Gary the Robot
The Design and Construction of a Robot for Use in the Study of Autism

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Overview
For our senior project, we designed and built a robot with the intended purpose of being used by researchers looking into autism. This idea was proposed to us by our advisor, Brian Scassellati. This report will discuss autism, explain how robots are used in its study, and describe our process from conceptualization through design, building, and coding.

Autism
Autism is described as “a lifelong developmental disability that affects the way a person communicates and relates to people around them.” Its symptoms are many and various, but mostly relate to social development and interaction. The National Autistic Society states the three main symptoms of autism as difficulty with social interaction, social communication and social imagination. There is no perfect way to diagnose the disease, especially at an early age, and the severity and characteristics expressed by individuals varies immensely from case to case. There is no cure, and the cause is also unknown, but has been shown to be related to genetic factors.¹

Robots and Autism
Robots are being used in the diagnosis, treatment, and study of autism. Autistic children have been shown to act very differently toward robots than towards other human beings. First of all, they will maintain eye contact with a robot much more readily than with a human. A noted characteristic of autism is a lack of eye contact as the child will more commonly look away, or often focus on the mouth. Interestingly, when interacting with human like robots, this ceases to be the case, although the reason is unsure.

Another behavior that has been noted deals with attention span. When a non autistic child is interacting with a robot, the child’s interest is held only as long as the robot is responding to the child. If the robot is performing a preprogrammed course of action, the normal child will quickly figure this out and become uninterested. This happens to not be the case with a child with autism. The child will sustain interest in the robot whether or not it is receiving a response to its actions. These features, along with the fact that they are easily controllable and can be made to do repeated actions, are why robots are used a great deal with autism.

Specific examples of robots currently being used in autism study are Keepon (Fig. 1) and AuRoRA. While Keepon is mainly being used in studies relating to autism, AuRoRA’s objectives deal more with therapeutic use and education. In one study performed using Keepon, autistic children “showed vivid facial expressions that even their parents had not seen before.”²

Our Concept
When initially thinking about what sort of robot we were going to build, we came up with many goals. First and foremost, we wanted to keep it very simple and straightforward. This would make sure it was feasible to build, but also we


realized that the most successful robots are those that come from simple ideas executed effectively. The perfect example of this is the robot Keepon mentioned above. Created by Hideki Kozima and his team at the National Institute of Information and Communications Technology, this robot, seen below, has been incredibly successful with regard to its human interaction, even with its incredibly simple, yet aesthetically pleasing, design.

The most important design goal was to create a robot that could maintain eye contact. As mentioned before, this is one of the most studied aspects of autistic children, and an extremely important social cue. The second ability we wanted our robot to have was to be able to approach or back away from the subject. The idea behind this is that it would be beneficial to be able to study the aspect of personal space with an autistic child. Not much research has been done into this subject, and we thought it could be an interesting thing to study.

After these two primary objectives, we also thought the robot would need some capability of showing responsiveness, other than simple movement. It is important to be able to show that the robot is responding to the child, not simply just there to look at. We also decided that this responsiveness should be able to convey some sort of emotion. Obviously showing emotion is extremely important in social interaction, and because this is what is affected in autistic children, it is of great use to be able to study it. The last aspect we wanted to attribute to the robot is modifiability. Specifically, we wanted our robot to have the ability to change its outward appearance so as to be able to study what response these changes would evoke in subjects. The only other requirement we imposed on the design is that the robot would need to be remote controlled by the person performing the study, as the child should be isolated in the room with the robot, and have no distraction.

**Hardware**

After establishing the concept for our project, we moved on to create a physical design for the robot which could fulfill our goals. Keeping in mind that we wanted to employ a simple design which would be aesthetically pleasing, we came up with a human-like shape in its suggestion of head, neck and torso; but abstract and interesting enough to hold the attention of an autistic child.

The desire to maintain eye contact necessitated a head which could look in all directions, requiring a neck joint with two degrees of freedom. The need to lean in and out is fulfilled by the long neck with a joint at the shoulder. We gave the robot two antennae on the top of its head, which allow it to express responses and general emotion by “wagging” at varying speeds.

