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Humanoid Robot Development

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by

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Abstract

Robotics is an industry that is rapidly growing all over the globe. One of the most fascinating areas is the industry of Humanoid Robotics. This project was to create a humanoid robot that would walk smoothly on two legs. The report details the process in which the robot was designed, manufactured, assembled, programmed, and tested. Also included is a series of recommendations for further expansion of the project.

Acknowledgements

This project was done in unison with members of the student and faculty at the Huazhong University of Science and Technology. We will like to take this time to thank these members who have helped us in the completion of this project.

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1 Introduction

The study of robotics originates back to ancient Egypt where priests created masks that moved as a way to intimidate their worshippers. Robotics, as we know it today, originated half a century ago with the creation of a robot named “Unimate”. This robot was created by George Devol and Joseph Engelberger. Unimate was created with the intention of being used in industry at a General Motors plant, working with heated die-casting machines.

In recent years the development of humanoid robots has become a larger area of focus for the engineering community. Humanoid robots are precisely what their name would lead you to expect, robots designed to look and act like humans. While their current use is primarily within the entertainment industry, there are hopes that one day they will be able to be used in a broader domain.

Modern investigations into humanoid robot development have lead to the desire to create a robot that can not only walk from one destination to another, but also discern objects in front of it and be able to compensate for that by moving around them. This was where the current project came into play. The purpose of this project was to design and build a humanoid robot that was capable of walking smoothly.

Due to constant advances in technology, humanoid robots of the future will be capable of helping mankind by accomplishing tasks that may too dangerous, dirty, dull or even physically impossible, such as exploring other planets. Though there is still room for improvement for the locomotion of these robots to become more and more similar to that of a human, the future looks bright for the development of the next generation of humanoid robots.

We created a humanoid robot with a pair of legs, a pair of arms a torso and a head, which was able to walk in a manner similar to that of a human. The walking motion was controlled by a program written by members of the team. For the head we used a camera that would eventually give the robot a vision capability and complete all the attributes required to be a “human”. Some extra capabilities that could potentially be added in the future were making the robot be able to detect obstacles in its path, and avoid these obstacles by finding the quickest path around that obstacle.

2 Background

2.1 Brief History of Robotics

According to the Webster dictionary, a robot is “a machine that looks like a human being and performs various complex acts (as walking or talking) of a human being.” The first place where the robot was introduced was in the play Rossums Universal Robots (RUR) in 1921 by the Czech writer, Karel Capek. The word robot comes from the Czech word “robota” which mean forced (compulsory) labor.

The first "modern" robot, digitally operated and teachable, was invented by George Devol and was called the Unimate. The intention of creating Unimate was for it to be implemented within the automotive industry as a tool that would help eliminate some of the dangerous and strenuous work current employees were doing. The first Unimate was personally sold by Devol to General Motors in 1960 and installed in 1961 in a plant in Trenton, New Jersey to lift hot pieces of metal from a die-casting machine and stack them.

2.2 Definition of Humanoid Robots

When asked to envision a “robot” most people will tell you they imagine a piece of machinery that resembles a human form. A humanoid robot can be defined as “… a robot with its overall appearance based on that of the human body. In general humanoid robots have a torso with a head, two arms, and two legs (although some forms of humanoid robots may model only part of the body)… A humanoid robot is an autonomous robot because it can adapt to changes in its environment or itself and continue to reach its goal" (Science Daily: Humanoid Robot).

The torso of a humanoid robot serves two major functions. The first is that is typically houses the central computer for the robot as well as the power, in most cases batteries. Secondly, the torso is where the center of mass is located. This will prove to be crucial when we are determining the placement of the power and computer in the robot. Attached to the torso are a head, arms, and legs.

Robots can have arms for many purposes. When designing a robot whose primary objective is walking, arms are likely not going to be needed to perform assigned tasks. The arms instead have the potential to be used to balance the robot. If a robot is turning, its center of gravity can be thrown off center and cause it to start to lean. The arms can be used in order to help it regain balance.

