CIARA: Children's Interactive Robotic Agent

Richard Priest

Department of Computer Science
The University of Reading
contact@missingwidget.com

Abstract

Human robot interaction is a recently emerged area of research that is working to understand how to build robots that are better at successfully navigating social interactions with people, especially children. Human robot interaction stems from several existing fields of inquiry, primarily human computer interaction, robotics and artificial intelligence. It also draws on, with lesser extent, other areas such as psychology, embodied conversational agents (animated agents), and also communications theory.

This paper presents an animated robotic agent, designed for research on social interactions between robots and children, with a special aim towards children diagnosed autistic. Within this study I address elements of interactions through animation of the robot, the visual interactions with children, as well as vocal interactions. Also the implications of this study are addressed, detailing the impact on teaching for the future.

1. Introduction

When analysing interactions between computers, robots and humans, of any age, the interaction can be assigned into low level behavioural criteria. These low level behaviours are also known as micro behaviours. These micro behaviours have been used in the "Aurora project", based here in Reading and also at the University of Hertfordshire in Hatfield. The project was used to develop the idea of using robots as therapeutic tools for children with autism. The study was based largely on the eye gaze of the children interacting with the robot.

2. Functionality

To play games in a physical way (animation of a physical robot) would require movement with a great degree of range. This includes "arms", "legs" or any other manipulative or motion creating device. However games can be played ion software, simple turn based games that can be found on desktop PC's. These are reduced social interactions compared to those between a child user and a robot.

Interacting during teaching is very important due to the inherent nature of the classroom i.e.

- Teacher asks question, student responds with answer, teacher acknowledges response.
- Student asks question, teacher responds with answer.

This interaction can be done through simple interfaces with a robot.

Amongst my research into the project I have found it is documented that children diagnosed autistic can be helped to learn quicker and easier through the interaction with machines and robots, rather than through communication with teachers and fellow students. As with any diagnosis of disability of reduced functionality of humans, there is always a spectrum of severity. This is the case with children diagnosed autistic. The problems they encounter however do have an underlying theme of deficits such as, social interactions with other people, be it either with children or adults, communication within social environments, and also imagination.

In the case of social interactions, autistic children find people's expressions and reactions and interactions overwhelming, therefore feel threatened and confused. It is documented that children diagnosed autistic have a great ability to relate to computers and objects. This is due to the inherent nature of computers, that they are programmed and only able to perform tasks which it is programmed to do. Such with CIARA, the movements and the ways CIARA reacts and interacts is predictable. This may to a non autistic person seem boring; however it is just what an autistic child needs. As CIARA does only simple responses helps the building of interactions. CIARA could be used with an autistic child with only a few reactions, then slowly over time, build these up to a wide range of movements and gestures.

Some autistic children are classed as on-verbal, as in they do not talk, this would cause many problems with CIARA as vocal communication is a key and vital role in the interaction. In this case the micro behaviours may be detected by computational vision though CIARA's camera. This would be possible through detection of facial expressions and movements, yet very hard to implement at the moment.

3. Design

Upon starting the research for Project CIARA, I had to think of ways of getting ideas, not only for the functionality of the robot, but also the physical appearance. In order to produce a robot that is "socially acceptable" to children (ages ~6 to ~11), I would have to design it from a child's point of view. Being 22 now, I have my own design ideas; however I'm not six years old! So in order to gain knowledge of a child's perspective and expectations of a robot designed for the age range, I had to get designs from them.

To do this I contacted my old primary school, via email. A strange concept, as they didn't even have computers when I was there 11 years ago! The Deputy Headmaster, MR Tromans was who I got in touch with; he was very helpful and accepted aiding me with this project. I requested that the children draw robots they perceived as fun and educational. I wanted to know what the children thought was fun so I could design a robot that could do several things:

Focus their attention

Make learning fun

Not "scare" children who don't "understand" the concept of robot

In return from this I was provided with 263 perceived not good looking or unfriendly and 263 good looking drawings of robots.

On a brief look, the differences between the top and bottom age are staggering. Ranging from very simple shapes, to very elaborate complex multi function designs.

4. System Architecture

4.1 Robot Architecture

CIARA is roughly 15 inches tall, "standing" on rubber feet. It is built as a prototype platform for development of teaching and interaction ideas in the future. CIARA has two fully movable arms and head (see Figure1). CIARA is designed to be a stationary agent, so only a torso is present. The processing is currently taken place off board, away from the robot; however the rest of the components are embedded into the body and head of CIARA, such as monitor, speakers, microphones etc. The external connections to the computer are made by two parallel cable connections in the back of the robot. These cables carry data from the camera, the audio in and out of the head, and also the power and signal for the control servos and monitor in the chest.

I have chosen not to use legs, or even a dummy representation of legs as I feel it unnecessary as they wont be used, and may imply to the children that it can move, when it doesn't, and really shouldn't.