The core of the robot is constructed out of aluminum, but it has an aesthetically interesting skin and face which are attached by Velcro, allowing it to change its appearance when necessary. Also, many levels of our design allow the robot to be remote controlled: user-operated software on a laptop controls the robot’s actions through a servo controller; a camera mounted in the head (disguised as the nose) allows the user to see what the robot sees; and, batteries provide a mobile power source. The robot can be seen in Fig. 2.
The neck joint, which connects the robot’s head to its neck, is composed of two identical servos, which provide the two degrees of freedom necessary. The servos and body parts are connected in series like so: neck → servo1 → servo2 → head. This allows the servos to use their full 90° range of motion. The first servo’s shaft is mounted vertically into the top of the neck, so that as it rotates, it spins the head side to side. The second servo is mounted horizontally into the side of the first, allowing the head to nod up and down. By controlling these two servos throughout their ranges, the user can make the robot look through a full window of directions in front of it. A close up of the neck joint can be seen in Fig. 3 and Fig. 4.

The head is also home to other devices besides the two servos which control its movement. A commercial web cam is mounted to the face plate and disguised as the nose of the robot. We had to strip away most of the plastic shell of the web cam, in order to make it fit in the confined space of the head. Two miniature servos are also mounted to the top of the head; these servos control the antennae, allowing them to wag back and forth above the head. These can be seen at the top of Fig. 3.

The shoulder joint, which connects the robot’s neck to its base, consists of a single servo which controls a lever system allowing the robot to lean in and out. The neck rotates about a fulcrum at the top of the base, but continues on to descend deep into the base itself. An axis held by bearings at this fulcrum bears the gravitational weight of the head and neck; meanwhile the servo is connected to the neck shaft by a U-shaped aluminum clasp, so that it bears no weight. Originally, the head was still too heavy for the servo to produce the necessary torque to allow the robot to lean. To counteract this issue, we stripped the head of all unnecessary weight, reducing it to an aluminum frame with a face plate. We also mounted a heavy weight at the bottom of the neck shaft to counter the weight of the head perched on top of the neck. With these weights balanced, the servo only has to produce a minimal amount of torque in order to rotate the neck, and it is capable of rotating through its full 90° range and still supporting the weight of the head. A close up of the contents of the base of the robot can be seen in Fig. 5.
Hidden inside the base are two other crucial components of the robot: the servo controller and the power source. The servo controller, purchased from Pololu, interfaces with a laptop through a USB connection and is capable of controlling up to 16 servos. This controller requires a power source of around five volts, which we provide using four 1.2V AA batteries connected in series. We chose rechargeable NiMH batteries because of their high capacity (2600mAh) which works well in powering a number of servos. With extra batteries always available waiting nearby in the charger, there is no reason the robot should ever have any power issues.

The final aspect of the design is the aesthetics of the robot. We chose a visually stimulating tie-dye blue fur as our initial cover for the robot. However, this skin is held on only by Velcro, so it is not at all permanent. If future researchers wish to modify the appearance of the robot, new skins can be selected and applied with relative ease. The removable skin also provides easy access when needed to the wires and components hidden beneath. The face itself is also fully customizable. We started with a simple face of just two ping-pong ball eyes in addition to the permanent web cam nose. Like the skin, facial features are attached with Velcro, so future users of the robot can easily design and apply their own faces. Even the antennae are fully customizable: they are made of a soft malleable wire which can be shaped in any way. One could even go as far as to replace the antennae all together with some other objects, such as rabbit ears or Martian eyeballs on stalks.

Software

The first step in creating the software was to implement servo control. To do this, we needed to communicate with the servo controller via the USB port. The way the servo controller driver works is to transform the USB port so that it appears to the computer as a serial port. The program then sends strings of bytes through this port that the servo controller interprets as commands and sends the appropriate voltages to the servos. To send the information to the serial port, we purchased Franson’s SerialTools.NET software.

Our second step in creating the code was to display the output from the camera in the form. To do this, we put a picture box in the upper left corner of the form. Our code then samples the output from the web cam and displays it in the picture box so that the video feed is embedded in the form.

