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Applying Mobile Robot Technology to the Rehabilitation of Autistic Children

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Abstract: *The paper discusses the background and major motivations which are driving the AuRoRA (Autonomous Robotic platform as a Remedial tool for children with Autism) research project. We argue that mobile robot technology can be used in a useful and scientifically challenging application area, namely the rehabilitation of children with autism. Initial steps of the development of a robotic platform as a remedial device are presented along with a discussion of the initial trials performed. We discuss work currently in progress, and believe that this particular application area has the potential to advance our understanding of human-robot interface design as well as having the possibility of aiding in the rehabilitation of autistic children.*

Background

A major area of research within the field of mobile robotics is in their use to aid the disabled or handicapped. This is an extension of the wheelchair and involves the use of robots to perform tasks which not only directly affect the user, but are a consequence of a users actions and requests (for example see Wilkes et al, 1998 or Bolmsjo et al, 1995). Since the intended user will be without any specific training and is often unable to perform a specific type of task due to a disability, the design and interface of the robot is critical. One specific area in which robots may be applied is that of autism.

Autism is a disorder which is prevalent from birth, affects children with no apparent logic and, at the present time, there is no cure for. It is able to be diagnosed within the first three years of the child's life, and while an autistic child will become an autistic adult, early diagnosis will allow more effective treatment. Current statistics show that autism affects up to two children in every thousand, and that it is three times more likely to affects boys than girls (see Tsai, 1998 and Trevarthen et al, 1996 for more information).

There are no 'standard' symptoms, only those which are more common. These can include an impairment of non-verbal communication, a lack of spontaneous activity and a dependence on repetitive actions. The result is that the autistic appears to be in a 'closed world' and one in which normal social skills are impaired. A stereotypical autistic child does not attempt to get attention unless it is to fulfil a need and other people become simply agents who provide for the child. Eye contact is not sought and physical closeness is avoided. Stimulation can cause irritation to the child and is avoided, while inanimate objects or simple toys may hold a particular fascination and command the child's attention (Schreibman, 1988).

The result of this is that the child seems to be ignoring the world at large and is usually very resistant to external interaction and communication. A number of treatments have been put forward in the rehabilitation of autism, from physical restraints forcing the child to confront frightening stimulus, to the alteration of the child's environment to limit the amount of potentially frightening sensations. Some therapists see language as central to the disability and so concentrate on this area, promoting complex and abstract sentences as a key to rehabilitation. Behaviour therapy takes the view that language is a symptom and so simple sentences with actual meaning are developed, normally involving the encouragement of interaction in a pro-active way, for example developing eye contact before requests are met and giving the child pictures of items, which are presented to the carer as a request for food or response. In this way, the aim is that the child learns that there is a lot to be gained by making an effort to communicate and to interact, encouraging the development of this process, and allowing the child to more easily fit into modern society (Grandin, 1998). One of the most challenging aspects to the rehabilitation of autistic children is that each child must be considered as an individual, with differing strengths and weaknesses, and each requiring a tailored approach, although the generic types of treatment may be applicable to groups of children.

One of the methods used to aid autistic children was developed at the University of North Carolina, called TEACCH (Watson et al, 1989; Mesibov, 1996). This method emphasises the use of a teacher who guides the child's behaviour in such a way that a response is given, and repetition grounds this response so that it becomes natural and a part of the 'normal' routine. This means that the child learns the 'proper' behaviours and communication methods, and this structure allows future behaviours and responses to be based on earlier ones. In this way, the child is gently guided and not forced into unnatural situations, but they are encouraged to make an effort to interact. This method has proven highly successful and, while obviously not a cure for autism, can allow autistic people to be more independent and to rely on others less. This eases the pressure on the family and improves the quality of life for the individual.

Based on this TEACCH philosophy, it is hoped that a robotic platform will provide the necessary stimulation to re-enforce the child's responses. This should encourage interaction by providing an enjoyable stimulus, reinforcing it by reacting in specific, non-threatening, ways. It is hoped that a robot will allow the child to relax and to view the activity as play, reducing the amount of fear presented. The robot should therefore appear to be a new and interesting toy, while stretching the interactive and communication limits of the individual child through an enjoyable medium of play. The robot will bridge the gap between the inner world of the autistic, and the unpredictable but necessary teacher, thus providing a secure method of teaching the child about the basics of interaction in a gradual manner, adapting with the child's development.