Figure1. CIARA from above, "the teacher's perspective"

4.1.1 CIARA's Head

The head shape itself has many reasons for its shape. When in profile, the bottom of the head forms a chin, this helps recognise where CIARA is looking. Also the shape is moulded around the basic shape of a human head, with a flat-ish face and forehead. When looking straight at the face, you can see how the head gets larger the further is gets from the "chin", this enables the microphones used for hearing to protrude from the head, to hear the user clearer. Also this design mirrors the shape of the body (discussed later).

As mentioned, there are many components within the head of CIARA. A VGA "web cam" is embedded within the head. Only one camera was decided to be used, as the need for stereo vision was considered unnecessary in this prototype. The camera was deigned to be placed near a computer monitor, an acceptable distance from a users face, because of this, the lens on the camera is sufficient for getting a large enough "picture of the world" from a distance of about 2 feet, which is about the distance children would sit from CIARA. To enable CIARA to "talk" there is a 3Watt amp, and a speaker also within the head. It was deigned to have these in the head as it helped the robot being socially acceptable to children, as the voice coming from the head, as apposed to the body, or even the PC.

The microphones are on the protruding part of the back of the head, as mentioned; this enables better hearing of the user, and also replicated the human head, with protruding ears.

There is no face! The head has no features such as a nose or eyes. This is due to the fact many autistic children find it hard to understand facial expressions, and can become confused and frightened at facial expressions. However there is a mouth, this is a string of LED's that light up in time to the voice.

4.1.2 CIARA's Body and Arms

The body holds the neck, arms and screen. The shape of the body mirrors the head shape, as described above. The body flares out as it gets toward the table. This stabilizes the robot, and provides a firm base for the weight it is carrying.

The neck is a simple 2 axis servo configuration, giving ~180 degree horizontal rotation, and also ~180 degree vertical rotation. This large range enables the head to produce obvious gestures, and also due to the frequency of possible positions, every 180/254= 0.7 degrees, subtle ones as well.

The two arms are symmetrically the same; the both have two parts, a forearm and an upper arm. The upper arm is fixed to the torso of CIARA by the shoulder joint. This is again a two axis servo configuration. This enables the arms to be lowered and raised, and also swept from side to side. The elbows are a simple single servo joint, enabling a flex and curl motions. In order to replicate the full motion of a human arms, there would need to be 5 different axes' of rotation, however I have been able to counteract this need by mounting the elbow joint at roughly 30 degrees to the fore arm. While making an initial prototype arm, I found that having the elbow not at this angle restricted the movement of the arm, and also made the motion very unnatural. By setting the elbow at 30 degrees inwards to the body, I found that it replicated the way humans arms naturally fall when relaxed. So when CIARA is not moving, the arms look like they are in a human's natural position. This also greatly increased the range of motion for the arms, and therefore the possible number of arm gestures. Without this for example, CIARA would not be able to clap.

To display information and teaching cue's there is a 4 inch TFT monitor within the chest. This is able to display full colour images and text.

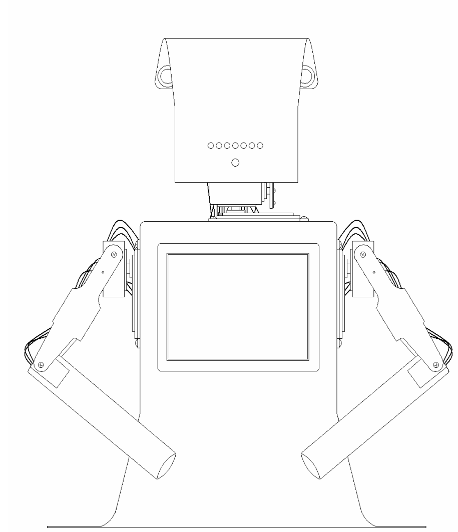

Figure2. CIARA's Design

4.2. Robot Control

4.2.1 Arms and Head

CIARA's arms and head movements are all done through pre programmed sequences of movements (discussed later). The gestures are complicated strings of these movements. For example the arm is moved to a position, followed bay another, then followed by another, this is done repeatedly to generate a gesture such as clapping or waving. When both arms and the head are moving simultaneously, the robot comes to life. These gestures have been generated through many hours of trial and error, programming and reprogramming to simulate realistic human gestures. CIARA's program decides what gesture to perform, dependant on the situation. This is done by interfacing with a servo controller, connecting to it, and controlling the eight servos. The control of the movement is done by sending a formatted string.

4.2.2 Video Camera

I have connected directly to the web camera, this streams video frames to the program to be analysed and edited. This is done by creating a capture window, connects to the driver, sets the preview frame rate (timed in ms), and starts the capture to the capture window.

In order to analyse the images received I have to copy the captured images to the clipboard, then paste then back onto an image.

4.2.3 Voice

For the robot to interact with the child socially, I have implemented the ability to talk. This uses the windows SAPI. I have called on this due to the simplicity to implement and reduced CPU usage. This method produces any word, some

The robot listens currently to every word and compares it to the expected answer; this is also done using windows SAPI. I have found this to work variably. This is one area I would like to develop further with the implementation of grammars to restrict to number of word the robot should expect the child to say. For example if the expected answer is four, the robot could hear the child say "for" and tell the child they are wrong, however with the use of grammars, the robot would understand "for" as "four" when expecting the answer "four". Some words are reproduced better than others. However it does give an understandable voice for children to understand. I would like to have a more realistic voice, maybe even a pre recorded voice for the robot to use, but this would limit the vocabulary and the ability to say anything.

