques, and because the robotic user interface needs to be given a personality.

2.3 Science, engineering and art

Animabotics can be compared with game development technology. Computer games have evolved from simple games to major Hollywood-type productions. Success is achieved by having cutting-edge tools and techniques (Baillie-De Byl, 2004). In the gaming industry scientists, engineers and artists work together to develop complex computer games in which non-player characters have interesting personalities and a high AI-level to make the game more challenging. The same is needed for animabotics.

2.3.1 Science

Just like any other technology animabotics needs a firm scientific foundation to mature further. The three sciences contributing directly to animabotics are robotics, human-robot interaction and artificial intelligence.

Robotics is an import research field from which animabotics can adopt many techniques. One of the most relevant results from robotics is the control architecture view on a robot system. A control architecture is a blueprint for the structuring of all decision making (AI) processes in a robotic system. Different paradigms have been proposed, such as the (STRIPS) planning-based architecture (Fikes and Nilsson, 1971), subsumption architecture (Brooks, 1985) and the hybrid architecture AuRA (Arkin, 1987). These paradigms all address different requirements, such as being able to reason about the environment or being able to react quickly to changes in the environment. An architecture for animabotics adds the additional requirement of making a personal robot behave believable. This requires a change of traditional robotic control architectures. Van Breemen (2004b) has proposed a control architecture, called the *Robot Animation Engine*, that combines the subsumption architecture for autonomous behaviour and animatronics techniques for believable behaviour.

Human-robot interaction is an exciting new research area. It is a multi-disciplinary field that brings technical and non-technical (psychology, social science) sciences together. Psychological models, such as the Big Five personality model (Wiggens, 1996), are now applied to personal robots in order to shape their "personality". Research results from this area have shown that the robot's appearance and "personality" affect the enjoyability and effectiveness of the interaction. Researchers at the Carnegie Mellon University have researched this aspect by creating a reconfigurable humanoid robot head that allows creating different characteristic robot heads (Goetz, 2003; DiSalvo, 2002). These results can be applied directly by animabotics engineers when building a robot user interface for a particular application domain.

Finally, the "intelligence" of a personal robot does not derive from clever planning or reasoning algorithms only. The ability, for instance, to extract features from sensory data also contributes to the intelligence of a personal robot. Vision algorithms for recognizing objects, faces and facial expressions allow personal robots to interact more naturally with their environment. Also, a speech synthesis system with an emotionally-modulated voice increases the believability of a personal robot. These topics are researched within the field of artificial intelligence.

2.3.2 Engineering

Animabotics needs methodologies and tools to support engineers during their design task. There are at least two fields from which such methodologies and tools can be derived: software engineering and mechatronics.

Being able to deal with the software complexity of a robotic system is one of the key requirements of any animabotics project. An adequate software architecture is needed to deal with many non-functional requirements such as extendibility of the software, support for different operating systems, support for distributed computing, security, ease of use, etc. Within the field of robotics one is working towards standardizing so called robot middleware (IROS, 2004). An animabotics project requires so many specialisms that one engineer cannot master them all. This means that being able to easily integrate research results becomes a key factor for making an animabotics project a success. A common software platform for robotics - robot middleware - is the key to realize this.

The mechanical and mechatronic design is also important. Believability is realized through animated movements. This requires that the robotic system is able to generate smooth movements. Here we see a difference between virtual characters that are rendered on a screen and real mechanically designed characters. Virtual rendering provides much more control over the movements, while mechanically design is limited by the types of actuators and mechanisms. Jerky movements with lot of noise decrease the believability of the mechanically rendered robot. A good mechatronic design may drastically improve the believability of the robot.

2.3.3 Art

A believable robotic user interface is a three dimensional character that benefits from a “personality”: an appropriate physical appearance and a characteristic way of behaving. This aspect has been the major focus of animatronics. The personality of a character determines the popularity and success (measured in terms of effectiveness or enjoyability) of the robotic user interface. The “personality” design is as important as the technology inside, because this is what the user is confronted with. Designing personalities is the specialism of designers, anim ators and story writers. Questions one should ask are: Is the appearance of the personal robot frightening or friendly?, Is a frog-like appearance appropriate for a robot that needs to guard your home, or does a dog-like or dragon-like appearance have more appeal?

3 Research platform

We are developing a research platform to study animabotics topics. This platform consists of a physical three-dimensional character called *iCat*, and a software platform called *Open Platform for Personal Robots* (OPPR).

3.1 Physical embodiment

The iCat is a research platform for studying animabotics topics. Because we are interested in developing consumer applications, the platform has a cat appearance to improve the acceptance in domestic environments.

The iCat is a 38 cm tall user-interface robot that lacks mobility (see figure 1). This way, we can solely focus on the robot-human interaction aspects during the development of this platform. The robot's head is equipped with 13 standard radio control R/C servos that control different parts of the face, such as the eyebrows, eyes, eyelids, mouth and head position. With this setup we are able to generate many different facial expressions that are needed to create an expressive character. Figure 2 illustrates some basic facial expressions

The camera installed in the iCat's head is used for different computer vision capabilities, such as recognizing objects and faces. Each foot contains a microphone to record sounds, perform speech recognition and to determine the direction of the sound source. Also, a speaker is installed to play sounds (WAV and MIDI files) and speech. Furthermore, iCat is connected to a home network to control domestic devices (e.g. light, VCR, TV, radio) and to obtain information from the Internet. Finally, touch sensors and multi-colour LEDs are installed in the feet and ears to sense whether the user touches the robot and to communicate further information encoded by coloured light. For instance, the operation mode of the iCat (e.g. sleeping, awake, busy, listening, etc.) is encoded by the colour of the LEDs in the ears.

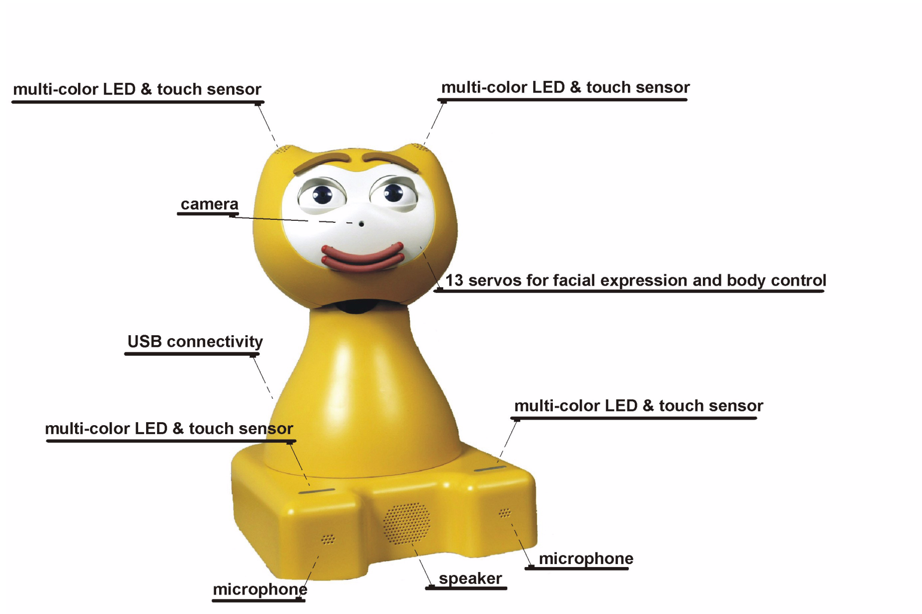

Figure 1. Hardware setup of the "iCat".

3.2 Software platform

We are developing a software platform to support animabotics engineers. This platform is called Open Platform for Personal Robots, or just OPPR. Figure 3 shows our software platform setup. There are five main software packages:

- **Architecture** - A robot middleware layer called Dynamic Module Library (DML) to support integrating various software components, such as vision and speech algorithms.
- **Workbench** - An integrated developed environment for animabotics projects. It contains high-level tools for creating configurations of software components, as well as animation and scripting tools for creating application content.
- **Believability** - A robot animation engine and editor (which is part of the workbench) to create believable robot animations.
- **Intelligence** - Software components for reasoning and editors (which are part of the workbench) for scripting dialogues.
- **Connectivity** - Software components to for interacting with domestic environments. Typical components are a Universal Plug and Play component to interact with comsumer electronic devices, X10 component to control lights and Internet components (e.g. email, ftp, http).

Figure 2. Some facial expressions. From left to right: happy, angry, surprised.

Animabotics applications are created using two main software components. The first component is the robot animation engine, which is part of the believability package. Traditionally robots are controlled using feedback control techniques, which results in rather machine like movements of the robot's body parts (e.g. constant velocities). This makes a robot likely to be perceived more like a machine then a believable and intelligent agent. Van Breemen (2004a) has demonstrated that by applying animation techniques to robotic devices, these devices become more believable. The believability package provides tools to create animated robot behaviour. One tool, called the Robot Animation Editor, has been developed to graphically design believable robot animations, such as eye-blinking, facial expressions, head movements, etc. Figure 4 shows some screenshots of this tool. The animations become part of the Robot Animation Engine's database such that they can be used while the robot is operational and combined with robotic behaviours (sensor-actuator control loops).

The second component is a scripting engine. Scripting is a technique frequently used in the gaming industry to make programming the intelligence of an application easier (Varanese, 2004). Our scripting engine allows easy merging of multiple scripts, each defining a part of the overall application logic. For instance, one script could define a chat dialogue between the robot and a user, while

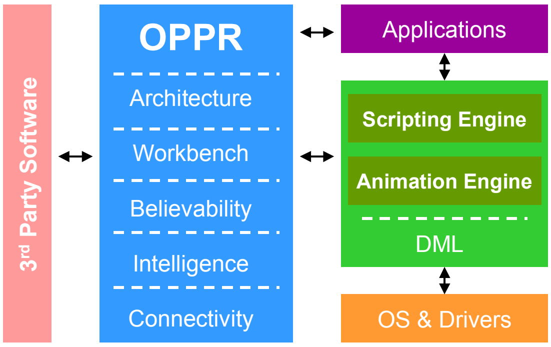

Figure 3. Animabotics software platform.

another script defines rules on how the robot should create a plan to go from one location in the home to another location. Below an outline of the scripting language is given:

```
; This rule defines how iCat should react
  when its left ear is touched
(defrule react-to-touch-left-ear
   (global $left-ear-touched)
      =>
   (retract global $left-ear-touched)
   (RAE.load("look-convenient-at-left-
       ear",4))  ; load animation channel 4
   (RAE.start(4)) ; start playing channel 4
   (RAE.speak("that is my left ear")))

; This rule defines what iCat should do when
  it sees some body
(defrule react-to-seeing-person
   (global $SEE=="person " $username={.*})
      =>
   (retract global $SEE)
   (assert $utterance ("hi " | "hello ")
      $username)
   (RAE.speak($utterance)))

; This rule defines what iCat should do when
  it hears a greeting
(defrule greet-user
   (global $HEAR==("hello"|"hi"))
      =>
   (retract global $HEAR)
   (assert $utterance ("hello " | "hi " |
       "nice to meet you ") $user-name)
   (RAE.speak($utterance)))
```

3.3 Research cases

Several user studies have been performed using the iCat platform. These studies were carried out in the living room of the Homelab. The Homelab is a smart home research facility at Philips Research Eindhoven, The Netherlands (Aarts, 2002). These experiments needed animabotics: engineers (software, mechanics, and electronics), psychologists and animators cooperated to carry out the experiments. The iCat platform provided a firm foundation to quickly realize the experiments.

The first study was on social intelligence. People need social intelligence to go through life: one needs social intelligence during business meetings, to get along with friends and family, and to go shopping. This study indicated that by adding social intelligence to the robotic character iCat the technology became more accepted by users. One explanation is that social intelligence allows people to approach and communicate with the iCat on a level that is close to communicating with another human.

The second study was carried out to study personality aspects of the iCat. During the experiment children of about 11 years old needed to play Tick-Tack-Toe with three iCats with different personalities. This study showed that children attribute different personality traits to iCats with a differently pre-programmed personality - a prediction that could be made from The Media Equation (Reeves and Nass, 1996). During the interviews with the participants they indicated a preference to interact with 'Katy', the slightly extravert and agreeable iCat.

4 Conclusions

With the rise of the new robotic user interface paradigm there is a need for a new discipline that effectively supports the development of such interfaces. In this paper we argued that this new discipline could be derived from the field of robotics and animatronics. This new direction was named *animabotics*.

Animabotics was compared to the gaming industry, where science, engineering and art are merging in order to create Hollywood-type game productions. Animabotics needs to develop itself further in the same direction.

Finally, our research platform for studying animabotics was introduced. This platform has been successfully used in two research studies, which were also described.

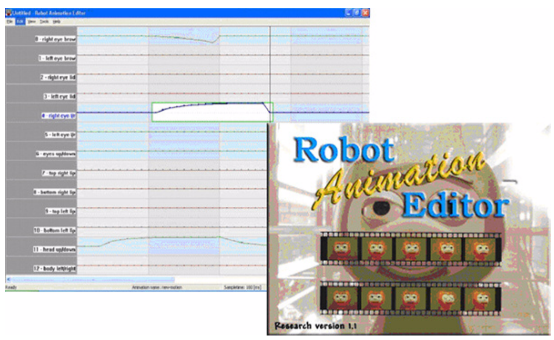

Figure 4. Robot Animation Editor: a graphical tool to create animation for robotic devices.

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Real Tech Support for Robotics

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Abstract

This paper proposes an alternate reading of the *Creative Robotics* agenda. It attempts to formulate a rational for robotics research in the arts that hold promise for delivering contributions to the broader question of coexistence between advanced information processing machines and human beings.

1 Role Models for Robots

The role of robots in human society has been a contested question ever since Karl Čapek coined the term robot in his 1920 play RUR [Čapek 1920]. The dichotomy between the intelligent machine and unexpected consequences arising from (self) interpretation of its protocols continues into Sci-Fi novels, television series and film, leaving the marriage of super-intelligence and social behavior in machines unresolved.

All robotics research inherits this quandary. Before robotics research extended to practical questions of interaction with humans, this problem remained fairly marginal. Technical advances and improvements in industrial production have made previously expensive sensing and actuation technologies affordable, and companies are eager to sell them to a willing audience. But once robots entered the home and the leisure sphere, through toy stores and online resources, the problem of robots amongst people began in earnest to play an important role.