The cameras and/or sensors used to discern objects in front of the robot are located in the robot's head. As with humans, robots have the capability of having their heads be able to turn around a certain pivot point, i.e. a spine. Having the ability to discern objects around it and not just in front of the robot will allow it to better adapt to its surroundings. Some robots are also given the capability of showing emotions when given extra sensors and programs to help it recognize the emotions of people it is interacting with.

The last, and possibly most important, characteristic that helps define a humanoid robot is legs. There are several different ways in which a robot can walk on two legs. One method was demonstrated by a team at the Massachusetts Institute of Technology (MIT) with their robot named Toddler. The robot wobbled side-to-side with two straight legs, thus giving it the name Toddler. More recently, robots have started to be created with a greater human likeness. Legs are being created with hips, knees, and ankle joints. With every robot, there are different methods of creating these legs based off of the task it is designed to do. Another important aspect to consider is the shape of the foot, particularly with regards to its interaction with the ankle joint. Some robots are created to push off with the foot in an effort to move it forward, while others depend on the motors in the robot's upper leg to move it.

The mechanical aspects of the robot are a major part in defining it as a humanoid robot; however the software is also unique. Humanoid robots are also known for being able to interact with humans and adapt to their surroundings. They are also known for being able to learn new material and then use it at a later date, whether it is face recognition or potentially remembering a path previously taken.

2.3 Current Uses of Humanoid Robots

Humanoid robots are currently being implemented in a wide range of industries. The most common place to find humanoid robots is within the entertainment industry. One popular attraction in America that uses these robots is the Hall of Presidents at the Walt Disney World theme park in Orlando, Florida. The hall contains robots created to imitate past and current presidents. Their life-like appearance and mannerisms adds an element of humanity to the attraction, while still being technologically fascinating. In terms of a product that is available to consumers, Sony developed a robot named Qrio which dances, runs, recognizes faces, maintains its balance, and can get up if knocked over.

In the work force humanoid robots are currently a couple popular uses that will eventually be expanded upon. These robots are being used as receptionists in large companies as well as some technological universities. Some of the capabilities these robots include are greeting people as they enter, giving directions, and transferring phone calls. Security is also a popular means by which humanoid robots are being introduced into the work force. Tmsuk, a Japanese based company, created a robot named Robo-Guard. Its capabilities include using an elevator, patrolling round-the-clock, replacing its own batteries, and wielding a fire extinguisher.

Figure 11: Commercial Robot (Qrio)

Figure 12: Commercial Robot (ASIMO)

2.4 HUST Robot Club's Biped Robot

The robot designed by the Huazhong University of Science & Technology's (HUST) Robot Club had several limitations that became obvious when the team first analyzed its capabilities. The most obvious limitations that stood out to us were the lack of a torso, head, and arms. Lacking these features did not allow the robot to fit the team's definition of a humanoid robot. Another problematic feature of the HUST robot was the unusual design of its feet. They were unnecessarily large and conflicted with one another while in motion.

The design was also flawed with regards to the fact that zip ties and electrical tape were used to keep some of the motors together as well as the electrical wiring. There was also no designated place to hold the battery and the control board, instead they were held on top of the legs and by zip ties. Regardless of its flaws, the HUST robot was able to walk. However the walking motion was not very steadily due to inadequate motors and a poorly assembled structure for legs. In addition it was capable of correcting its leg placement, i.e. made sure both legs were facing straight ahead, before it was given the command to walk forward.

The Robot Club's robot was also capable of carrying a heavy load and as a result it came in first place through a series of tests at the RoboCup in this category by a wide margin. Because the HUST robot had no upper body and hence had no sensor to sense a white line and make a turn, it lost at this event in competition. An example of the HUST robot can be seen below in Figure 2 and one of the designs can be seen below in Figure 3.