4.2.4 Interacting

The interaction with the robot instils the nature of taking turns, waiting to be asked questions, and responding correctly.

The robot goes through a set of questions which are defined within editable text files. All questions are created abstractly and are not set. In the case of learning words, each level of education has a document listing the words the school ages should learn how to spell. When the file is loaded for the child's education, a word is randomly selected, and a question asked. In this prototype the actual questions asked are just a display of how the project works; they are not based on teacher's real questions, but can be changed to replicate a more realistic conversation. In this prototype, I implemented these questions when asking about words:

"How do you spell the word (say word randomly selected)?"
"What is this word?"
"What is the first letter of this word?"

When asking the child how to spell a word, the screen displays "SPELL" and waits for the child's response.

When asking the other two questions the word is displayed on the screen to act a visual aid to the child. In having these two random ways of expecting an answer from the children:

1. Child answers from memory with no cue apart from audibly hearing the word.
2. child reads the word or first letter

The child is developing 3 different skills. Using what they have previously learnt in the way of recalling spellings, and also identifying words written in front of them, and maybe more importantly how letters are put together to form words. Asking the question of "what is the first letter?" helps children remember the first letter of a word, a way of mentally organising words.

This is done also with letters, colours, numbers and simple mathematics. As with learning words, the skill level for the individual child is loaded up; this stops questions which the child would find impossible to answer being asked.

As the child may not be supervised 100% of the time by a teacher, the interface with the child is recorded in a log file to enable the teacher to look at the responses of the child after the interaction session has concluded. This enables the teacher to pick out problems or issues with the child's learning development, and tailor their own methods and subjects of teaching fro every child. It is almost a continuous assessment of the child's abilities, without it being in a "test" situation. This progress report would be a vital piece of study information in testing CIARA's acceptance by children

5. Development

To develop the project, I would do several things:

The voice recognition system would be updated to recognise words more accurately.

The camera which CIARA has would be used to recognise faces and the "flash cards".

More movements would be implemented to increase the realism. Also the movements would be tweaked to give more lifelike motions.

I have used two microphones either side of the head, but they are connected to the same line into the computer, thus only having mono hearing. I would separate these microphones to get stereo hearing so CIARA could literally look at where the voice is coming from, very useful if more than one child is talking to the robot.

6. Testing

As used in the Aurora project, in order to test the success of the design and interactions of CIARA a test situation would have to be set up. To do this, children within the determined age range, with or without autism or other learning disabilities would be required. If this was to be set up I would have CIARA setup and running within a room with a supervisor the child already knows and trusts, i.e. their school teacher. The child would not be told how to interact with CIARA that will be left up to the child. Several sources of measuring the interaction levels between CIARA and the child would be used. Whether the child firstly talks to CIARA is of great importance as it shows the design encourages verbal communication with a seemingly static object. The basis of turn taking is built into the whole interactions of CIARA, and therefore would be interesting to note how children fit into this taking of turns, and how quickly they realise this is how to interact. The camera in the head of CIARA could be used to determine how much attention is taken to the robot, either by eye gaze or being sat in front of the robot. This can also be recorded by the teacher supervisor in the room. An interesting point to find out within the eye gaze study would be where on the robot the child looks when being asked a question. As CIARA has deliberately been given a "moving" mouth to simulate the speech coming from the robot, and at the same time a screen to display question cues, it would be interesting to see if children look at the mouth or screen when CIARA is talking. CIARA is designed to have four main focuses for the children, which one is most noticed?

As CIARA would not understand every words a child says, and therefore presumes the answer to a question is wrong, where actually the child may have answered correctly. In this case, the study of how long it takes some children rather than others to get frustrated and annoyed could be used to research other areas such as anger management in children.

As well as getting frustrated with CIARA, the test situation would enable me to see if children enjoy talking and interacting with CIARA. As in the project specification, using CIARA should fun for any child, and this could be seen in the reactions of the children, either smiling or laughing or any other response apart from "this thing is rubbish"!

7. Conclusion

Many children may be scared of a robot. For these children, a robot could be seen as a threat. This can be due to the lack of knowledge, understanding and interaction with robots and computers. In this case CIARA could be used as the breaking introduction to modern technology, and interface with computers.

In order to test the effectiveness of CIARA I needed to get a professional opinion on the project. To do this I got in touch with a Senior Paediatric Occupational Therapist, Anna Wilson from the Camden NHS. I sent her the introduction and specification and functionality, along with 9 images of the building of CIARA (development images). She replied with a formal letter and a review of the project. This letter explains that CIARA would be helpful to those children diagnosed autistic. She says "CIARA would be a fantastic resource for children with Autism" and would "develop their social skills, language and learning". This shows that project CIARA has succeeded in aspects of possible functionality.

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