The robotics research community has actively engaged this question in recent years. The new field of Social Robotics [Fong et al 2002] investigates learning and imitation, gesture and natural language communication, emotion, and recognition of usually benign interaction and social behavior. Thus, social robots are usually designed as assistants, companions, or pets, in addition to the more traditional role of servants. As such, robots are designed with the intention that people might have "natural" exchanges with them, and the term natural is most often translated into robots that act like (some) people act and look like (some) people look. Since most humans are more comfortable interacting with their own kind, it is believed human beings would most readily accept the presence of a robot if it appeared as they do. The tradition of dolls, puppets and automata, together with the social robotics agenda have converged in the entertainment industry to cement the validity of familiarity in the design of robots. Whether it is a pet or a companion, an entertainment robot usually "looks like" what it is intended to be perceived as. The most decisive formulation of this hypothesis resulted in the class of humanoid robots. To date, however, even the very best attempts at artificial lifelikeness fall disappointingly short of life itself.

1.1 Post-Mimetic Robotics

In the 1970s Masahiro Mori developed the principle of the *Uncanny Valley*. This principle states the following: As a robot is made more humanlike in its appearance, the emotional response from a human being to the robot will become increasingly positive and empathetic, until a point is reached at which the response suddenly becomes strongly repulsive. At this point the robot resembles a human, but differs from a human in slight but perceptable and cumulatively significant ways. Thenceforth, as the appearance and motion are made to be indistinguishable to that of human being, the emotional response becomes positive once more and approaches human-human empathy levels. Some researchers have challenged this principle, while others have embraced it with certain caveats. Dautenhahn [Dautenhahn 2002], for example, argues that appearance is secondary to movement. Humanlikeness would need to be achieved on multiple levels simultaneously (appearance, motion, speech, behavior, etc) in order to be believable.

The history of the (visual) arts might offer some unexpected guidance for researchers struggling with this question. Artists at the end of the 19th century radically departed from direct forms of representation once technologies that superceded human mimetic capabilities were in place. Photography irrevocably altered the role of painting, and film irrevocably altered and augmented the role of photography. In the course of the 20th century, a variety of conceptual, performative and socially engaged art agendas emerged that continued the non-mimetic approach. Even media that use established techniques of drawing and coloring, such as comics, usually achieve believability in character by deviating from common notions of realism, as Scott McCloud observes [Bolhafner 1994].

This observation is conceptually in synch with some of the more interesting new ideas in Artificial Intelligence research. Drescher [Drescher 1991] sees an engineering replica of a universal human learning mechanism as an intractable problem, and a rather useless one at that. Because thinking is always thinking about something – and that something is fundamentally different in the machine than in the human, the synthetic thinking of robots will be very different from our own. Consequently, we need not imitate our own thoughts in the machines we make.

In the Believable Agents research community [Bates, Loyal, Reilly 1992], the notion of lifelikeness is also not equated with mimicry. Believable agents are the union of AI-based autonomous agents and the personality-rich, emotive characters that appear in the dramatic arts (e.g. theater, cinema). Believability is a term used by character artists to describe a property of compelling characters. Believability strives for internally consistent, lifelike and readable behavior in such a manner as to support an audience in suspending disbelief and entering the internal world of the character. This is not the same as realism. Characters are not simulations of people, exhibiting behavior indistinguishable from humans under some controlled laboratory condition. Rather, characters are abstractions of people, whose behavior, motivations, and internal life have been simplified and exaggerated in just such a way as to engage the audience [Mateas 2002].

For these and other reasons that will become apparent below I argue for intelligently designed robotic systems that are informed by the history in the arts and that do not strive for obvious similarity with humans. Furthermore I will expand the argument against mimesis and suggest a form of robot design outside of that which we would "normally expect" from a machine.

2 Querying the Role of Automation

In "The Question Concerning Technology" Heidegger analyzes the reasons for his discomfort towards technology form the perspective of existential philosophy [Heidegger 1955]. He observes that automation technologies create a "standing reserve'" and that this standing reserve, while beneficial to economics, alienates people from their origins. Why worry about grinding grain when you can buy bread, cheaply, sliced and packaged, at your local food market. Heidegger might have argued that this efficiency has a price, and that the price is the difference between the lived experience of the complete cycle vs. the partial but practical experience of pre-prepared goods. Heidegger's observations of second order effects of automation and efficiency on our psyche are useful here.

When we build machines we make statements about the world. We make statements about things that should be changed, about materials that should be properly bent, finely grinded or cautiously heated up. When using computing machines, we implicitly make statements about data and the fact that the output of an operation does something useful to the input. Moreover, the effect of seeing these processes in action generates the belief that they produce something useful, that they truthfully interpret the data they collect and that, well, since it is so complicated, it is best left to the experts to decide how to go about these questions. But must all acts of automation result in such a standing reserve that removes one from original experiences? Must we always believe the experts who build and program the machines that surround us?

3 The Real Tech Support Initiative

The *real tech support initiative* is an attempt to conceive, design and build robotic systems that actively address the challenges of the standing reserve by querying the processes inherent in creating efficient machines. Real tech support is a reinterpretation of the popular coinage "tech support" that we have become familiar with in our daily struggles with ailing machinery. Real tech support interprets the role of automation differently; not as culminating in efficiency and optimal design, but in the thoughts, hopes, illusions and fears that accompany the desire for technologically inspired improvements to the human condition. Under real tech support, philosophical and social considerations are included in the initial parameter set; they are to be addressed with the same level of dedication as the more clearly definable technical questions. A calendar utility designed for a handheld computer under the real tech support design philosophy might periodically remind a user not to work too much, for example.

Machines devised under real tech support often perform no obviously useful work. However, these machines, *critical robots*, alter the flow of efficiency processes and replace them with situations and experiences that bring a person closer to an original experience. Since the real tech support initiative is interested in creating alternatives to efficiency driven automation, it must include in its agenda hard questions of reliability and robustness as standard engineering practices do. With this, critical robots under real tech support exceed the domain of traditional "robots for the arts". Real tech support is, thus, a practical philosophy and a critical engineering practice at once.

3.1 Practical Examples of Critical Robots under the Real Tech Support Initiative

The best way to show the kind of results this approach can achieve is to describe a few examples. The next section will describe four built and tested critical robot systems under the real tech support initiative.

3.1.1 Advanced Perception (1999/2000)

– Animal machine interaction (AMI)

This project was an early experiment in mixing machines and animal societies. Three chickens, Rhode Island Red hens, were held in a spacious cage together with a mobile robot for 60 days. The robot was programmed to share the space with the animals and to not infringe on their habits and movements. A camera mounted above the cage continuously monitored the state of affairs, the positions of all the chickens and the robot. Information from the camera was linked to a computer where the interaction scenarios were monitored. Corrective actions and plans were sent via radio signal back to the robot.

Figure 1: A Rhode Island Red hen pecking a robot

At first the chickens were very anxious about the robot's motions. They would scurry away every time the machine began to move. In order to reduce the anxiety of the surprise effect, the notion of movement by a machine, as perceived by a simple animal, required some attention. Audio queues were added such that the robot "announced" impending movement. This gave the chickens a perceptual queue by which they could know when to expect motion from the machine. Also, the robot would roam around but never hit an animal while moving forward. Over time the chickens got used to this and let the robot approach them to within an inch or so before moving out of its path. A series of different robot behavior algorithms were developed to test how well the chickens remembered the past actions of the robot. As one might expect, chickens have a short memory span. A fuzzy cognitive map based robot controller generated no deeper interactions between the machine and the chickens than a purely reactive system.

With the desire to share the insights from this research with a wider community, a new from of information dissemination had to be explored. In addition to publication in the engineering science community [Böhlen 1999], the results from these experiments were also presented in the form of a gala omelet dinner in an art gallery. A world-famous chef, Rudy Stanish created omelets by secret recipes that have been savored over the years by many dignitaries, even by some US presidents. A professor of philosophy was hired to help the chef. His job was to instigate discussions on theories of perception with the guests as they lined up for an omelet.

The intention in this work was to confront visitors with the cumulative results from the interaction, i.e. the chicken eggs. Would cohabitation with a robot affect the hens to the point that their eggs taste differently? This obvious question acted as a redirection towards a much more important issue. When we judge experiences that do not have prior references, we usually revert to opinion and taste. If one sees three chickens in a cage with a robot and tastes the omelet of the eggs from these animals, one is inclined to pass judgment on the basis of what one knows (how the omelet tastes), not on what one does not know (how the animals experience the robot), and likely to conflate the first with the later.

This experiment was called "Advanced Perception". It was left to the visitors to ponder where the advanced perception was to be found, whether it was in the machine vision system guiding the robot in the cage, the chickens' perception modalities -that are in some ways superior to our own-, or in the idea of an advanced/alternate mode of perception necessary to contemplate solutions for a future in which our technologies kindly intertwine with the world of "lesser" creatures. For details on this project see [Böhlen 1999].

3.1.2 The Open Biometrics Project (2001/2002)

-Transparent extraction of biometric data

The Open Biometric Project proposed an alternate approach to biometrics by challenging hard and fast classification of biometric data. A kiosk-like object asked passersby to place their index finger on a finger print scanner (see below) and then created a probabilistic map of how their finger scan might be tallied.

Of all biometric validation techniques, fingerprint based validation is the most established through out the world. The Open Biometric Project contested the clean fabrication of automated biometric identification. Whoever placed their finger on this machine was shown what kind of information biometric readers extract and how much judgment accompanies the creation of a final decision.

A fingerprint is made of a series of ridges and furrows on the surface of the finger. The uniqueness of a fingerprint can be determined by the pattern of ridges and furrows as well as the singular or minutiae points, local ridge characteristics that occur at either a ridge bifurcation or a ridge ending. The extraction of the minutiae points from a scan delivers the structural basis of identification.

Fingerprint matching techniques that use minutiae-based methods first find minutiae point positions and angles and then compare their relative placements to a reference fingerprint. The constellation and number of minutiae points build the basis for matching one fingerprint to another. Formerly a domain reserved for human forensics experts, minutiae extraction can now be translated into executable computer code. In the machine, both minutiae map and minutiae matching are found within degrees of likeliness and translated into probabilities. The results of these mathematical operations generate information that is valid within certain limits and under certain assumptions. The rules of probability theory ensure that the assumptions are computationally tractable.

Figure 2: The *Open Biometrics Project* in use

All of the underlying processes (signal analysis based noise removal, image enhancement, and feature extraction) are strongly dependent on the premises of probability theory. This robot percolated the decision processes of these mathematical substrata to the surface, and opened a window onto the reality of signal processing constraints that is usually not acknowledged in security applications. Each finger scan was accompanied by a list of the minutiae points and the likelihood (as a percentage) of actually being valid data. As opposed to claiming binary clarity and ultimate authority, the result of a finger scan from this machine was a mathematically precise and open list of probable results. It allowed the user insight into the internals of an otherwise hidden process and made the decision mechanism transparent and open for scrutiny and debate. Even the science of biometrics is prone to error, and neither heightened desire for secure and reliable solutions nor Hollywood thrillers should convince us otherwise. The machine printed this tabulated information as a probability map with all characteristic points of a finger scan, and encouraged users to keep their minutiae map cards handy, just in case a standard black box biometric reader improperly interpreted their fingerprint data.

For more information on this project see [OpenBiometrics 2002].

3.1.3 Unseen (2002/2003)

– A nature interpretation center with second thoughts

Unseen was a nature interpretation center with second thoughts; a knowledge mixing system that dynamically proposed expertise on plants and shared this with its visitors.

Nature interpretation centers are a romantic expression of the desire to understand and experience nature without giving up the comforts of civilization.

Figure 3: *Unseen* in the gardens of Grand Métis, Québec

Interpretation centers attempt to shore up this deficit through visual effects. Following trends in news and entertainment TV, they offer seductive media shows depicting portraits of wildlife busily eating, hunting, cleaning, and so forth—in contrast to the reality where usually nothing much happens.

A public garden offers an interesting conditioning of the natural environment for those interested in querying this cultural malaise. Midway between untouched, pristine land and controlled construction, public gardens are established forms of colonialized wildlife. Following the Linnaean tradition, marked trees and labeled plants promise clear classifications with no secrets. Paved paths and directional cues prevent accidental disorientation and exposure to unstructured spaces. There is no room and no need for questions.

Unseen proposed a very different approach. Set in the Reford Gardens of Grand-Métis on the Gaspé Peninsula of eastern Québec during the summer of 2003, the multi-camera real time machine vision system observed select plants indigenous to the region. The Dogwood, the Wild Sarsaparilla, the Harebell, the Foamflower, the Wild Columbine, the Garden Columbine, the Alpine Woodsia, the Lowbush Blueberry and the Canadian Burnet were under continued observation during the entire summer. Borrowing from data analysis and classification techniques, the system searched for, found and tallied instances of these plants. Short texts, constructed from a large database of acknowledged expert sources, depicted factual data on the plants and on computer screens in a small hut adjacent to the garden. Over the course of the summer, however, the flavour of the texts changed. As the initially sparse garden grew luscious, the system followed the changes and altered its "opinion" on the plants. The texts it created shifted from descriptive to hypothetical, and, having second thoughts, confronted the visitor with imagined future understandings of plant life. *Unseen* was an expert system driven by the very objects it observed. It was an open invitation to look again, with a fresh eye, at a simple garden. For more information on this project see [Unseen 2004 and Böhlen, Tan 2004].

3.1.4 The Universal Whistling Machine (2004/2005)

- Transgressing language boundaries

The *Universal Whistling Machine* (*U.W.M.*) is an experiment in establishing alternate communication channels between humans, machines and animals. Whistle at this machine and it will counter with its own composition, based on a time-frequency analysis of the original.

The impetus for this work was created by frustrating experiences with current computer based dictation systems. Given the unsatisfactory state of machine-based language understanding, it appeared interesting and necessary to experiment with a radically different approach to the representation of language in the machine. Instead of forcing machines to meet us humans on our (linguistic) terms, why not meet halfway, on the level of pure signal, where machines are better posed to perform well and humans still have the capacity to express themselves?

Usually, language is represented by a formal grammar, a set of combinational rules and a vocabulary. But language is more than a box of words and rules by which to combine them. Fuzzy aspects of language such as innuendo defy formal linguistic descriptions and are not even modeled in computational models of language that seek to represent communication in general. Languages are not static, and not fully describable through the grammatical rules that constrain them, however refined the rules may be. Many philosophers of linguistics, semioticians, and writers have pointed this out. Lecercle proposed the term "remainder" as a formal entry into the levels below, above, and adjacent to strait-laced meaning covered by linguists' version of language [Lecercle 1990]. For Lecercle, the remainder is the fallout from the intended use of language. It is the essence of poetry and metaphor, but also of miscommunication, word play, and double-entendre. It is the fuzziness and leakage of meaning amongst words.