Figure 1: HUST Robot Club Assembled Robot

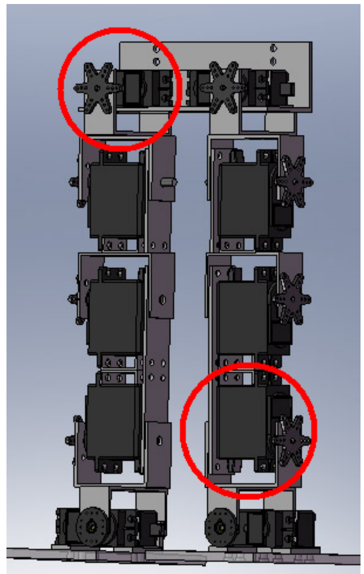

Figure 2: HUST Robot Club Second Design

2.5 Future Uses of Humanoid Robots

The possibilities for the use of robots in the future might seem limited to some but to many others, the possibilities are endless. With advances in technology every year and current improvement being made to robotics, robots will in the future be doing more than painting cars at Ford plants, assembling Milano cookies for Pepperidge Farms, walking into live volcanoes, driving trains in Paris, and defusing bombs in Northern Ireland.

Robots are becoming extremely important because they will do things that we can not do or in some cases do what we do not want to do. In the future, we may also see robots being used for prosthetics. Both doctors and engineers, are working together to create prosthetic limbs that use robotic mechanisms.

3 Methodology

The goal of our project was to create a robot that will improve upon a previously made robot by correcting its walking movement and adding an upper body. In order to meet this goal we will need to accomplish the following tasks:

1. Design a robot with two legs and an upper body
2. Manufacture the required parts
3. Assemble the robot
4. Create a program which will allow the robot to walk smoothly
5. Test the robot

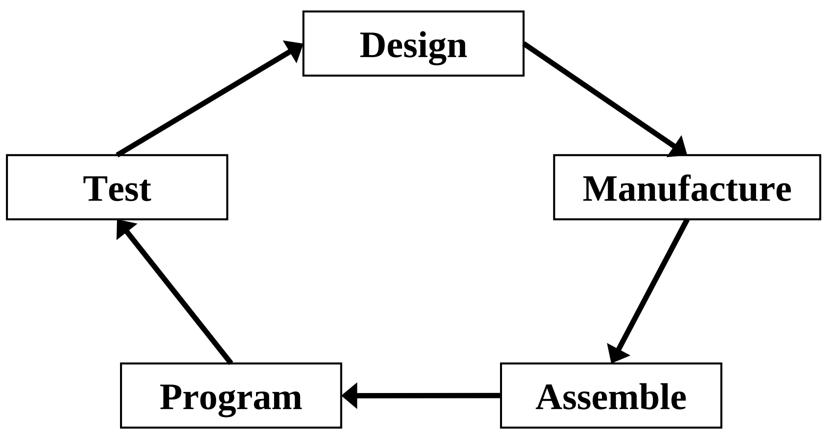

Figure 3: Methodology Flowchart

3.1 Designing the Robot

Prior to designing a new robot, the team investigated other successful designs for biped robots, primarily the design of a biped robot previously created by the Huazhong University of Science & Technology's (HUST) Robot Club. When analyzing the Robot

Club’s walking robot the team created a list of Pros and Cons with regards to the aim of our project:

Pros	Cons
Can walk on two legs	Doesn’t walk smoothly or straight
Has 10 Degrees of Freedom	Has no upper body
Corrects hip placement	Shakes (Motors vibrate, screws loose)
Capable of turning	Motors relax easily

Table 1: Current HUST Robot Pros and Cons

After creating this list we investigated another robot designed by the Robot Club that had been disassembled. This robot was similar to the assembled robot that we first analyzed, however it had some differences. The major differences were the placement of the ankle motors and the orientation of the motors in the hips (see Figures 2 and 3 below).

Following the analysis of these two robots the team would need to decide what aspects of the two robots we wanted to use again, and which aspects we would need to redesign. Some of the major concerns with the designing of the new robot were, the number of degrees of freedom that the legs would have, the hip joint orientation, the ankle joint orientation, foot size and shape, and how to attach the upper body.

In addition to redesigning the robots legs the team would also need to design an original upper body. The upper body would be required to serve two main purposes. Firstly, the upper body would serve as a place to hold the robots power supply. Secondly, the upper body would be used as a base for a camera to be added, if time permits, to allow the robot to detect images, i.e. boundaries of a soccer field.

The program we decided to use to design the robot was SolidWorks. The reason we chose this program was because the Robot Club’s designs were created in SolidWorks and a few of the team members had prior experience with SolidWorks. The main benefits of the program was that it was easy to learn for the team members who had not had the chance to use SolidWorks and we would not be required to convert the designs created by the Robot Club into another program.