A variety of explanations of autism have been discussed, among them the widely discussed 'theory of mind' model which is conceiving autism as a cognitive disorder (Baron-Cohen et al, 1985; Baron-Cohen, 1995), and a more recent explanation given by Hendriks-Jansen in 1997. He hypothesises as the primary cause, early developmental disorders which prevent the child and its caretakers to 'get the interaction dynamics right' which normally scaffold the development of appropriate social interactions such as situated dialogues between infant and caretaker. The importance of interaction dynamics are also part of the hypothesis suggested in Dautenhahn, 1997, which implies a lack of empathic processes which prevent the child from developing 'normal' kinds of social action and interaction. In Russell, 1997, we find extensive supporting evidence that not impairments of mental concepts, but rather disorders of executive functions, namely functions which are responsible for the control of thought and action, are primary to the autistic disorder.

AuRoRA

The need for repetitive actions and a stable environment provide a strong argument for using robotics in the rehabilitation process of autistic people, and children in particular. It is hoped that a robotic agent will disarm the child's fears and enable the child to relax, reducing the stress and pressure involved in the process of interaction. At the same time, a robot is able to adapt to the child and its environment in subtle ways and stretch the child's existing limits. A robot also has the dual advantages of being able to perform repetative actions tirelessly and not appearing to the child as a teacher figure which could be associated with learning. A robot provides the structure and repetition needed by autistic children to learn while also being a friendly agent in the child's world. Children have become used to various forms of robots through television and toys in general and are able to relate to them in ways which they cannot relate to other people. This allows a degree of trust to be built up, which in turn encourages interaction. However, the aim of this project is not to replace people, simply to use the technology to aid carers. Ideally, the robot will be viewed as a companion and a friend of both the child and the carer, and will perform the role of a teaching device (for a further discussion, see Cooper et al, 1999).

The AuRoRA project (Autonomous Robotic platform as a Remedial tool for children with Autism) draws heavily on this idea of encouraging a pro-active response from an autistic child. It has been observed that autistic children are easily startled and frightened by sudden changes in environment and unpredictable behaviour. It is envisioned that a balance will be achieved, providing the child with a stable environment within certain bounds, leading to a secure environment while still giving enough room for the child to interact and control specific aspects directly. It is also hoped that we will be able to stretch the current development of the child and so promote further interaction. In this way, the technology will bridge the gap between the unpredictable external world and the internal world of the autistic.

This approach differs from most robotic applications in that it places the emphasis on the interaction aspect and the ability of the robot to express its actions, since this will build and reinforce the child's learning of the link between action and robot reaction. Studies which concentrate on the interaction in this way have primarily been done with software agents and have involved the expression of the agent while performing a specific task or goal (for example, see Sengers, 1998). Our project differs from this, since the interaction is the goal. This changes the emphasis, as the robot will need to express itself in a way which will tell the user about it, and humanly attributed internal states, which will relate only to the robot and user, and not to a specific task. This means that the robot will not be designed to perform a task, rather it will need to perform relatively simple actions but with expression, allowing a strong bond to be developed between the child and the robot. One of the most important aims of the project will be to develop a robot which is fun for the children to interact with. Since the overall goal is to encourage communication, the robot must provoke interest and enjoyment or the children will not be motivated to interact. Once this goal is met, the robot must engage the child's attention without becoming threatening or dangerous in any way. Since the robotic platform used is sturdy and robust, it is able to be pushed around, and it is also required to avoid obstacles at all costs and moves relatively slowly and so therefore will rarely come into contact with the children. The robot must perform two roles when interacting with the children:

- It must provide a stable environment in which the child feels secure. Autistic children generally prefer strict structure and limited environmental changes and so repetative actions must be used.
- It must also hold the child's attention and not become boring for the child. It must stretch the child's existing interactive and communicative abilities.