Figure 4: *U.W.M.* tested by a discerning young man

But how could one possibly attempt to include the language remainder in computational systems? Is it at all possible, given that the rigor of linguistics seems even tighter in the limited corpora of texts, the defined rules and intelligent but blind numerical clustering methods underlying computational linguistics? In order to prevent varied and flavored meaning and language remainders from being filtered out of computation, it might be worthwhile to investigate varied and less structured forms of knowing, unorthodox methods of input, and unexpected flavors of output. This is not only a difficult problem, but also a poorly defined one. How can one even begin to formulate such issues as tasks, let alone make them computationally tractable? A general solution to this problem is beyond the scope of this work. However, one could suggest a replacement problem, one that can be solved and can serve as a lens by which to look at the original problem. Would it be possible to reduce the complexity of language to a more manageable subset, albeit one that still allows instances of language remainders to exist? Rather than creating a machine that is conceived with hardwired knowledge of a fully structured language, including vocabulary and grammatical system, would it be possible to create a device that is only *primed* for language? Is the ability to perceive and imitate a limited bandwidth of data that is mutually suggestive by machine and user as communication, a precursor to language, and can meaning arise in such a situation?

Playing initially with a variety of input methods we eventually settled for whistling. There are indeed numerous examples of human communication systems based entirely on whistling. This phenomenon was widely reported during the late 1970s in linguistics' circles [Busnel, Classe 1976]. Two of the better-known whistling languages are "el Silbo", practiced on the Isla de la Gomera, one of the Canary Islands off the coast of Morocco, and the whistled language of Kuskoy, a remote village by the Black Sea in Turkey that has only recently been connected to the telephone grid. In La Gomera, the skill is still being passed on to youngsters today.

Whistled languages are generally reduced languages, in the sense that not everything that can be expressed in speech can be expressed by whistling. However, they are far closer to languages than to codes or to simple signalization systems. They are speech-like and carry the vocabulary, the grammar, and in many cases the phonology of the local language they have emerged from, especially at the level of prosody.

Informed by these observations the *real tech support* initiative has designed and built a machine that is immune to spoken language but very sensitive to whistled input. The longer one interacts with the whistling machine, the more varied the response whistles become. Furthermore, multiple whistling machines can whistle with each other when no whistling humans are present. Examples of the kinds of exchanges that people and canaries have been able to generate with the machine can also be found on the project website [UWM 2004 and Böhlen, Rinker 2004].

4. Broader Implications

The robotics agenda I have portrayed in these examples differs strongly from that given by an entertainment industry driven agenda. This alternate agenda is inspired by the wish to carve a different niche for the artist in the age of intelligent machines. The artist need not be confined to the role of the beautifier, to the role of the expert on color matching and to the handy man for visual effects. There are too many instances where artists are delegated to create fancy surface effects for the work of scientists. Such is the case when cosmologists at NASA render their ideas visible for the public with the help of an *artist's rendering*. Supernovae and Mars Express Orbiters [JPL 2004] become visually salient and sellable with the help of graphic rhetoric.

I am proposing a more ambitious role for the artist as a maker in the technology arena. Why not make use of the highly experimental nature of the arts as an addition to accepted research methods? Engineers and scientists are not trained to include issues outside of their expertise into their work to the same degree artists have become accustomed to. The integration of advanced robots into the social fabric - and the creative robotics agenda is a new part of this challenge - touches on so many aspects of our existence that we cannot expect the established science of robotics to meet these challenges without additional support. Alternately, simply adding a playful appendage for "creativity" to the periphery of the current research paradigm holds promise only for even more robots that draw, sing and dance.

4.1 New Forms of Research

We should not continue with business as usual. Making intelligent machines for robust cross-cultural action in the real world will change both our ideas of what robotics research should consider as its object of inquiry and the notion of where acts of creativity start and end. Creativity is part of every endeavor and every discipline, and not limited to a specific practice such as the arts. We need to alter the expectation we have towards the artist. Hence forth he/she will be challenged to leave the comfortable role of the amateur behind and take on the role of the technically competent experimental maker. This new figure should be comfortable with the tools of the engineering sciences, yet retain the intuitive and direct approaches of the craftsperson and remain ready to "play against the apparatus" [Flusser 1983]. As opposed to carrying robotic technologies into the arts, I suggest carrying experimental methods and goals of the arts into robotics research in order to create a new form of inquiry that has real agency on social, conceptual and economic levels.

Robotic research in general can profit from this proposition. For example, the issue of *long-term interaction* between robots and humans can and should be informed from the practice that has always known an intricate mix of engineering skills and intuition: architecture. Architects have always had to find ways of integrating built systems into lived spaces, robustly for long-term interaction. While decidedly low-tech by robotics standards, the elevator might be a good case study for robots that are so effectively integrated into our environment that nobody notices them any longer.

Likewise, the new field of *mixed societies* [LEURRE 2005], the integration of robots and animals, could profit from observations in cultural studies [Agamben 2004] as well as from studio experiments by artists querying the same field before mixed societies was acknowledged as a research domain. While some methods typical of the humanities, such as ethnographic evaluation and social psychology have found acceptance in robotics research, the informal experimental methods of studio artists have not. But the integration of socially robust and pleasurable pervasive technologies into our daily lives will not be achieved along the paradigms of the engineering and social sciences alone. It is time we mixed all forms of knowing to meet this grand challenge. What such expanded disciplines will look like in the future is still hard to predict. Hopefully, the *real tech support* and similar initiatives will be helpful in this context.

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Narrative In Robotic Scenarios For Art Works

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Abstract

This paper discusses narrative as a sub-field of creative robotics. We make the premise that every robotic system (regardless of the original intention of it's engineers) is layered with context and meaning both in itself, and in its process of coming into being. Through artistic observation and interpretation these layers can be made tangible as scenarios for art works manifested in art forms such as literature, film, installation and live performance. As a case study, we present an ongoing project entitled "archipelago.ch" which works solely with scientific robotic platforms developed at the Artificial Intelligence Laboratory of the Department of Informatics, University of Zurich, Switzerland (the “AILab”). By working with existing robotic systems originated in the AILab we move away from sculptural or choreographic concerns to develop a dramatic scenario, which is true to capabilities of a particular robot or robotic system. We argue that such scenarios are both an effective form of art expression and that they also have the potential to re-enter and inform the science from which they emerge.

1 Introduction

There have been two familiar approaches in narrative, which emulate how the spark of life can begin in a machine. One is the scenario of a thing becoming more than the sum of its parts. This can be found in Mary Shelley’s Frankenstein when Victor Frankenstein finds credence in the fact that assembling human body parts and subjecting the result to electricity will render the thing “alive”.

The other approach is where an entity with powers beyond those of a human is required for rescue or remediation; i.e., where there is a task to be done and the machine is designed and executed to fulfill the goal of that task. The robot then becomes characterized as a “device”, whether it lives in an industrial assembly line of a manufacturer or in a theatrical work such as the deus ex machina in Euripides, or as the ilk of the robots in Karel Capek’s R.U.R.

One could even construe the use of the “other” in Shakespeare, as a dramaturgical device that could be characterized as “robotic” because its behavior and motivations serve the story of the play.

Practically speaking, since the earliest art robotic installations produced by such artists as Nicolas Schöffer [Schöffer, Nicolas. Nicolas Schöffer (Neuchatel: Editions du Griffon, 1963), p. 50.], artists have been experimenting with robots. In most artworks, artists have either adapted existing robots or developed entirely novel robots in order to fit them into a particular artistic concept. In the latter instance, the robots play the role of actors and therefore must adapt to a strictly choreographed scenario and take on a particular role and characteristics, which serves the narration. These adaptations quite often hide the specifics of the robots and in case of robots which have been developed by scientists or engineers leads to an obliteration of their original intents.

We will describe a form of artistic engagement with robots which has hardly been explored: an empirical form of developing robotic narratives where an artist takes on the role of an observer, a partner in ideas, and an interpreter of robotic research and where the development of the narrative becomes an exploratory and experimental process for the artist that runs in parallel to the researchers. To a certain degree the artists gives up authorship by openly taking into account the robot's peculiarities and respecting its (partial) autonomy. We believe that such an approach could lead to novel forms of narrative which move away from stereotyped interpretations and utilizations, and instead serve to amplify robots as particularly interesting creatures possessing inherent potential for meaning and expression emerging from the research process which led to its creation. With this methodology, a robot can surpass a human actor because it is no longer emulating a human but rather expressing its own "nature." The robot also surpasses simple machines in its potential for narrative because it depends less on arbitrary projections from the human audience or inter-actors for its effectiveness in telling a story.

1.1 Our Motivation

1.1.1. Robotics and Narration

Robots lend themselves to narration as archetypical beings that question our understanding of living things while constantly reminding us of the delicate balance between our control and their autonomy. Their entirely alien nature gives rise to a vast variety of mystifications, interpretations and anthropomorphizations. The ample territories of fiction and fact made available there allows artists collaborating with researchers the creative movement between didactic, spiritual, philosophical and artistic concerns required for effective expression.

1.1.2. Public Perception of Robots

One of the authors herewith (Adrianne Wortzel) has been creating interactive robotic art installations and performance productions for the past ten years. One aspect that emerges during the tenure of these works is the persistence with which humans enjoy interacting with robotic simulations of presence as if the robot is cognizant. This occurs even when it is obvious that the robot is a machine following procedural instructions without an iota of artificial intelligence. In these instances, the public's reactions to robots reflect a large discrepancy between their perception of robots and the actual capabilities of those robots. This results in the stereotyping and demonization of robots - imprinting on these artificial beings the role of service to humans as the "other" - seen as a threat such as a cold tool which is superior in domains such as in military and economic decision-making processes and their implementation.

These stereotyped views are so persistent that they have become redundant and curtail the wide variety of possible artistic and scientific explorations of robotics. And so, by merging an engineer's awareness of a robot's capabilities with an artists' expertise in creating imaginative narrative where that narrative adheres to the true nature of the robotic research at hand, we hope to broaden the public perception of robots.

1.1.3. Robotic Science and Robotic Art

For an overview of seminal robotic artworks the reader is referred to a paper by Eduardo Kac [Art Journal, Vol. 56, N. 3, Digital Reflections: The Dialogue of Art and Technology, Special issue on Electronic Art, Johanna Drucker, (ed.), CAA, NY, 1997, pp. 60-67.].

Artistic endeavors and scientific research can and should inform each other. Such exchange can only function effecitvely if both scientists and artist maintain a delicate balance: each keeping a critical distance to each other's positions, while at the same time, each immersing themselves in the other's process. In this way it is possible to circumvent the common pitfalls in art and science collaborations such as the relegation of artists to function only as public relations or educational communicators for the researchers, or, on the other hand, the researchers functioning only as technicians to serve the art. Instead, the goal would be to truly conduct independent and complementary forms of analysis.

The development of robotic narratives also fills a void which is felt by engineers and scientists who try to stay away from interpretation and speculation. This void can be filled by artists in a variety of interesting ways which may ultimately help to define the relationship between robots and society through experimentation with robots in novel (non laboratory) environments, juxtaposition of natural and artificial traits, or exploration of interactions between humans and robots.

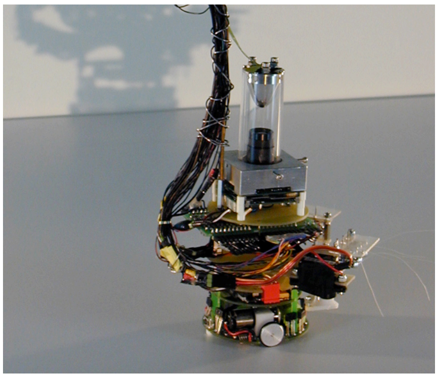
2. archipelago.ch

2.1. Artist-In-Labs Residency

The project started in July 2004 during a five-month residency of artist Adrianne Wortzel at the AILab. This residency was part of a larger "Artists-In-Labs" residency program initiated by Jill Scott of the University of Art and Design in Zürich The artist's goal of this particular residency was to develop a dramatic scenario for robotic entities created at the AILab. Early on it was decided that each scenario should be adapted to its robotic actor in such a way that it not only depicts the peculiarities of the robot but also reflects the research interests and working methodologies of the participating researchers.

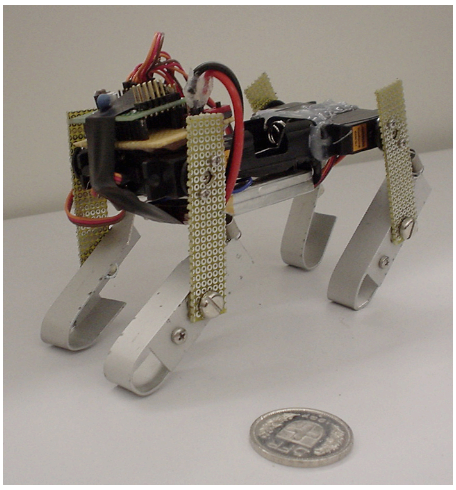
2.2.. The AILab Focus

The main research focus of the AILab is to build robotic systems in order to study the interrelationship between morphology, cognitive capabilities, and environment in generating behavior. For example, current developments there include the embodiment of morphologies such as an insect eye learning to measure distance via reactive behavior to light, a humanoid hand developing identification methodologies for identifying grasped objects, a "mouse" capable of perceiving its environment by relying on whiskers as a sensory modality, aquatic creatures moving only through stimulated oscillation, four-legged running creatures, and more.



Artificial Mouse with Sensor Whiskers, Researchers: Dr. Miriam Fend, Dr. Simon Bovet, Artificial Intelligence Laboratory, Director, Dr. Rolf Pfeiffer

The research at the AILab consists of separate projects with little more than just conceptual overlap. The series of labs with idiosyncratic entities being developed was transformed into a geographical territory of dispersed islands on which each robotic species evolves in isolation.



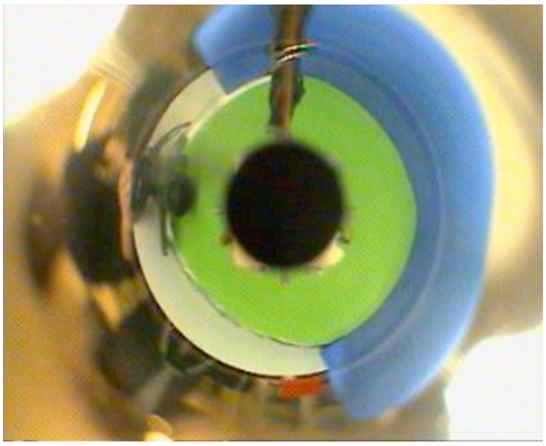
Minidog, Researcher, Dr. Fumiya Iida, Artificial Intelligence Laboratory, Director: Dr. Rolf Pfeiffer

2.3 Narrative Development

This holistic approach inspired the artist to evoke the role of Charles Darwin, a 19th century naturalist attempting to observe and understand, in an entirely empirical way, the appearance and behavior of robotic creatures in the context of their bodily adaptations to a particular ecological niche. The artist then "rewrote" Darwin's Chapter 17 on the Galapagos in the "Voyage of the Beagle" as a narrative context for the scenario for the AILab substituting each of Darwin's discoveries of creatures with a creature from the robot and naming each "island" after the researcher responsible for the evolution of that particular robot.