The robot built by the Robot Club was manufactured out of steel and aluminum. These materials were the two which the team decided to investigate using for the robot. We also needed to investigate what motors we would use for the robot's legs and upper body. The design could not be finalized until we researched and chose what motors and developing board we would use for the robot (see 3.3 Programming the Robot for more details). One of the major concerns the team had when determining what materials we would use for our robot was our budget. The team was originally given a budget of 1000 Yuan, however if we could justify needing more money we were allowed to present our case to our advisors.

3.2 Manufacturing the Required Parts

Before being able to manufacture the parts the team would need for the robot, the team had to contact the head engineer in the Engineering Training Center. Our initial contact included asking for permission to use the lab and also having our final design approved. After getting in contact with him the team learned correct manufacturing techniques. These techniques included, but were not limited to, proper use of the mills, drills, files, and saws.

In order to convert our design into a tangible product the team had to convert our 3D designs into 2D drawings. This was possible to be done in SolidWorks. The drawings needed to have proper dimensions for every length, hole diameter, and material thickness.

Most of the parts the team required had a length of either 25mm or 50mm at the base of the part. To accommodate these dimensions the team bought two pieces of hollowed aluminum stock which were 25mm x 50mm and 50mm x 50mm, each having a thickness of 1.2mm and 2mm, respectively. The reasons the team chose aluminum was because it is light, cheap, and easily found in Wuhan. The one major drawback to choosing aluminum was that it is not very strong and easily bent.

When manufacturing the parts for the robot, we needed to follow certain steps in order to assure the parts would be made correctly and quickly. First the team had to measure the material and mark the dimensions of the parts we would create from that specific piece of stock material. Once the parts were all measured the material was sawed to get a rough shape that could later be reconstructed to make a specific element for the robot. These pieces were then measured and sawed again to accommodate any remaining sides that had different dimensions.

After the pieces were cut into a raw shape they were milled. This process was done to make the parts their correct dimensions and give them flat and smooth sides. Once the parts were milled to their correct size the 2D drawings were consulted to determine the hole's location and diameter. Following lines being drawn on the part, the hole was marked for drilling. The holes were then drilled the diameter that was required and inspected to assure the parts were high enough quality to be used in the robot. After all the parts were manufactured and the motors were delivered the team was able to assemble the robot.

3.3 Programming the Robot

The programming of this robot can be broken down into three sections, firstly the developing board, secondly the walking program, and finally the vision program. The main challenge that teammates were presented with when programming the robot was learning the programs. Learning the programs included applying theory teammates had learned in classes as well as communicating with other students who have done similar programming, people in the Robot Club, and professors. Students also had to learn how to use Linux and/or programming in the C language.

3.3.1 The Developing Board

When choosing a developing board, the team searched the internet to find something that would be capable of executing the actions the team desired of our motors. Some of the main criteria the team felt were necessary for the developing board were size, features, how recent the technology was, and if it would have the capabilities to eventually add more advanced features in the future.

3.3.2 Walking Program

The walking program for the robot was intended to have all fifteen motors working simultaneously to allow the robot to walk. The main walking program would coordinate the walking motion of the legs with the movement of the arms in order to better allow it to maintain its balance. Another aspect of the walking program was allowing the robot to correct its hip placement before walking. This was all written in the C programming language and controlled by the developing board.

3.3.3 Vision Program

The main function of the vision program is to take the images the camera gathers and processing them. The key to this aspect of the robot is having the correct type of camera. The camera must be able to communicate with our developing board and outputs uncompressed data. Having the camera output uncompressed data will make it easier to program. Some other functions that will be essential are speed of the image processing and accuracy of the camera. For help with learning to program two professors in the Image Center were consulted as well as a member of the Robot Club who had previously done this sort of image processing.