These two points mean that the development and control of the robot are of paramount importance (see Dautenhahn, 1999). The robot must advance slightly ahead of the child, not becoming stale and also not becoming too advanced. This is complicated further by the individual nature of the autistic disorder.

The Robotic Platform

The robot currently used is a Labo-1 mobile platform, resembling a sturdy flat-topped buggy, provided by Applied AI Systems, Inc. It currently uses eight infrared sensors pointing in four directions, which allow the avoidance of obstacles, and a singe positional heat sensor.

The main communication that the robot currently has with the outside world is through the sensors. There is no link to another computer via a tether or any other device. This means that the robot must be able to be an independent agent and rely on solely on its own inputs and decision routines. The only other limited method of control is through two buttons on the robot. Although these are currently inactive and only used for behaviour selection, they have the potential to be utilised by the children to force the robot the perform specific actions, possible keeping a record of the number of requests made or by only allowing a specific button to function for a set number of times.

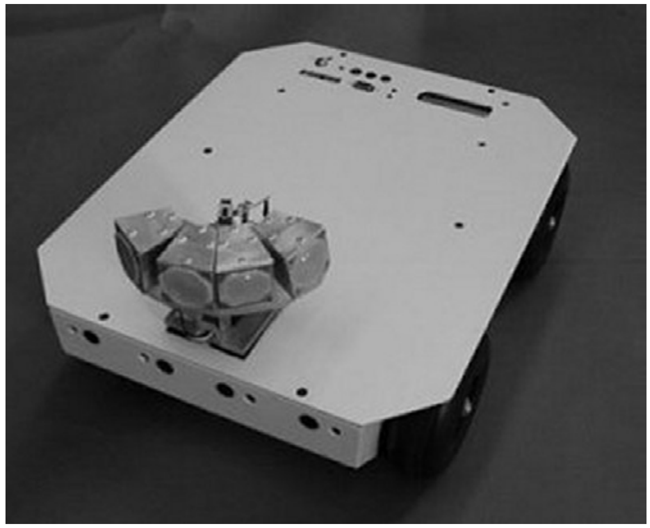

Figure 1: The robotic platform used.

The robot is 38cm by 30cm and is a total of 21cm high, including the positional heat sensor. It weighs 6.5kg and has a top speed of 40cm/sec.

Architecture

The robot is programmed in C and currently uses production rules to determine behaviour modules, which are run until the robot is turned off. This allows the architecture to be constructed hierarchically and more complex behaviours to be based on existing ones. Such a behaviour-based architecture allows a modular approach to the software, with a central 'decision' module selecting a behaviour from a list which can be adapted and modified.

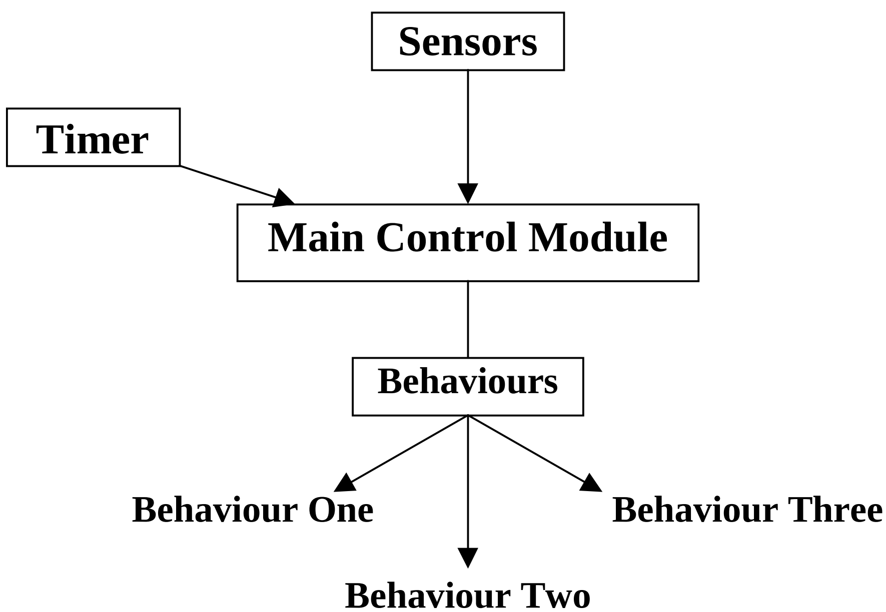

Figure 2: The current robot architecture.