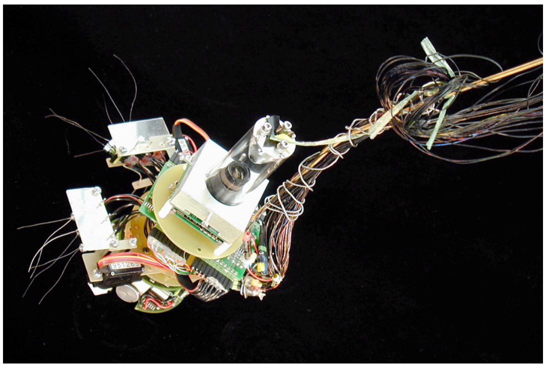
Filming of the robots aimed at the production of a wide diversity of video material to emphasize the fact that robotic content is very open towards their emergence into roles and characteristics which are inherently present in them.

Material taken from a robot's perspective favors the perception of the robot as an independent subject.



Panoramic Image from the Camera of the AMouse Robot. Researchers: Miriam Fend and Simon Bovet. The robot learns correlations between camera and whisker based sensory data.

Placing a robot in front of uniformly colored backgrounds creates a staged situation which emphasizes the robot's iconic characteristics.



Amouse on the Set, whisker mechanism, Researchers: Dr. Miriam Fend, Dr. Simon Bovet

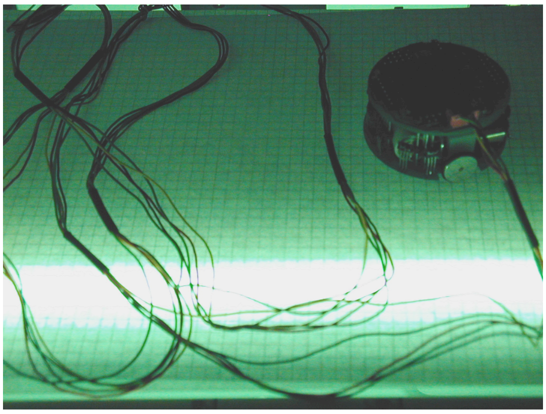
3. Initial Conclusions

3.1. AILab Researchers and the AIL Residency

Despite the fact, that the archipelago.ch project is still in progress at the time of this writing, we would like to draw some initial conclusions.

So far, the reactions both from peers, both scientists and artists, to the cinematographic output of this residency have been very positive. While the feedback was uniformly positive the interpretations and impressions of the robots behavior and characteristics were highly individualistic. This non-representative sample of people indicates that our short film promotes a versatile and non-stereotyped perception of the AILab's robots.

The depiction of isolated robotic parts puts the robot back into the position of a specimen existing only for the sake of experimentation.



Amouse “ancestor”

In accordance with the AILab's scientific engineering principle which is subsumed under the term of "design for emergence", we put great emphasis on open evolution of the robotic narratives. The artist's exploration of the behavioral repertoire of the robot constantly fed back into the process of storyboard generation. Another strategy we employed in order to minimize the artist's (or scientist's) preconceptions consisted in the occasional reassignment of the participants' roles during filming. For example, shooting was done either by the artist, the scientists or the robot itself (by taking video material from an autonomous robot's own camera). Furthermore, the role of acting was also reassigned by letting the robot operate either autonomously or subject it to remote control by the artist or scientists.

Throughout the entire residency the artist's decisions and drafts were communicated to the researchers. This constant exchange of information proved to be beneficial not only for the development of the narrative but also for the scientist's own research. For instance, the metaphorical depiction of the AILab as an archipelago of dispersed islands provoked a lively discussion among the researchers themselves on the topic of sharing research ideas and practical skills in between projects. Another example involves an experiment conducted by an artistic collaborator on the project, Reto Inäbnit, who transformed the sensory data from the whiskers of the AMouse robot into an audible spectral range and thereby initiated new scientific experiments in data analysis.

We also feel encouraged by the fact that the establishment of an informal feedback loop between the artist and the scientists had a conceptual and practical impact on the AILab as dedscribed above. We attribute this success at least in part to our methodology of developing a robotic narration. In addition, some scientists stated that they intend to casually take on an "artistic" position in order to embed their robotic developments into a narrative that helps them explicate their work both for themeselves, peers and the public at large.

On the other hand it is also clear that the short duration of this residency was hardly sufficient to develop a finalized version of the robotic narrative as we intend it. Our approach is clearly a costly one that requires a large amount of time for the work and for collaborative communication in order to develop an appreciation for a robot's capabilities. This appreciation requires a mutual understanding of both artist and scientists for each other's methodology and interests. This understanding is particularly hard to obtain if the scientists are not able to dedicate some of their work hours to discussions and feedback. At the same time this approach requires from the artist some reconsideration of what creative work actually involves both in terms of content and collaboration. The actual writing of the narrative is significantly shifted towards to the end of a project in order to favor a long period of observation and re-observation of the robots behavior.

There has been encouraging exchange between the artist and the scientists that supports our point that this form of open narration indeed feeds back and forth between the artists and scientists and this has encouraged us to continue our project, archipelago.ch, despite the fact that the residency has ended. The communication channels between the artist and the scientists remain established and have the support of the AILab's Director, Dr. Rolf Pfeifer, for us to continue to conduct this experimentation in robotic narration with more robots and a longer timeframe.

3.2. Broad View

Inventions of our own making have allowed us to physically remove ourselves far enough away from our planet so that we can turn and set our gaze on it as the real object in space it is.- perspective that had been only imagined for millennia is suddenly empirical.

Concepts of moving around, and our roles as explorers, or other types of agents are forever changed with the development of new surveillance and tracking modes. Whether we use ourselves, or extensions of ourselves in the form of software, hardware or biological robots, to interact with places, people and things- i.e., to be situated in scenarios, the model of perceiving ourselves and being perceived has also expanded to points of view that were previously inaccessible to us. In thinking about "robots" and their relationship to narrative, we seek a new type of "presence" for artificial beings – taking our cues from a platform of empiricism--- the researchers' developments in robotic form----and amplifying it in situated environments of our own imaginations.

Acknowledgements

We would like to thank the following persons who generously supported us throughout the entire project:

Jill Scott, Rolf Pfeifer, Miriam Fend, Simon Bovet, Fumiya Iida, Gabriel Gomez, Lukas Lichtensteiger, Mark Ziegler, Reto Inäbnit, Nathan Labhart, Nigel Helyer, Axel Vogelsang, Thomas Isler, John Flury, Claudia Wirth, Harri Valpoli, Pascal Kaufman

‘Stigmergy’: Biologically-Inspired Robotic Art

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Abstract

This paper presents a robotic art installation that was exhibited at the Big Blip ’04 event in Brighton on the 10th and 11th September 2004. The installation modelled the foraging behaviour of ants using swarm-intelligence techniques, and created glowing patterns on an arena floor through stigmergy and the actions and interactions of two robots. The motivation, biological foundation and technical aspects of the project are presented, along with a discussion of audience reactions and further work.

1.0 Motivation

Between art and science there exists a large (and largely unexplored) no-man’s land where old concepts are waiting to be explored in new ways; order from chaos, the interaction of man and technology, and the hidden complexities of nature are just some. Robots can have a significant part to play in helping us explore this territory. The tendency of man to be drawn towards objects which exhibit characteristics of life, and to anthropomorphically assign intelligence and emotions to them, allows robot exhibits to engage and play with an audience’s perceptions and preconceptions in a very direct way.

2.0 Overview

Stigmergy was an extension of a project undertaken to model the foraging behaviour of ants. Ant foraging is an example of self-organised swarm behaviour, where multiple agents co-operatively perform a task with no centralised control. The original project investigated this behaviour by modelling it with real robots. Each robot’s task was to roam the arena in search of food, and when food was found return to the nest. The food was represented by metal plates on the floor and the nest by an infrared beacon. The robots were equipped with sensors to avoid obstacles, register food, follow trails, ascertain the direction of the nest and register that they were at the nest. The exhibit was situated in a dark room, which allowed the use of LEDs on the robot bodies to leave glowing lines on the floor of the arena, modelling the pheremone trails left by real ants. An interesting aspect of the piece is that it makes visible what is invisible in the real world and hides that which is normally seen. It was realised from the outset that this project would work well as a robotic art exhibit, and when the chance came to show it at Blip it was displayed with only minor modifications.

3.0 Biological Foundation

Ants have been widely studied by artificial life researchers, and have become something of a mascot for the discipline. Their speed, strength, and great range of individual and collective behaviours (including foraging, sorting, building, defence, nursing, and farming) means they are still a benchmark for man-made robots and swarm systems.

3.1 Swarm Intelligence

The self-organising behaviour of social insects has been the subject of many studies in recent years. Various collective behaviours have been modelled including ant trail following (Sharpe and Webb, 1998) brood sorting (Holland and Melhuish, 1999), nest building (Bonabeau *et al*, 2000), food transport (Kube and Bonabeau, 2000) and collective decision making in honeybees (Seely *et al*, 1991).

All self-organised systems rely on a balance of positive and negative feedback combined with an element of randomness to achieve the global behaviour, which emerges from the multiple interactions of agents who are *only following local rules*. Additionally swarm-based systems use agents with no symbolic representation of their environment, in stark contrast to the classical AI sense-plan-act approach (Brooks, 1991).

3.2 Foraging and Stigmergy

This piece was inspired by just one of the ants' collective behaviours; foraging. Ant foraging has been studied and modelled several times (e.g. Bonabeau *et al*, 1999; Schweitzer *et al*, 1997), as it is a prime example of both self-organised behaviour and stigmergy. When an ant finds a food source she will carry some back to the nest whilst leaving a chemical trail of pheremone. Other ants, attracted to this pheremone, will pick up the trail and follow it to the food. As they return they will also leave pheremone, reinforcing the trail and attracting more ants. It is a simple and elegant system which increases foraging efficiency by the process of mass-recruitment and also by ensuring the shortest path is followed back to the nest.

Path creation is one process that relies on stigmergy, that is, communication through the environment (Grasse, 1959). An ant, by laying pheremone, is communicating to her fellows that food has been found and lies at the end of the trail. This system is used by other social insects including termites and wasps for nest building. Stigmergy is interesting because it addresses the problem of communication between multiple agents. Direct peer to peer communication rapidly gets very complicated and time consuming as the number of agents grows, but stigmergy allows mass communication with little additional overhead per agent. Although social insects do communicate directly, the use of stigmergy enables efficient mass recruitment to take place.

4.0 Technical Implementation

4.1 Trail Formation

An essential part of the exhibit was the use of high-sensitivity glowpaint on the arena floor. It reacts instantly to ultra-violet light, creating a bright green glowing trail which gradually fades over about two hours. It provides an ideal tool for experiments into stigmergy. Trails formed in the paint are a fairly good model for real ant trails as they decay over time in the same way that the pheremones evaporate. However there are limitations; they do not disperse spatially once created, and they are only two-dimensional. Real ant trail-following behaviour is more complex as the ant attempts to stay inside a three-dimensional 'tunnel' of evaporating pheremone.

4.2 The Arena

Two sheets clear Perspex were used, making an arena of 2400x1800mm (roughly 8x6 feet). Each was coated on the underside with 3 coats of glowpaint. The painted sheets were placed on lino (the white underlay provided an ideal backing for the glowpaint) which was placed in turn on a wooden base. Free-standing wooden walls were constructed and fastened around the floor area. A wooden gantry supported the nest beacon (figs. 4.1, 4.2).

4.3 Robot Construction

Each robot was built around an EASyMind, a Motorola 68332 microcontroller built into a Lego brick. The 68332 is equipped with 512K of RAM, analogue and digital IO and PWM (pulse-width modulation) outputs. The EASyMind enables sensors and actuators to be plugged in to an interface board on the top surface of the brick. There is a pre-written library of software functions for accessing the analogue and digital ports and driving the motors. Two matched [1] Lego motors were placed near the back of the robot, with a single multi-directional wheel at the front centre. The motor driver h-bridge units were placed on the top of the EASyMind. The sensors were added and Lego and plastic pipe bumpers were added to the front and sides of the robot to protect the sensors and to stop the robots getting entangled in the event of a collision (fig. 4.3).

[1] Lego motors were found to have enormous variance in their speed and torque

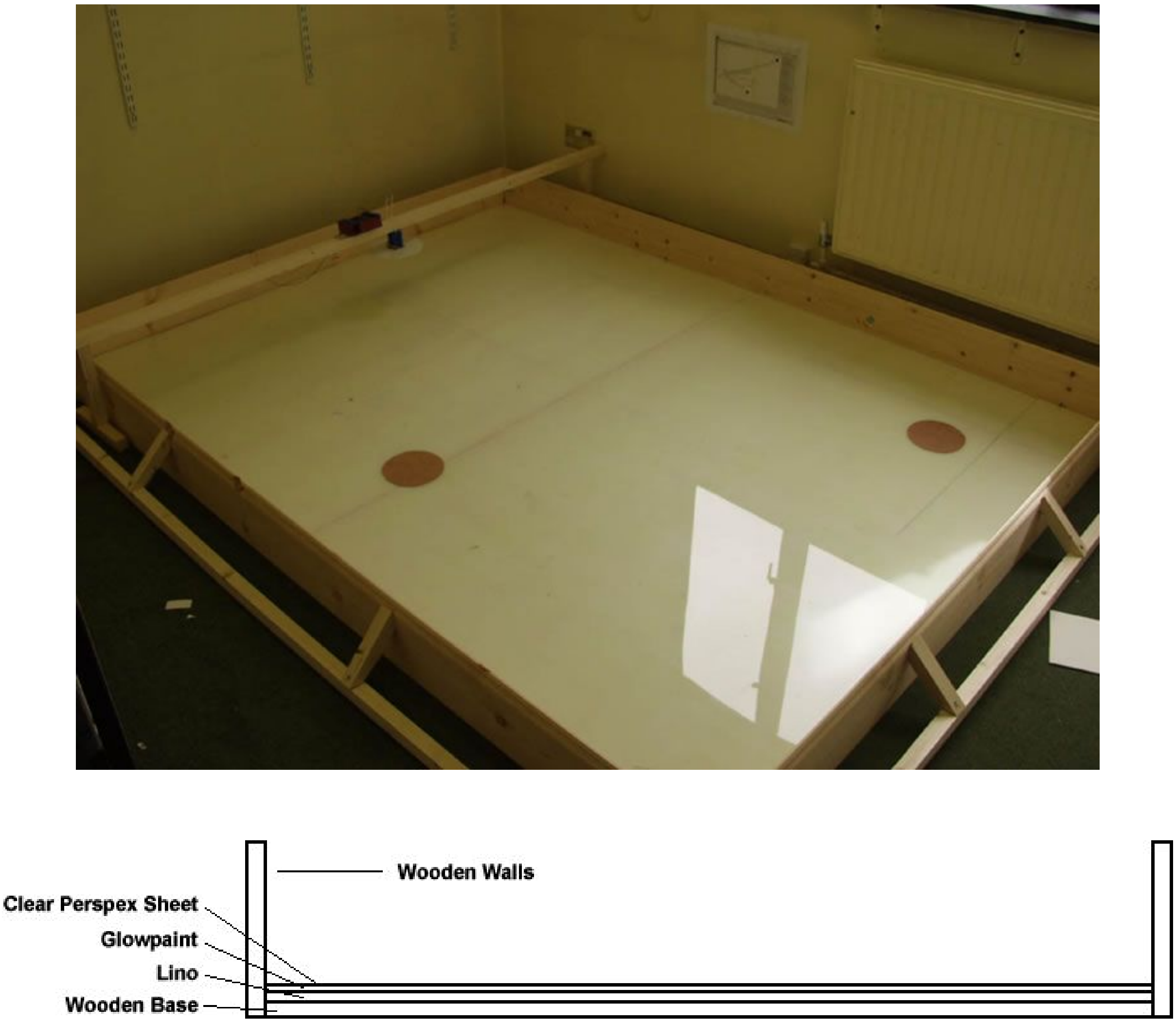

Figure 4.1: The arena (with cross sectional view of construction below), showing the nest gantry and food discs.