The final program is intended to resemble the following diagram, incorporating both the walking and the image processing:

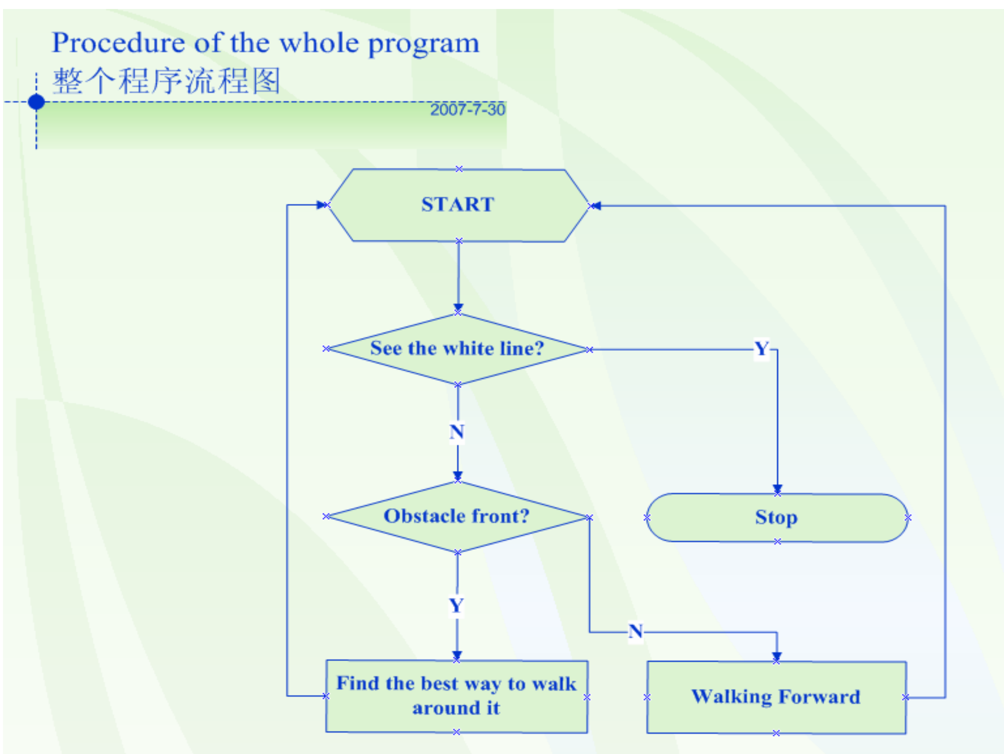

Figure 4: Procedure of the Whole Program

3.4 Testing the Robot

After designing, manufacturing, assembling, and programming the robot, the final product needed to be tested. The team decided to set some standards in order to determine what would qualify as a successfully completed robot and a robot that would require more work. The major standards are as follows:

1. Does the robot maintain its balance?
2. Do the motors all function simultaneously?
3. Does the robot walk smoothly?
4. Does the upper body move?
5. Does the camera move?

If the robot achieved the first three goals it would be considered a successfully completed robot. These goals were set forth at the beginning of the project in order to give the team a base goal to achieve. The fourth and fifth goals were set in place as a higher goal that the team would strive for in order to take the project above and beyond its expected limitations. If the fourth and fifth steps were completed the robot was considered beyond successful.

4 Results and Analysis

4.1 Designing the Robot

The design for the team's robot was generally based off those of the Robot Club. Based off the two main designs we investigated, the HUST assembled robot and second design, the team took the best features of leg and compiled them into one design that maximized both of their potentials.

4.1.1 Designing the Legs

From the HUST assembled robot the team used the hip placement of the legs as well as the visual appeal of grouping two motors to serve as the thigh and knee and two of the motors grouped to serve as the ankle. As for the second HUST robot design, the aspects the team was interested in using were the feet, and ankle combination, the top plate that allowed for an upper body to be attached as well as giving somewhere to place the battery, and the overall streamlined, almost human-like, look of the legs.

Before we were able to design the legs we had to order motors in order to get their dimensions so we could make our model accurate. After searching on the internet the team came up with three options for motors. The first motor was a MG995 (Figure 5). The MG995 had a torsion force of 13kg-cm, had the dimensions of 40mm x 20mm x 36.5mm, and the cost was 53 Yuan/motor. The second motor was an Esky (Figure 6). The Esky had a torsion force of 3.2 kg-cm, dimensions of 40.4mm x 19.8mm x 36mm, and the cost was 45 Yuan/motor. The third motor was a 13DM81 (Figure 7). The 13DM81 had a torsion force of 13kg-cm, dimensions of 41mm x 20mm x 36mm, and the cost was 450 Yuan/motor. The team decided to chose the MG995 because it had the largest torsion force for the lowest price.