The main module controls the co-ordination and selection of the behaviours, as well as the amount of time that each one will run. The user or teacher is currently presented with a choice of four simple behaviour programs; a demonstration sequence, a simple forward and backwards movement, and heat following behaviour and a simple movement behaviour triggered by the presence of a heat source (e.g. a human). These behaviours run indefinitely until the robot is stopped. The architecture is run on two levels. The lower level controls actions which are repeated in sequence and so deals with the inputs from the sensors, updates the timer and generally controls the avoidance of obstacles. This cycles through a list of up to fifteen sub-procedures at a rate of sixty four times each second. The other level deals with the more specific selection of the behaviours and the timing and duration of them. This two-layered approach allows us to write the interactive routines and avoids the replication of code dealing with the avoidance of obstacles. This is only possible because we do not require the robot to come into contact with objects or people at any time and so this takes precedence over the second layers functions but does not drastically interfere with its running. Sensor readings are stored in variables accessible by both levels and are updated by the lower level, while the motors are similarly driven by variables in the lower level.

Within the confines of each of the four behaviour patterns, there are a number of behaviour atoms which are run. These are simple actions directing the movement of the robot in a certain direction, and they are run for a finite length of time, specified and controlled by the main module. This hierarchical, behaviour-based approach will keep the robots architecture flexible, allowing adaptations to be made depending on the situation and targeted user. The control architecture is developed using an experimentally driven (incremental) design methodology (see Arkin, 1998 for a general introduction into behaviour-based robotic control).

Initial Trials

Initial trials have been conducted with a selection of children from Radlett Lodge School, Hertfordshire. The first visits involved observations in the way in which the children's learning was structured and the level and intensity of learning. This was accompanied by a visit including a robotic doll which mimicked and copied simple actions, in order to gauge how the children would react to this type of experience (for a detailed description of the robotic doll, see Billard, Dautenhahn & Hayes, 1998).

Trials were then performed with five children (one child at a time) interacting with the Labo-1 robotic platform. The children were allowed to interact freely with the robot in the presence of a supervising teacher, who also terminated the session when the child became tired or disinterested in the robot. The children showed no fear of the robot and were happy to play with it. Initially, the simple behaviour patterns were used, such as a forward and backward movement, in order to introduce the robot gradually. All the children then interacted with the robot while it was showing the heat following behaviour. The children showed a visible interest in the robot and appeared to enjoy the interactive process, with reactions including laughter and vocalisation, both to and about the robot. The children performed elements of active play and interaction such as moving away from the robot and looking to see if it was following. All children also showed a substantial amount of eye focusing and attention focusing, features which typical autistic children lack.

Since the teacher was on hand to halt the trials when the child became bored, the trial length is an indication of the child's interest. We found that, of the five trials, three lasted approximately four minutes, while the other two had a duration of around fourteen minutes. This clear difference is one of the issues which will need to be investigated further, possibly in respect to the level of the child's functioning. Since the children were focused on the robot the amount of stereotypical autistic behaviour, such as empty gazing, was reduced and the child was prompted to move around more than in normal play since they are not in complete control of the robots actions. Also, because the robot reacted differently according to its position in relation to the child, repetative behaviour did not occur. A number of the children also became pre-occupied with the buttons at the rear of the robot. While most of the children either walked or crawled around the room during interaction with the robot, one child simply lay on the floor and interacted by reaching and arm movement.

Future Developments

The initial trial and further developments have located a number of key areas which will be developed in the future. On the hardware level, we hope to have another robot available soon with which to perform tests, as well as a speech device, allowing the robot both to speak and to recognise spoken commands. This will allow a much greater degree of flexibility of interaction and make the interaction both more complicated and varied.