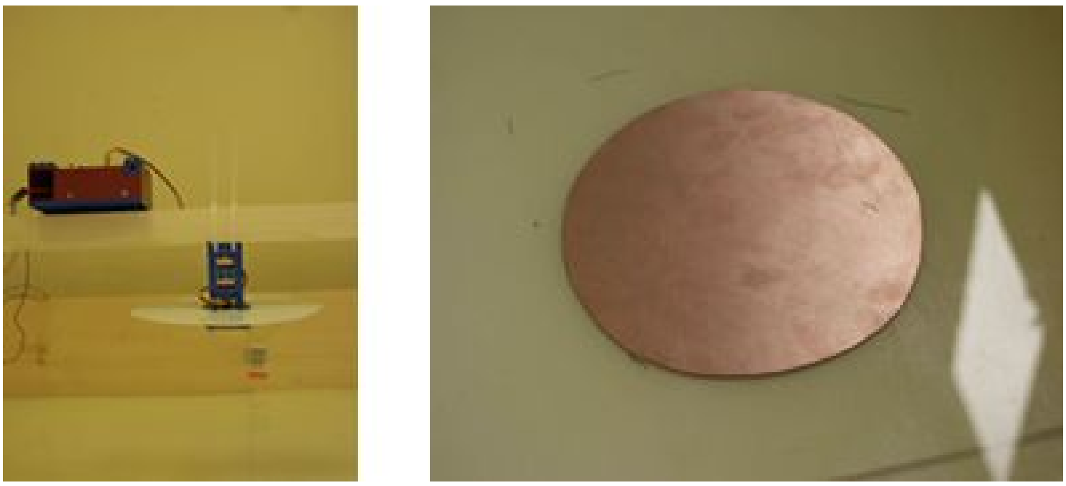

Figure 4.2: Detail of the nest suspended below the gantry and the copper plate food.

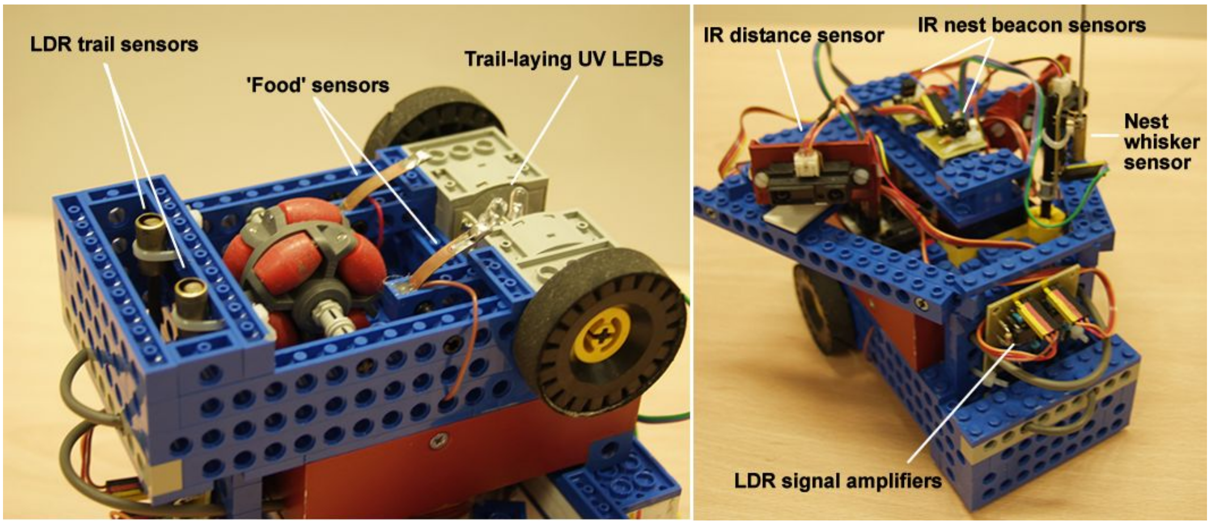

Figure 4.3: The top and bottom of one of the robots. The bottom view (left) shows the trail sensors at the front of the robot, copper strip food sensors and the UV LEDs between the motors. The top view (right) shows an IR distance sensor on the side of the robot, the IR nest sensors on top and the nest whisker sensor.

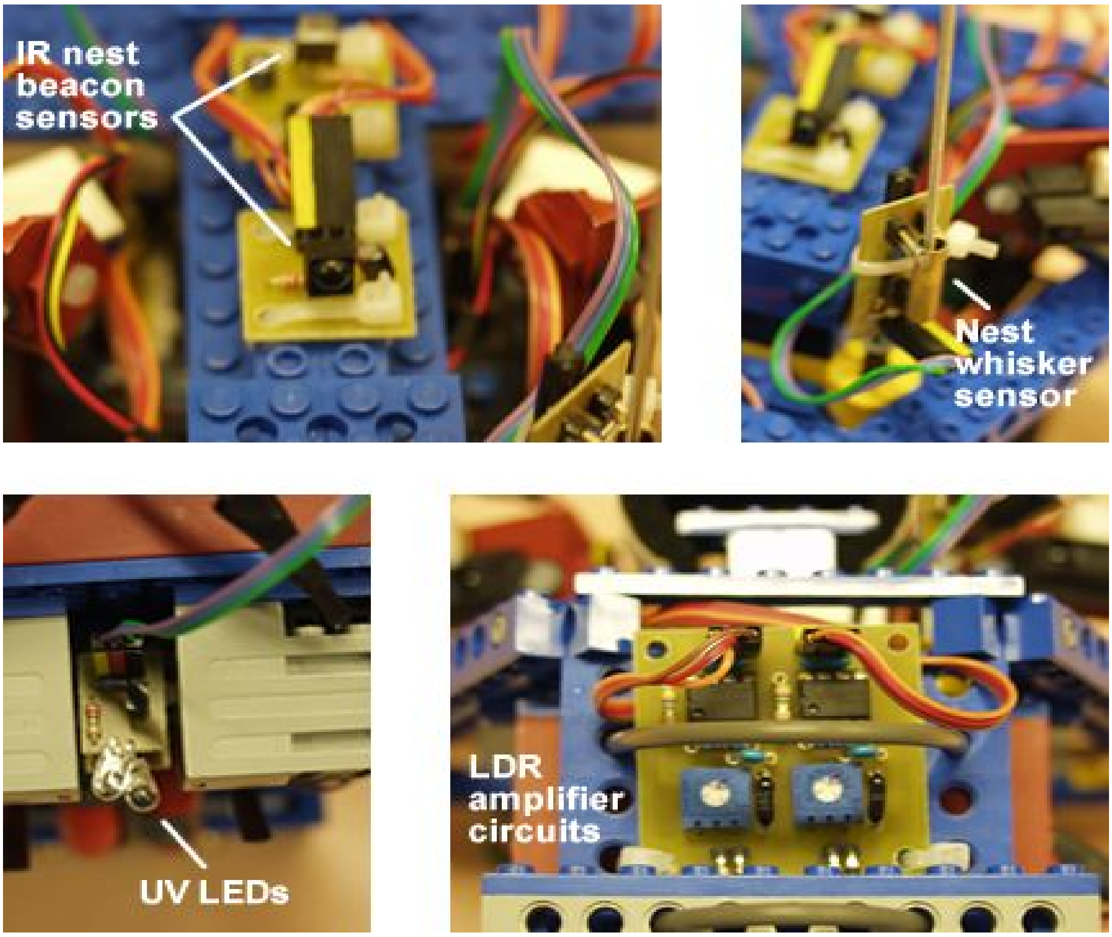

Figure 4.4: Sensor details. Clockwise from top left: the IR nest direction sensors, which were shrouded when in use to increase sensitivity, the nest whisker sensor, the amplifier circuits for the two LDR trail sensors and the UV LEDs used to lay the trail.

4.4 Sensors

Five types of sensor were required for the Stigmergy robots (Figure 4.4):

1) Obstacle sensors. Sharp GP2D12 infrared distance sensors were mounted on the top of the robot pointing 30 degrees either side of vertical.

2) Pheremone Sensors. The ant pheremone trails were represented by luminous trails left in glowpaint and were sensed using a pair of light-dependent resistors (LDRs). Two pieces of brass tubing shielded the LDRs from ambient light, and from the UV LEDs.

3) Food Sensors. Food was represented by metal plates on the arena floor. Two springy copper contacts were made and positioned underneath the robot so they dragged along the ground. Five volts was applied to one contact and the other attached to a normally-grounded signal input of an EASyMind digital port. When the robot ran over a copper plate the circuit was completed and food was registered.

4) Nest Direction Sensors. The nest was represented by an omni-directional cluster of 8 IR LEDs transmitting pulses of 38khz. IR receivers were placed facing forward and backward on each robot.

5) Nest Sensors. The nest beacon was suspended above the arena floor, and a plastic disc was secured above the nest transmitter. Each robot was equipped with whisker that was triggered by pressing against the disc.

4.5 Trail Laying

Each robot carried two ultra-violet LEDs which could be switched on to leave a glowing trail on the arena floor. These LEDs were chosen because the glowpaint was most reactive to UV light.

4.6 Control Structure

The robot controller was implemented as a finite state machine, that is, a computational model consisting of a set of states with a transition function that maps input data and current states to next states.

- **States** were defined as being a persistent goals that the agent could be undertaking, for instance searching for food or avoiding an obstacle. Transfer between states was caused by exterior events, such as sensing an obstacle.
- **Actions** were defined as non-persistent operations that could be carried out in one timestep.

Fuzzy logic was used to decide the actions of the robots. The Markovian state/action table, which was evolved in simulation using a microbial genetic algorithm (Harvey, 1996), is shown in figure 4.5. The states the robots could be in are shown along the top of the table, and the various actions the robot could carry out while in a state are shown at the left. The values show the probabilities of the actions being performed for each state. Actions were coded in the robots as an appropriate activation of the motors for a certain number of timesteps, for example left motor reverse and right motor forward to spin left. Sensors were checked every timestep.

In each timestep a random number was chosen between 1 and 100 which decided the action performed depending on what state the robot was in. For instance, when searching the arena in WANDER state the robot had a high chance of moving forwards, following an existing trail, or stopping laying trail (figure 4.5). When a wall on the left was sensed the robot would switch to OBS_LEFT state in which it probabilistically had a high chance of spinning right, thus avoiding the wall.

4.7The Evolved Algorithm

From inspection the evolved algorithm used in the robots can broadly be expressed as: 'While searching for food move forwards, follow a trail if one is found and do not lay trail. If an obstacle is sensed on the left then spin right; if one is sensed on the right spin left or go backwards. While carrying food, move forwards, periodically check the location of the nest and lay trail'. In comparison to other evolvable controllers such as neural networks, the use of Markovian tables allowed easy analysis of the evolved behaviours by inspection. Interestingly the evolved controller used in this exhibit outperformed a hand-coded controller in tests, because the (intuitively detrimental) small probability of moving backwards whilst carrying food allowed the robots to more efficiently avoid collisions with others while following the trail. More detailed analysis is contained in the original project report, available by emailing mike@artificiallife.co.uk.

4.8 Robot Interactions

Given that the search behaviour was essentially 'move forward', it can be seen that redirection due to the interactions between the two robots and the arena walls was essential to ensure the arena was searched. Usually the robots would avoid each other, but on the occasion they did collide they would always free themselves eventually with no human intervention when the interaction of both behaviours caused them to move apart.

5.0 Showing 'Stigmergy' at Blip

5.1 The Blip Version

The original research project consisted of three robots searching the arena, but at Blip only two were used. This decision allowed a spare robot in case of operational problems (i.e. over-attention from children), and meant that the glowing trails built up gradually during a 40 minute demonstration. The exhibit was equipped with four metal plates representing food. The nest was placed at the end of the arena and the food placed in the corners and at the sides so as to cause an interesting pattern to be created. In the event this often resembled a humanoid figure, a completely unintentional but pleasing effect (Figure 5.1). An example of the glowing trails building up over time is shown in the sequence in Figure 5.2.

5.2 Logistics

During Blip shows were performed at two-hour intervals, lasting for 45 minutes each. Two robots were used for each show. With two sets of batteries and two chargers this gave ample time to recharge, however it did highlight the work involved in looking after a robot exhibit. It became obvious that appropriate design (robust robots; powered floor etc.) would be essential for any long-term robot exhibit.

5.3 Audience Reaction

Stigmergy was consistently popular during blip, and the combination of robotics and emergent patterns (as well as the anticipation of a robot finding some food) held people's attention for up to half an hour. It was especially popular with children, who

	WANDER	OBS_LEFT	OBS_RIGHT	CARRYING
Forwards	39.68	0.22	5.38	29.12
Backwards	0.56	8.25	14.77	3.62
Spin Left	0.05	8.95	27.32	0.0
Spin Right	0.0	57.56	5.9	0.76
Head for Nest	0.0	8.58	13.2	36.32
Head awy fm Nest	3.95	1.04	5.58	0.0
Follow Trail	33.12	8.65	0.3	2.01
Start Laying Trail	0.0	0.2	5.16	28.48
Stop Laying Trail	22.98	6.97	23.2	0.04

Fig 4.5 The Markovian state/action table for the the robot controller.