Figure 5: MG995 Motor

Figure 6: Esky Motor

Figure 7: 13DM81 Motor

With these considerations in mind the team started to design their own legs. In order to maximize the time the team had to create this robot the team members in charge of designing decided to recycle most of the parts that the Robot Club had designed in SolidWorks for their robot. The team designed one leg in about 2 days. The design consisted of two motors attached to each other at the base in order to create the hip and knee joints of the thigh. The motor on top was put in place in order to compensate for the forward and backward motion of the hip. The “thigh” was attached to another motor whose orientation was upside down in order to resemble the shin and ankle. This motor was to be used for the forward and back motion of the foot. Below that there was another motor given a horizontal orientation in order to allow the feet to have a perpendicular degree of freedom as well. See Figure 8 below for a SolidWorks image of the leg design.

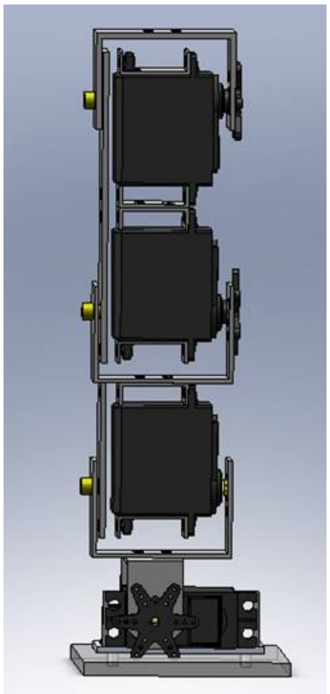

Figure 8: Team 5 Leg Design

4.1.2 Designing the Upper Body

For the upper body, the team decided that rather than use the Robot Club's design for an upper body as the basis for the team's design they would create their own design. In order to compensate for the upper body being able to move from side to side, like a human, the plate designated to serve as the torso for the robot would have a shape similar to that of home plate on a baseball field. This shape allowed the robot to not only have it's torso move, but it also mad the upper body more firm. Next to be designed was the arms. As the team currently does not have any specific tasks for the arms to complete, the arms were designed to have the basic function of moving up and down at the shoulder and elbow joints. In order to make the arms look more human-like the robot was given "hands". The head of the robot would be the camera which would be used to detect white line boundaries on a soccer field.

In addition to the torso and arms, the team also had to design a part to hold together the upper body and the legs. This part would also encase the motors that served as the horizontal rotation for the hips. It also served as a platform to hold the developing board and battery. See Figure 9 below for the SolidWorks image of the upper body design.

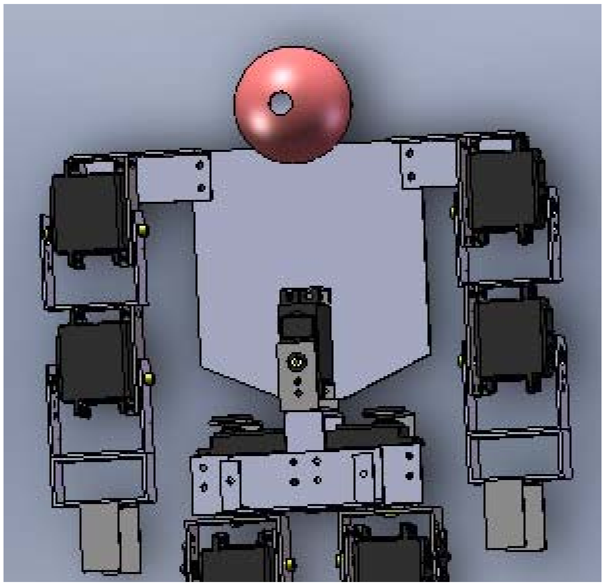

Figure 9: Team 5 Upper Body Design

4.2 Manufacturing the Required Parts

When manufacturing the parts for the robot the team ran into two major areas of concern. The first area was that the milling and drilling machines were manual, so even after being measured twice there was room for human error. For example, when milling the parts to the desired dimensions, there were a few parts that were milled to a width that was between 1mm and 3mm smaller than the needed size. This meant that some parts had to be made more than once.