As soon as we were able to control the motion of the servos and display the video feed, we had to design an easy to use interface so that the experimenter could smoothly control the robot. We wanted to have something that was intuitive and thus would take a very short time to learn. The first movement we needed to control was the neck joint. This joint is very important as it is what allows our robot to maintain eye contact with the subject. The experimenter would be looking at the subject via a camera that would be displayed in the program. To make it easy to follow the subject’s head, we initially wanted to have the neck joint being controlled by placing the mouse over the video display so that the robot would move toward where the mouse was pointing. This way the experimenter could be looking at the incoming video and looking at where he was clicking at the same time. However, the problem with this was that while the mouse was over the picture box, the program could not see its location.

Our next design was to create a control box below the picture box so that the experimenter could be looking at the video and mouse at the
same time. Then the movement would be controlled in the same fashion as if the mouse was over the video input. If the experimenter clicked in the upper left, the robot would move to look at that position. However, this also proved not to be a viable option in the end. The problem with this idea is that the computer cannot tell the servo to simply move one way or another. It has to communicate an exact position. Additionally, the computer does not know the location of a servo at a particular time. All it knows is where it last told the servo to go, not if it is there yet or how close it may be. So we could not tell the servo to simply move right and then stop at some point in time, we needed to directly control the position.

The final solution to this problem was to have the control box represent the range of motion of the servo, meaning if you click in the top right corner, the robot will look up and right. Initially, we divided the box into a three by three grid, so that depending on which of the nine squares you clicked in, it would move to one of nine set positions. After testing this method and discovering that it worked, we decided that we wanted a finer control of the position, especially as this is important in maintaining eye contact. To do this, we take the mouse position and convert it to a fraction of the control box size in the x and y direction. We then tell each servo to go this fractional distance between its minimum and maximum positions. This allows the maximum possible control of the servos. As a finishing step, we preprogrammed two movements into the joint, a nod movement for “yes,” and a shake movement for “no.” We thought it would be useful to be able to perform these basic signals of communication.

After the neck joint, we moved on to the shoulder joint. This was easier as it is linear, and does not need to be as precise since it is not going to have to follow anything, only be able to convey leaning in and leaning out. The control of this joint is facilitated by a scroll bar to the left of the neck joint control box. By default, the up and down arrow keys will control the lean. Also, clicking on the bar will also change the lean position. We currently have the bar’s possible values set from 0 to 10 for 11 different lean positions. However, this mechanism also employs a fractional control of the servo, so by changing the maximum and minimum values, it is easy to modify the control of the lean.

The last servos we implemented were those controlling the antennae. These were much simpler, as all we wanted to do was control the speed at which they would wag back and forth. We programmed three settings: stationary, fast, and slow. This is the robot’s main method of responsiveness, and communicates its emotions: neutral, happy, and sad, respectively. Additionally, when conveying sadness, we had the robot tilt its head down. This is due to the fact that slowly moving antennae alone do not necessarily convey sadness.

The final step was to design the program to be aesthetically pleasing and easy to use and learn quickly. The form is dominated by the video display, and the main servo control below. This allows the experimenter to easily see what the robot is looking at, and precisely control its movements. Down the right side we placed the emotions and preprogrammed movements. These are grouped as such, and allow whoever is controlling the robot to quickly change from between moods, and nod and shake when necessary (fig. 6).

Conclusion

In the end, we have created a robot that does exactly what we sought out to achieve. We have met all our goals and objectives, and have built an easy, clean, and relatively simple robot that will be able to be used in research relating to autism.

The main area in which we would like to see improvement is the motion. The robot does not move as smoothly and naturally as we would
like. The reason for this lies in the servos. First of all, the torque of the servo controlling the lean causes this motion to oscillate slightly as it moves from position to position. The other movement is that of spinning the head back and forth. The position of the servo cannot be held as firmly as we would like to stop it from shaking as it looks from side to side. Lastly, the noise that the servos create is mildly distracting and it would be nice if it could be eliminated. These problems are not a function of our design, but more so of the limitations of the motors.

Despite these imperfections, we are proud of what we have achieved. We will now pass our robot and program over to Professor Scassellati to be used in studies in conjunction with the Child Study Center.