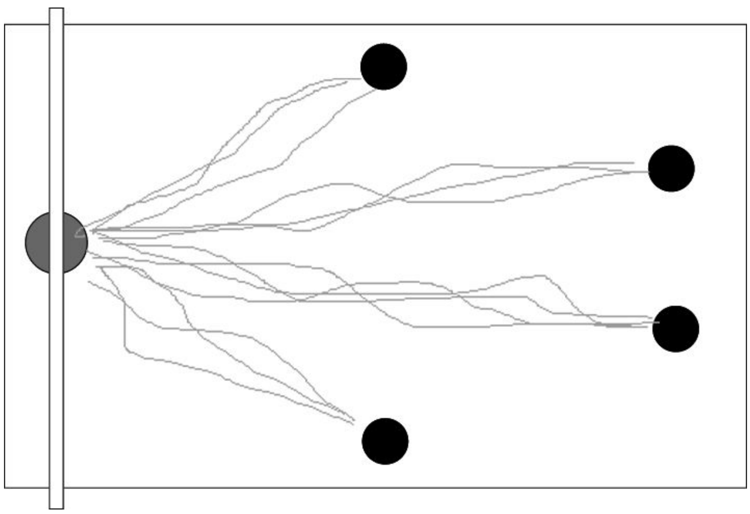

Figure 5.1: 'Stigmergy' setup at Blip: the black circles represent the food, the grey circle at left is the nest hanging under the gantry. The robot trails are the grey lines between the food and nest.

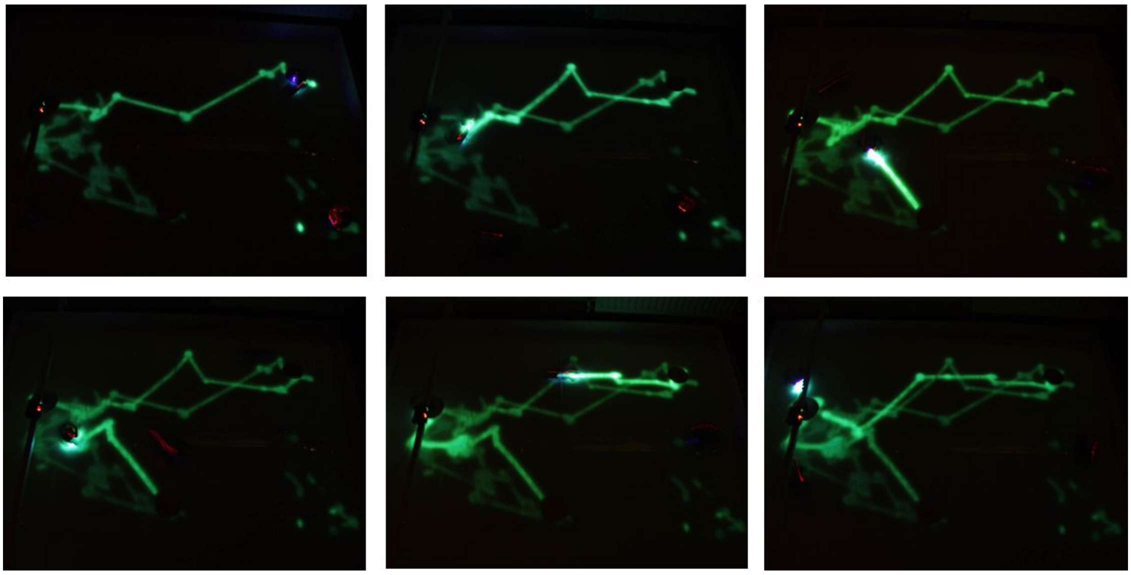

Figure 5.2: The glowing trails formed by the robots. The trails can be seen fading away over time in this sequence which runs from top left to bottom right. The nest is mid-left of each picture.

often seemed to immediately grasp the biological principles behind the piece.

Children were also very keen to touch the robots. Interaction is an area where robots excel, and in this piece and the Blip collaborative robot project (‘There does not, in fact, appear to be a plan’), the audience’s experience was clearly enhanced by handling the robots. Interactivity in robotic art can be seen as a ‘cheap trick’, and its use should be carefully considered to avoid overshadowing any other artistic intentions the piece has. In this case the robots were not robust enough to withstand too much attention, but I shamelessly encouraged people to interact with them as much as possible.

6.0 Further Work

Future plans for Stigmergy include redesigning the robots to increase their consistency and robustness, and a version using more, much smaller robots, to give a better impression of swarming behaviour. The entertainment value of the exhibit could be improved by adding more behaviours - perhaps a celebration behaviour on returning food to the nest, or by having two opposing teams of robots competing for a limited food supply. Given the amount of interest from children at Blip it might also be worth investigating the potential of the exhibit as an educational tool.

Acknowledgements

I would like to thank Dr. Emmet Spier and Bill Bigge for their help during this project, and Jon Bird and Alice Eldridge for their enthusiasm and logistical wonders at Blip.

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Osama Seeker

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Abstract

Osama Seeker is an Art installation exhibited initially at 'Interventions' in Southampton. Julie Henry (Anthony Wilkinson Gallery) and Giles Perry (then Goldsmiths College) were the two contemporary artists involved. This paper discusses the design and realisation processes from the perspective of the collaborative technologist and designer, Darren Southee (Brunel University) and the artists. It is essentially a reflective ' walk-through' the project detailing some technological aspects contextualised by an opening statement from the artists. A closing statement reflects upon the final outcome and seeks to put the presented installation in context.

1 Introduction

1.1 Artists' Introductory Statement

In 2003 we were invited to participate in 'Intervention', a group exhibition at John Hansard Gallery that would depict artists' responses to the 'War on Terrorism'. In our case that meant producing work specifically for the show as we had not worked together previously.

The British and American governments had accused Saddam Hussein and Iraq of having links with Al Quaeda, but had yet to present much evidence of this. As is often the case in war, it was becoming difficult to distinguish between information and propaganda. We felt it was important to acknowledge the complexity of the issues by maintaining an open approach.

We began by considering the conflict in terms of its representation, and the way it had been narrated through the construction of powerful images such as the 'War on Terrorism', or 'Weapons of Mass Destruction', or 'Osama Bin Laden'. Much emphasis had been placed on the search for Bin Laden, so we decided to build an Osama seeking robot. It seemed to be in the interests of both governments and their allies to keep the public in a state of fear and paranoia about further terrorist attacks. Perhaps finding Osama could short-circuit this policy.

The Osama we were looking for was as much mythical as real and, as such, would be difficult to find. But our artistic investment was in treating the task we had set ourselves very seriously, rather than producing an object for the gallery, so we approached Brunel University's department of Design and Darren Southee for help.

At this stage we had no preconceptions about what we would actually present in the exhibition, and we considered the design process as much part of the artwork as any outcome. We presented Darren with a functional requirements document written to avoid indicating how the problem would be solved.

1.2 The Brief

A summary of the brief is given below:

The robot will be an autonomous unit, capable of conducting its search indefinitely. The robot will be a serious and deeply committed entity, and will not be expected to perform tricks for the gallery going public; its behaviour and appearance will be determined only by the task it has been set.
The robot's core functional requirements as follows:

- The ability to operate autonomously.
- The ability to negotiate the natural environment.
- The ability to identify Osama by the assessment and comparison of individuals it encounters to its concept of him.
- The determination to never give up.
- The ability to communicate its position and progress to the artists.

- Where an Osama suspect is matched above a threshold confidence level, the robot will transmit notification of the suspect together with its position and the 'probability of correct identification' value.

However, the specifics of the design solution will - quite rightly - be left for the designer to determine. The cost per robot should not exceed £500.

1.3 Initial Concepts

An early idea considered the concept of embedding intelligence within objects considered precious, allowing the problem of transportation to be effectively carried out by humans. Replacing the precious object with a functional item, such as a ‘camel bell’, would allow animals to move the monitoring system around. While both these solutions offer points of interest, it could be argued that they do not fulfil the artist’s request for a robot. Also, the probability of discovery, and the damage this would inflict upon ‘the search’, were sufficient grounds for rejection. After consideration of the geology of Afghanistan[1], the concept of an autonomous rock was born.

2 The Design

2.1 Sensing

A number of sensor technologies were considered. These included:

- DNA analysis
- Iris scanning
- Face recognition
- Fingerprint recognition
- Electronic nose technology
- Voice recognition

DNA analysis, iris scanning and face recognition were rejected immediately for budgetary reasons. The electronic nose technology, introduced in 1982, when Persaud and Dodd proposed a system, comprising an array of essentially non-selective sensors and an appropriate pattern recognition system, would struggle to be selective enough to discern an individual [1]. Fingerprint recognition technology was certainly at a stage where it might be incorporated into the design, but any robot attempting to find an individual using this method, would be somewhat environmentally invasive. The chosen method was therefore voice recognition. The implementation of this technology allows for non-invasive monitoring of a particular location.

2.2 Location and Communications

2.2.1 GPS

The Global Positioning System (GPS) was developed by the US Department of Defence as a world wide navigation and positioning resource for both military and civilian use. It’s based on a constellation of twenty-four satellites orbiting the earth. These satellites act as reference points from which GPS receivers on the ground can identify their position. The satellites are positioned in the orbit, so that at any one time 4 or 5 satellites are "in-view". This allows position coordinates (latitude, longitude) to be obtained from GPS signals 24 hours a day.
This was the chosen location technology. GPS was a readily available cost-effective solution which had reached a suitable level of miniaturisation.

2.2.2 Spread-Spectrum Techniques

Spread-Spectrum is regarded as a ‘secret communications technique’. In simple terms, the message containing location details is divided into short-duration packets. These short packages would then be transmitted over a range of frequencies. This means that:

- Only a receiver with knowledge of the transmitting algorithm can make sense of the message
- It is very difficult to discern that any communications are occurring because the short bursts of transmitted energy barely rise above background noise levels.

This method was discussed with the artists for information purposes only, given that it is a proven technology. Practical implementation would be difficult, and unnecessary for the installation, given radio licensing regulations. The chosen design solution would text a mobile phone

2.3 Power

Wind and solar power were the two considered options in order to achieve the brief’s requirement that the rock should have a ‘determination to never give up’. Solar power was chosen as the climate in the area of interest was suitable and it could be implemented more robustly than a wind-driven system.

[1] http://www.cageo.com/afghan_geo.htm

2.4 Transport Mechanism

A number of transport mechanisms were considered:

- A scissor mechanism that pushes two rock segments apart was rejected because of its inherent vulnerability to wind-blown objects such as sand.
- A weight-shifting mechanism attempting to cause a rolling action was also rejected due to the potential damage to the external pseudo-rock shell.
- A geared transport mechanism was chosen allowing 'flipping' to occur. Figure 1 illustrates this concept modelled in ALIAS[2].

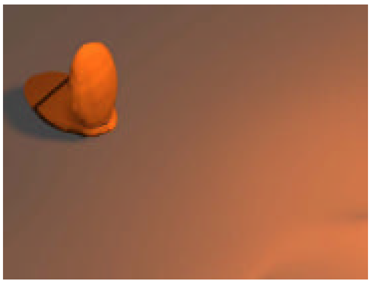

Figure 1: The flipping rock

2.5 Design Overview

Figure 2 shows a block diagram of the proposed Osama Seeker

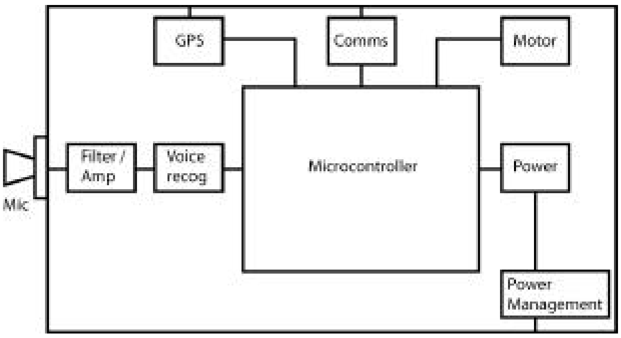

Figure 2: Osama Seeker block diagram

The rock is designed to 'listen' to its immediate environment in order to:

- Discern if any voices detected match the on-board algorithm of Osama's voice
- Discern if anyone is around. If not, it can enter basking mode and open the solar panels to the sun

If the voice recognition system believes that it has found a match, the GPS location information is communicated via the communications system.

3 Realisation

With the exhibition deadline a matter of weeks away, a decision was taken to develop a prototype to demonstrate the robot's movement. The concept for the fully operational device, including internal solar panels, GPS, communications systems and voice recognition would be communicated using a computer game-like DVD animation. The installation would therefore consist of a microcontroller-based rock-like artefact able to demonstrate movement, basking and listening modes and a short animation showing the proposed operation. Figure 3 shows the transport mechanism under construction. Figure 4 illustrates the style used in the animation. An assembly language program was implemented on a MICROCHIP[3] PIC™16F877 microcontroller and the PCB installed within the rock.

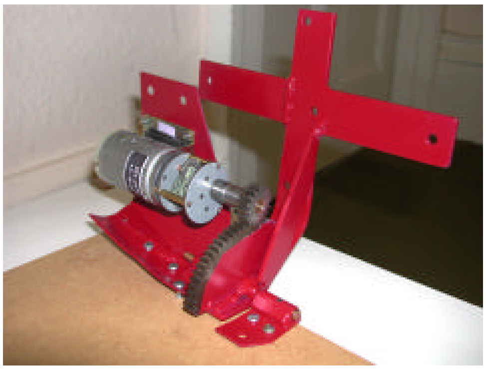

Figure 3: The flipping mechanism

2 www.alias.com

3 www.microchip.com

Figure 4: Animation still

Figure 4: The prototype ‘on the move’ at the John Hansard gallery

4 Exhibitions and Reaction

Osama Seeker has been in the following exhibitions:

2004 'All tomorrow’s parties', Yugoslav Biennial of Young Artists,
Galerija Zvono, Belgrade.

2004 'Ready, steady, GO', Three Colts Gallery, London.

2003 'Interventions', John Hansard Gallery, Southampton

Bernadette Buckley, head of Education and Research at the John Hansard Gallery, commented in an interview with Kathy Kenny, the Interventions curator, that ‘the piece is interesting in that it manages to use humour to respond to this horrible situation …in effect, to parody. I think humour is a very effective coping mechanism in times of duress. But also, there is a serious side to their work which is about the nature of surveillance and the notion that even a seemingly innocent object, like a stone, could be spying on us.’ She also concluded that ‘…...this response might be compared to that of the Dadaists – as opposed to that of Wilfred Owen’s who had a direct involvement in the war. The Dadaists went off to Zurich and danced and played and wrote poetry. They had an anti-art response’[4]. Figure 4 shows the completed prototype at the Interventions exhibition.