For the children to gain more from the interactions involved, it would be advantageous if the robots behaviour could adapt over the length of a single session. This would require the use of a memory module, coupled with a device to allow learning. The behaviour-based architecture is designed with this expansion in mind and an extra module can be added with a minimum number of changes being made to the existing software. In the same way, new behaviours can be added and the existing program can grow in a number of different directions.

In order to make the robot applicable to children with varying abilities, two functions will be added. The first will control the actions of the robot by limiting values such as the speed of the robot and the amount of movement made, allowing us to use the robot in different sized arenas. The second will control the amount of time waited between behaviours. With this changing between a fraction of a second and a number of seconds, the robot will seem continuous or discrete. This is important in building up an action/reaction pairing, ensuring that the child realises that his actions cause the discrete response in the robot and also allowing the more advanced children to interact with the robot at a faster rate. The continuous setting will also allow behaviours to interrupt each other and so the robot will appear to move smoothly and to be more life-like.

An obvious development is the addition of more behaviours. It was found that all of the children interacting with the robot were able to use the more advanced behaviours, such as following, and that the higher functioning children grew bored with this as it did not stretch them sufficiently. Additional behaviours would need to address the aspect of interaction more closely in order to make the robot more complicated, and therefore interesting. It is also hoped that behaviours will be able to correspond to the children's class environment, for example if the children are learning to group objects with regards to shape, the robot can have a behaviour which prescribes a circle on the vocal command "circle". The current interactions and behaviours are restricted by the sensors available on the robot. While a speech device will increase the amount of interaction involved, the robot has a very limited number of methods for detecting its environment. The infrared sensors allow the detection of objects close to the robot but have a limited range and will only result in distance, with no information about size or orientation. Similarly, the heat sensor will allow the detection of heat sources and a direction, but not the objects size or facing, details which could be extremely useful in more complicated interactions. To this end, we will be investigating the use of a global camera which will monitor both the robot and the child, and give a greater variety of information.

Additionally, the robot has no method of knowing how far it has moved, aside from the use of the amount of time spent moving. This means that the it will move a varying amount on different types of surface, which may interfere with the behaviour if it is designed to move in a complete circle or to spin three hundred and sixty degrees.

Conclusion

Initial research and observations have directed the short term goals of this project. It has become apparent that it will be necessary to increase the scope of sensors available on the robot to allow a greater variety of input and, in turn, to lead to more varied behaviours and responses. Also, in order to give the robot a longer 'entertainment' span for the children, it will be necessary that it adapts and provides a continually new experience without becoming totally unpredictable, and this will entail the use of a short-term memory module and learning routine. Since the target group of autistic children may have many different strengths and weaknesses, it will also be necessary for the teacher or carer to be able to have a degree of control over the robot. A future development will involve the use of a teacher moderated speech interface, however since some autistic children are reluctant to use speech this will need to be optional.

It has also become apparent that a number of key areas are present in this research. The individuality of autistic children requires us to develop a robot which is flexible enough to meet the requirements of each child, and at the same time is structured enough to aim towards a similar goal, that of increased interaction, in different ways. A second important aspect relates to the method and result of behaviour selection and stimulus-response pairing. The aim is to provide a response in an altogether different agent from the child, which is recognisable and coupled to a specific stimulation action. The decision mechanism will need to be robust enough to produce the same responses given a similar stimulus, while still being able to develop with the child's interactions and increase in complexity. This rate of complexity must also be rapid enough to maintain the child's interest while not developing too far ahead of the child.

In conclusion, robots can make a valid contribution in the process of rehabilitation (for example Harwin et al, 1995, Keates & Robinson, 1997, and Stroud et al, 1996) and have the potential to make a contribution in the area of autism. They are able to produce consistent, repeatable and reliable behaviours. This produces a stable environment for the user and builds a level of trust in the interactions present. At the same time, a robot is able to subtly adjust its actions to maintain the interest level without becoming greatly unpredictable. We believe that robots have the potential to make a contribution in area of autism and posses the relevant qualities to aid in the rehabilitation of autistic children, while also giving enjoyment to the children

Notes

Interactions between robots and children with autism are said to have been studied years ago at University of Edinburgh, UK, but so far we are unsuccessful in tracking down scientific documentation on this.

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