[4]http://www.hansardgallery.org.uk/exhibition/archive/2003/intervention/index1.html#interview

The curator Cecilia Canziani writes in the exhibition catalogue for the 2004 Yugoslav Biennial of Young Artists[2] that:

"… American foreign policy also provides the scenario for Giles Perry and Julie Henry's Osama Seeker. An installation composed of an object and a computer-animated video projection, the work comments on issues of global paranoia in the age of terrorism and makes the space of the gallery party to this general state. **….** Similarly, each work on show proposes a reading of the present from a specific angle, thus agreeing with [Italo] Calvino that art functions existentially, as a way to make sense of the world. It is no accident, then, that these artists make use of media generally regarded as a translation of the real and conferring a degree of truth to its subject matter, for example photography, documentary and text – the written word has to be believed, the camera never lies. Even animation gains a stamp of authenticity when located in the appropriate context, such as TV news broadcasts or when used to demonstrate the deployment of a device in search of weapons of mass destruction. Nevertheless, there is something slightly discomforting in these otherwise plain bits of reality. They make us laugh and, by doing so, they make us think."

5 Artists' Closing Statement

Our original aim was always to build a fully functioning Osama Seeker. The gallery in Southampton might have been used as a showcase for the robot or, more likely, just a starting point on its journey. Either way, we wanted our audience to think about the robot, somewhere in the world, tirelessly searching. We chose the robotic rock solution because we felt that its attempt at invisibility, by mimicking the natural world, produced the perfect mental image.

In terms of a final outcome, this image represents an end of sorts. Perhaps the artistic purpose of actually building a fully functioning robot, rather than simply proposing one, can be argued if we think about 'Osama Seeker' the artwork having characteristics similar to those of a myth. Myths circulate in culture through narration, and are imaginary but in many cases have actual historical origins. The myth seems to form out of material generated by real events. In the case of Osama Seeker the suggestion is that an actual robot is needed to seed its mythological formation.

The prototype robot that was eventually built might function in the same way. It was displayed in the gallery alongside an arrangement of real, similarly sized, rocks and a 3D computer animation that imagines the robot's deployment. A short text was provided explaining that the device on display was a prototype and listing some of the technology that would be included in the final system. At intervals the robotic rock changed position by opening and flipping over. This action gives the work a comic edge and anticipates the Osama Seeker's inevitable failure.

The animation solved the problem of presenting Osama Seeker in a gallery context. It tells the robot's story, but positions the work more precisely than a straightforward description. Like the prototype, we see it as a physical manifestation of a larger project, albeit a later and therefore more fully resolved one.

Acknowledgements

Thanks to Graeme Povey and George Simpson (Brunel) for help with mechanical aspects, Glen Thompson (London South Bank) for ALIAS and brainstorming input and Timm Burgess from Barking Mad Productions for his work on the DVD animation.

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There Does Not, in Fact, Appear to Be a Plan: A Collaborative Experiment in Creative Robotics

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Abstract

This paper describes a recent collaborative creative robotics project which developed two exhibits (*There does not, in fact, appear to be a plan* and *Clutch*) that were shown at the Big Blip 04. It gives an overview of two key aspects of the project: the design of the robot technology; and the collaborative process between the participating artists and scientists. We highlight some of the key lessons learnt and outline some possible future developments of the project.

1 Introduction

The collaborative project described in this paper was organized by Blip, a Brighton-based arts-science forum (www.blip.me.uk) where artists and scientists can meet, exchange ideas, get advice, form collaborations and seed projects. It aims to explore the relationship between scientific enquiry and artistic practice and stimulate new critical debate about this emerging cultural hybrid. Traditionally, the sciences and the arts have worked in isolation from each other. At Blip scientists and artists of note are invited to present their work through talks and performances, with a focus on how art and science combine in their practice. We also organize a larger two day festival (the Big Blip) where we curate a generative art show of both local and international artists. As part of the Big Blip 04 we decided to encourage local artists and scientists to collaboratively develop an installation for the show.

This paper combines, on the one hand, a technical description of the robot design and, on the other, reflections by the participants on the collaborative process that determined how this technology was used to create two installations: *There does not, in fact, appear to be a plan* (Figures 1 and 2); and *Clutch* (Figure 5). This structure echoes the tension between practical constraints and creative ideas that was very evident in the collaborative project and that is at the heart of much artistic and scientific practice.

2 Organization of the Project

2.1 Call for Participants

Blip put out a call to the local artistic and scientific communities for enthusiastic, open-minded artists, scientists and technologists who could make a commitment to working collaboratively for up to twelve weeks with the goal of producing an interactive artwork for the Big Blip 04. Participants had to have some free time during the day to attend workshops at the University of Sussex and the University of Brighton. We offered training, equipment and support. We emphasized that enthusiasm and a willingness to collaborate and learn new skills were of more importance than any particular expertise.

2.2 Participants

The project was initiated and co-ordinated by Jon Bird, Bill Bigge was technical co-ordinator and the artists Tom Grimsey, Richard Brown and Andy Webster acted as mentors (the latter two through web-based feedback). Two Brighton-based artists, Ed Clive and Rowena Easton, and three scientists from the Evolutionary and Adaptive Systems MSc course at the University of Sussex, Mike Blow, Garvin Haslett and John Popadic, committed two months of their time to collaboratively develop an installation for the Big Blip 04.

2.3 Training

The project began with two one-day workshops. The first, held at the University of Brighton, was run by sculptor Tom Grimsey. In the morning, his challenging brief was to give a wide perspective on sculpture through time and across cultures and highlight some of the current issues in this artistic practice. In the afternoon he gave a hands-on introduction to sculpting with foam. The second workshop, run by Bill Bigge, introduced real-time robot control. Using Lego robots, participants explored how to link sensors and motors to generate simple behaviours such as light seeking and obstacle avoidance. The aim was to introduce simple robot technology to people with no previous experience of this area. In a later third workshop, Tom Grimsey taught the participants how to cast polyurethane foam rubber structures.

2.4 Facilitating the Collaborative Process

Blip tried to facilitate the collaborative process in four ways:

1. As well as identifying some of the artistic and technical issues that formed the context of the project, the two initial one-day workshops introduced the participants to each other and got them working together to achieve practical goals (constructing foam sculptures and Lego robots).

2. We set up a web-based collaborative forum that enabled participants to send messages to each other, upload shared files and co-ordinate meeting times.

3. The participants met regularly, initially once a week and then more frequently closer to the exhibition.

Figure 1: *There does not, in fact, appear to be a plan* installed at the Big Blip 04. Photo by James Fry.

4. Artists Richard Brown and Andy Webster acted as distance mentors to the project, responding to the postings on the online forum and offering a ‘big picture’ perspective.

3 Concept Development

The initial project concept was structured by three main constraints: the resulting installation would have an interactive aspect (in keeping with much of the work being exhibited at the Big Blip 04); it had to be constructed in two months in time for the exhibition; and it had to be realised with a small budget. As the project was supported by the Autonomous Systems Lab at the University of Sussex, we decided to use robots as the basis for the art work. Given the financial constraints we opted to build simple, custom-made robots, with 2 degrees of freedom (DOF) and limited sensors, whose motor behaviours could be tuned without requiring extensive programming or electronics knowledge. The general aim was to enable participants to experiment with the dynamics of both individual and group robot behaviours and explore how they could be incorporated into an interactive installation. A major issue throughout the project was how the installation would function as an artwork: what would the group of robots do?; how should they be decorated (if at all)?; and how should they be displayed as an installation? By the third week of the project the group decided that eight to

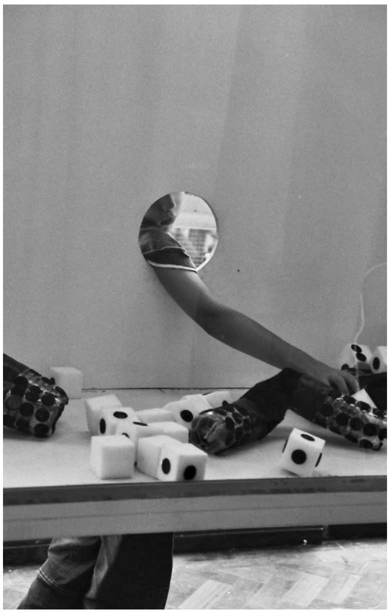

Figure 2: Visitor interacting with *There does not, in fact, appear to be a plan* at the Big Blip 04. Photo by Andrea Campos-Little.

ten robots would be used to make a dynamic assembling/disassembling three dimensional sculpture. It was decided that the simplest solution for enabling the robots to stick to each other and other structures in their environment was to cover them in velcro (the black circles in Figures 1, 2 and 4 on the foam cubes and robots). Different robot arm shapes were experimented with to see which would facilitate the dynamic formation of structures. However, the issue of what the robots would look like and how they would be displayed was still not resolved. After six weeks of the project, the group refined their installation concept and decided to build an art work that explored the relationship between voyeurism and interactivity. The development of this idea is shown by the following project documentation.

Garvin Haslett (from an email, 16 August, 2004) *The robots make some nice sounds when flopping around on the lino floor currently in the Autonomous Systems lab. On the one had there is the mechanical groove of the robot (think minimalist Detroit Techno), on the other the scrape of the velcro on the floor sounds similar to the outgroove on a vinyl 12".*

Rowena Easton (from an email, 17 August, 2004) *Like the sound of the sound. Can we get them to 'grunt/groan/gasp/moan/sigh/scratch' relative to each other? Hmmm, sounds like a robot orgy.*

Rowena Easton (from an email, 18 August, 2004) *Can robots feel shame? Can a robot display inappropriate or degenerate behaviour? SHOULD THEY SEPARATE WHEN THEY REALISE THEY ARE BEING WATCHED? This would create a nice tension between notions of the 'viewer' or 'voyeur' versus the 'user' or 'interactivist', as they would only make themselves into sculptural forms when nobody's looking. The visitor may be able to sneak a peek at the robots sticking themselves together, and he may also have access to a video of a remote performance, but on one level he will only ever see his own distorted reflection.*

Richard Brown (from an email, 18 August, 2004) *Voyeurism, cameras, suggestive sounds and any other devices could be explored to great effect... webcam robots, sensual fabrics, lighting - the installation(s) could reference kitsch, soft porn, Amsterdam windows, red lights, peep shows etc etc... I guess its now down to how far or how explicit or subtle people want to go with this... I can imagine a twist on the museum display of animals in their natural habitat - glass/perspex display boxes/tanks, erotic robot rooms.*

Garvin Haslett (from an email, 24 August, 2004) *The idea we are going after at the moment is that of trying to get the robots to do what they do only when people aren't looking. Our intuition at this stage is that the motion of the robots should make interesting forms out of static objects when those movements are slow. On the other hand when the robots move rapidly the structure should hopefully disassemble. So what we're trying at the moment is to use some sort of sensor (light, infrared) that will tally with the presence of a viewer. Sensor off: robots elegantly form structures; sensor on: robots wiggle like crazy for 15 seconds and demolish all their hard work.*

Constructing eight robots took most of the two months of the project and consequently it was not possible to construct the planned voyeuristic installation. There was also limited time for the participants to explore the dynamics of the robot behaviour. The final installation was comprised of six 'trash aesthetic' robots (to use participant Mike Blow's phrase). The motor-controller units were encased in the ends of transparent plastic bottles covered in black velcro discs and the central joint was covered with black tights material (Figure 4). The back wall of the display cabinet contained a hole through which the public could handle the robots (Figure 2). Two microphones picked up the noises from the installation which were amplified and played in the exhibition space: velcro tearing apart; the robots slapping against the wooden floor; and their clutches popping (see Section 4). The robots were able to move across flat surfaces but only very occasionally able to roll over each other. Although the robots did stick together and to the foam cubes, their random interactions did not lead to the formation of ordered three-dimensional structures and the overall effect was one of a noisy mass of writhing movement across the floor of the display cabinet.

During the process of installing *There does not, in fact, appear to be a plan* on the day before the exhibition, an unexpected artwork, *Clutch* (Figure 5) was constructed by the two participating artists as they were dissatisfied with the installation and its failure to realise either the voyeuristic concept or a dynamic three dimensional sculpture. *Clutch* was an arresting piece. The display cabinet was taken apart and the velcro covered foam cubes scattered on the floor along with excess materials and some of the tools that had been used in the construction of the initial installation. Two robots were trapped under a wooden A-frame, putting their motors under stress and causing their clutches to pop as well as making the frame repeatedly hammer on the cabinet floor. A third robot was positioned so that its thrashing around moved a cluster of foam cubes. The amplifier was adjusted to increase the white noise emitted from the speakers. *Clutch* was filmed for display on a monitor at the Big Blip 04 and then the participants reconstructed *There does not, in fact, appear to be a plan*. A short version of the video can be downloaded from www.blip.me.uk. Section 5.2 gives some of the participants' perspectives on this stage of the collaborative process.

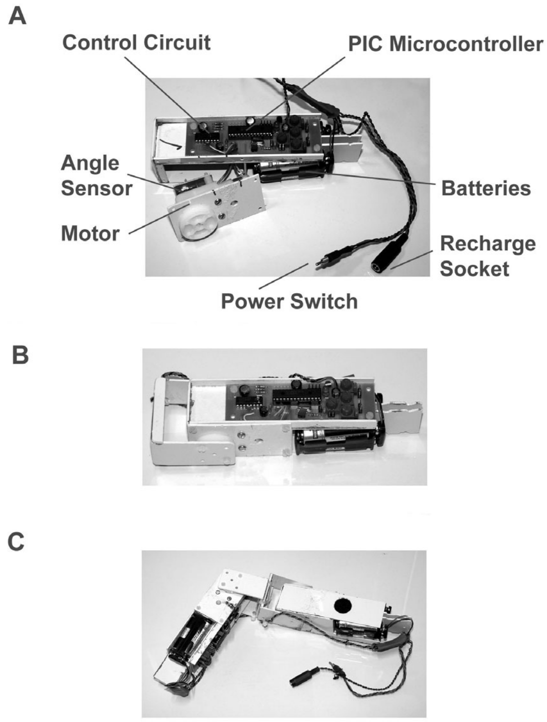

Figure 3: A - a single motor-controller unit, disassembled to show the components; B - an assembled single motor-controller unit; C - two motor-controller units coupled to form a robot.

4 The Robot Hardware

The robots consist of two identical arms linked by a two DOF joint (Figure 3c). It was not necessary for the arms to communicate with each other so each one was designed as an essentially self-contained unit containing a motor, controller electronics and batteries (Figures 3a and 3b).

The first task in building a prototype robot was to choose the motors we would use. The obvious choice was to use servo motors of the type normally found in radio controlled cars and aircraft. These are often used in robotics because: they are relatively inexpensive; they come in a huge range of sizes and powers; and they are simple to use. The servo contains its own electronics, gearing and feedback systems that together control the position, or angle, of the motor output shaft. It is easy to construct motorised joints which are controlled by sending a servo motor a series of pulses whose length specifies a target angle.

However, the principal drawback with servo motors is that they provide no feedback about whether the motor shaft is at the target angle. Furthermore, while some servo motors are extremely tough, our limited budget meant that we were restricted to the cheaper, less robust models. This was a significant limitation in the context of our project where the robots had to interact with the public, including children. We needed motors with tough gearboxes or there was a risk that rough handling would result in stripped gears and non-functional robots. Consequently, we decided to use gear motors obtained from Solarbotics (www.solarbotics.com). Their advantages over servo motors are: they are cheap but reasonably powerful; they can be easily modified to include a cheap angle sensor; and they have torque limiting clutches. These clutches pop if the strain on the gears reaches a certain point, preventing damage to the motor.

The motors and control units are mounted in custom-made ABS plastic boxes. Each robot uses eight rechargeable Nickel Metal Hydride AA batteries (four in each of the two motor-controller units), giving a working voltage of 9.6v. The power switch is situated on a lead that protrudes 8 inches from the casing to allow easy access however the robot is covered or decorated (Figure 3a). The charging socket is on a separate lead so that the robots can be plugged in for recharging without the need to disassemble them and extract the batteries (Figure 3a). The power switch, charging socket and batteries are all wired together so both motor-controller units run off the same set of batteries and can be controlled from one power switch. To make a complete robot two motor-controller units are attached to each other at ninety degrees so that each unit provides movement in orthogonal axes, giving each robot two DOF (Figures 3c and 4).

4.1 Robot Controllers

Each motor is controlled with a small microcontroller, the PIC16F876, which is relatively cheap and easy to work with. This PIC chip has five analogue inputs. One of these is used to measure the motor's angle sensor and the remaining four are connected to potentiometers so that they can be used to adjust the behaviour of a motor-controller. There are also a number of pin headers and jumper switches to allow additional inputs and outputs. Each motor-controller unit is programmed to constantly oscillate between two angles at a fixed speed. The two angles and the motor speed can be set independently using three of the potentiometers attached to the PIC chip. A fourth potentiometer sets an error threshold which is used to provide some crude feedback on how a motor-controller unit is moving. If something in the environment inhibits its movement, then the angular error accumulates and if this value reaches the error threshold the motor reverses its direction.

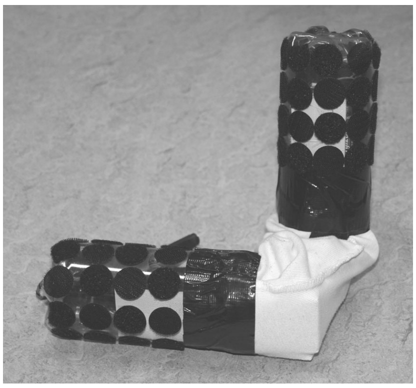

Figure 4: A complete robot. Each motor-controller is encased in the end of transparent plastic bottle which is covered in discs of velcro. The exhibition robots had black tights material over the joint connecting the two motor-controller units, rather than the white covering shown in this picture. Photo by Bill Bigge.

Although in the basic design each half of the robot is completely independent, the circuit board was constructed so that there is an option to add extra sensors and share signals between the two motor-controller units. A series of experiments were carried out where a light sensor was attached to a motor-controller unit, resulting in a robot displaying rudimentary phototactic behaviour. One idea was to implement the voyeuristic installation by placing the robots in a dark cabinet and forcing viewers to use a torch to see their behaviour, thereby triggering the robots' light sensors and changing their movements (see Section 3). However, there was not enough time to incorporate this capability in the final installation.

5 Views of the Participants

In this section we present some of the views of the participants on different aspects of the project. The text is an edited version of their written feedback after the exhibition.

5.1 Collaborative Process

Andy Webster
I feel this project is a good case study for further discussion surrounding the pros and cons of collaboration. The question today is no longer 'why collaborate?' but rather 'how might one collaborate?'. The carefully planned structuring of meetings, workshops, and further discussion online encouraged the development of common goals and ambitions, no mean feat considering the diversity of the collaborators' interests and backgrounds. Importantly, the development of this common goal, a necessary facet of the project, did not impose order and stability on the development of the collaboration. In the place of certitude, the collaboration explored connective possibilities, evolutionary methodologies, and most importantly collaborative practice as a dynamic learning system with multiple feedback loops.

Ed Clive
I have not had much success collaborating with artists in the past - perhaps due to a battle of egos, perhaps because realistically everyone has a different agenda. I thought that working with scientists would be different because of their different work ethic - more test and experiment. In retrospect I have learnt that the spirit of collaboration is much the same across both fields. Everyone does have their own agenda and some voices are louder than others.

However, I feel the collaboration progressed well - despite the artists being outnumbered 2:1! It was probably this ratio that led the project, initially, towards a more science-based approach. The early process for the artists was an incredibly steep learning curve, a crash course in the fascinating history of robotics and current theories and practices of robot making. It was difficult for the artists to be sure of their input - this was partly due to the fact that we never planned how we were going to work (hence the title of the installation) and partly because any aesthetic thoughts were always replaced with practical considerations.

5.2 The Emergence of Clutch

Figure 5: The *Clutch* installation at the Big Blip 04. Photo by Ed Clive.

Ed Clive
As the opening of the exhibition drew closer, last minute problem solving became more and more hurried. It was at this point *Clutch* was formed - understandably to the dismay and confusion of surrounding participants. I would like to state here, and this was paramount to our thoughts at the time, that *Clutch* was not in any way meant to be degrading to the work we had achieved in the previous months. On the contrary, despite *Clutch's* spontaneous birth we felt it captured the spirit of collaboration more successfully than *There does not, in fact, appear to be a plan*. That is not to belittle what was achieved in that project; rather, *Clutch* was meant as a commentary about the working process between two different practices. The discarded velcro buttons, coke bottles and BHS tights were shown off in all their glory, demonstrating the ‘make do and adapt’ aesthetic of scientific experiments. I love that use of materials - the adaptation of the nearest thing to hand to demonstrate or explain the idea in your head.

Rowena Easton
Up to the point of installation the project had been concerned with getting the robots to function. It then became apparent that we would not be able to achieve the original idea of making a robotic sculpture which made and remade itself into different forms. The artists, not understanding the technology, did not recognise its limitations in time and that this project would need a lot more work to be fully realised. *Clutch* evolved because Ed and I were very unhappy about showing the installation as it was and were desperately trying to find some way to make it work as art. Until we installed the work, and explored how we could make it work as art (a period of intense and chaotic playing) the artists did not own it. It was inevitable that they would take it apart and recreate it in their own image when left to their own devices. I was shocked by the angry reaction that *Clutch* provoked from some of the scientists. One of the jobs I was given (lightheartedly?) as part of the team was to decide at what point the installation became Art. When I did make that decision I was not believed. This reinforced a feeling that not enough respect was given me as an artist. Although my initial reaction was also one of anger, because my practice seemed to count for nothing in this discussion, I was, however, interested that we had managed to provoke such a strong response and felt it lent weight to the work. Unable to reconcile the logic of a scientific approach with the creative impulse, it came down to keeping the scientists happy.

A compromise suggested by Ed was that *Clutch* could be shown as a video. I was all for ‘battling it out’, feeling that *Clutch's* dynamic qualities and presence would be lost, but this was impossible without the whole team there to discuss it. A failure of the project was that, when something interesting happened, the whole team was not involved. Another familiar argument put forward was that *Clutch* was not possible from a practical point of view. This is a distraction. The splitting of the work into two was a real cop out (it could have been made to work), and as such the integrity of the project suffered. The result was that *Clutch* was seen only as a document of this particular collaborative process, and a simple illustration of one moment in time. Nothing other than an interesting footnote to the project. Instead of a work in its own right, with a wider significance than this collaboration. Its wonderfully dysfunctional presence could have had a real impact on the Big Blip exhibition, which tended towards the sterility of the execution of the 'cute idea'.

Garvin Haslett
My underlying motive, derived from my training as an Artificial Life researcher, was to explore the extent to which the general public would accept an artifact as alive. Hence, I was happier with *There does not, in fact, appear to be a plan* than the artists were. *Clutch* appeared magically for a few brief hours during the endless tweaking that was the search for an ideal configuration for *There does not, in fact, appear to be a plan*. I initially found the artists' satisfaction with *Clutch* utterly beyond my comprehension. Upon reflection though I think the video has significance in that it captures aspects of the scientific process that don't make it to scientific journals. Firstly, the murky issue of results that don't conform with a desired hypothesis. Secondly, the lonely romance of the road to implementation.

5.3 Assessment of the Project

Andy Webster
A natural, if predictable response, is to look at the outcomes in order to evaluate a project's success, but I think it is crucial to shift the focus onto the dynamics of the evolving discourse that led to the concrete results. A simple critique of this project is therefore that the discussion, dialogue, testing and lab culture was ultimately displaced by orthodoxy and obsolete tradition: 'It's an exhibition so we must have an object/closure'. For me, the real area of interest was the discourse developed through the art/science collaboration and not the resulting object. If collaborative practice engenders the potential for dynamic learning, why not use an exhibition to expand the feedback loops rather than deny the audience access to these?

Tom Grimsey
The title of the installation captures the fact that there was not a single plan but a rich variety of possibilities that could not be explored in the limited time. The video piece, *Clutch*, was perhaps a necessary diversion, expressing some of the chaos along the way out of which came very tangible results. A diversion, but not without its own charm. *There does not, in fact, appear to be a plan* is a strong prototype which is operationally fragile but conceptually robust. I enjoyed the scientists' easy facility in practical problem solving. Their experience and a mental agility in these areas often quickly generated a range of possible solutions - practical issues are often formative of the whole look and feel of the end results.

Rowena Easton
It is very liberating to work in a new area and with people who have different perspectives. I also enjoy the friction it creates. I was very encouraged that the scientists came round to taking *Clutch* seriously and that through it they gained an understanding of how art works. The difficulties enabled a real dialogue. I still believe in the original idea and would love to see it happen. I would definitely do it again, having wanted to work with scientists for ages, and am now collaborating with one of the team on another project.

Mike Blow
The Blip project was an exciting opportunity and a positive learning experience. As an engineer, working with artists broadened my outlook and gave me an insight into what aspects of an artwork they deem important. The conceptual distinction between a 'diagram' and a 'sculpture', that is, the merely representational as opposed to the symbolic, was a point that had particular impact. However, given the short duration of the project, I am pleased, and surprised, that we got two exhibits out of the collaboration. It strikes me that the two exhibits neatly exemplify the differing approaches of artists and scientists. *Clutch* was contemplative, extremely interesting to view and totally impractical to exhibit in a show open to children. *There does not, in fact, appear to be a plan* on the other hand, was more direct, more interactive and easier to look after, but less symbolic and provoking. There was always quite a crowd around the piece at the demonstration times and in this respect it was very successful. The hole in the back of the display cabinet allowed the robots to be withdrawn and handled and the audience would stroke the robots, cuddle them like a baby, pass them around, and even throw them against the wall (thankfully we had spares). There was also some squeamishness at picking up writhing objects. The intensity of reaction was noticeably greater when the robots were handled than when they were simply observed. An important point here is that the robots did not look at all lifelike. Due to time constraints they were, in fact, quite obviously made of plastic bottles and black socks: the trash aesthetic! The reaction of people watching and handling the robots was due to their behaviour rather than their appearance.

5.4 Enhancing Collaboration

Rowena Easton
We needed to spend more time together at the beginning thinking about the project in creative terms, but because of time pressures it was felt we needed

to start making as quickly as possible. The making took over and became a production line. The project became driven by the technology. I think it would have been helpful if Ed and I had given a presentation about our own work, instead of giving a potted account of hundreds of other artists work. With so little time, the scientists would have gained more of an insight into art practice if they had been able to ask an artist standing in front of them questions about their work.

Mike Blow

In retrospect there are things I would do differently: perhaps make fewer robots in order to allow more time for the aesthetic considerations and testing to discover the capability of the robots to self-assemble and so on.

Tom Grimsey

I still think there is still plenty to do in the area of how the results appear. The appearance of the robots and of course the evolution of the work through mutation, could, in future collaborations, be more of a motor to developing ideas. This is ground where we might expect the artists to feel more sure-footed but certainly not exclusively. In summary, it was a very exciting project which I was sorry not to have been more directly involved in.

6 Conclusions

There does not, in fact, appear to be a plan did not achieve the artistic goals of the participants, who spent most of their time constructing the robots and had very little time to explore their behaviour and artistic potential. Time restrictions also meant that the robot sensors were not used and the voyeuristic installation was not implemented. The idea of an emergent sculpture was not fully realised due to the high mass to power ratio of the robots and the limited ways that they could form bonds. The construction of *Clutch* was partly a consequence of the frustration of the artists with the robot technology. Having struggled right up to the last minute to try and get the installation to work, the artists focused on making an alternative work which they felt had artistic integrity. It was perhaps understandable that the scientists initially viewed this work as a rejection of all the hard work and emotional investment that had gone into building the robots. Although *Clutch* may initially appear a destructive critique of the use of technology in art, it also positively highlights the most successful aspect of the project: the creative interaction of the artists and scientists led to the generation of a work that had not been envisaged when the project was set up and that would not have been produced by the artists or scientists working in isolation. All the scientists eventually came to appreciate *Clutch*, both as an expression of the collaborative dynamic and for the insights it offered into artistic practice.

Clutch seems an aptly named piece as it released the pressure that had built up in the collaborative process in a creative way, just like the motor clutches prevent damage to the robots' gears. All of the participants are positive about their involvement in the project and still convinced about the value of their original concept for an interactive installation. The collaborative process is still ongoing, as this paper illustrates. Some of the participants have moved away from Brighton, but the intention is to continue with the project and bring in some more collaborators in order to try and construct the voyeuristic installation. It will be beneficial to have more time to creatively explore the robot technology rather than having to focus on the fabrication process. It would also be useful to get the distance mentors more involved as their overview of the project is very useful, and in hindsight, their emails identified the key issues in the collaborative process at an early stage.

The main reason for collaborating with another person is because they can add something to a project that we could not do on our own. An analogy can be drawn between the collaborative process and the biological phenomenon of symbiosis: the close association of two distinct entities. Biologists have identified three different types of association: parasitism, where the host suffers; mutualism, where both entities require each other for survival; and commensalism where one entity benefits, but not at the expense of the other one. Arts-science collaborations have the potential to be parasitic; for example, scientists using artists as 'decorators' or 'illustrators' of their scientific project, or conversely artists using scientists as technicians to implement their ideas. However, collaborations also have the potential to be mutually beneficial to both artists and scientists, enabling them to generate and explore more creative opportunities than would be possible alone.

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