The major problem the team ran into was the realization that some of the parts the Robot Club had created were good in theory, however when they were actually manufactured their quality was less than desirable. The main issue with these parts was that several holes were only 1mm apart, which did not leave any room for error. Also, aluminum, not being a very strong material, would bend and break if there was not enough of a clearance between the two holes. This meant several parts had to be redesigned and remanufactured. As a result of this, the team did not have enough material to make the torso of the robot out of aluminum, so it was manufactured in a polycarbonate resin plastic, similar to Lexan. This task set the team's schedule back half a week.

Assembling the robot also had its challenges. The team purchased screws and nuts after the first design of the robot. These screws and bolts were purchased in 3 different sizes. It was quickly observed that the number of screws purchased were not enough to finish the assembly, so the team had to purchase more, which set the schedule back another half day. There were also some parts that the robot required that were borrowed from the Robot Club because they were either expensive or not readily available in the market.

4.3 Programming the Robot

4.3.1 The Developing Board

After doing much research on the internet the team decided to purchase an AT2440EVB-I board (See Figure 10). This board was chosen because:

- It contains a Samsung s3c2440 Micro Processing Unit (MPU) which uses an ARM920T core. This means it is a current advanced embedded technology.
- It has the USB interface to support the camera and also 44 extra General Purpose Input/Output (GPIO) ports to support the motor control.

- It has audio, video, internet, BUS, Liquid Crystal Display (LCD), Universal Asynchronous Receiver/Transmitter (UART), and other sufficient resources to support future development of the robot.
- It is the smallest board compared to other boards that have the same character performance.

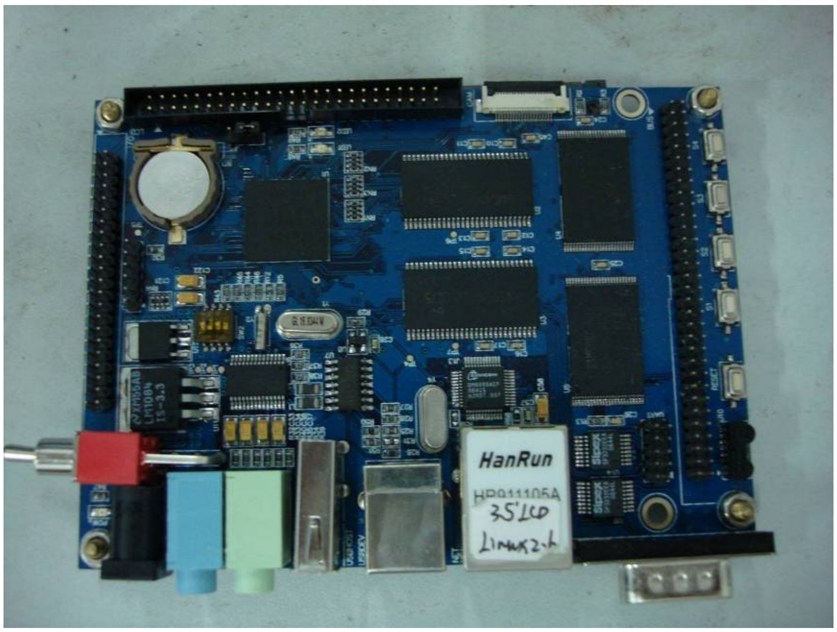

Figure 10: The AT2440EVB-I Developing Board

4.3.2 Walking Program

The walking program took several attempts to complete, however given the limited time the final product was satisfactory. The first attempt to create the walking program was very unsuccessful. The motors did not respond to the program. Following some adjustment to the program, the motors actually worked in the reverse. This malfunction caused the team to question whether or not the program was written correctly.

In order to determine whether or not the program was the problem or if it was something external, like the motors or developing board, the team consulted a member of the HUST Robot Club. This person informed the team that the program was written correctly and the potential error could be in the motors. This caused the team to disassemble the entire robot to exchange the motors for ones that the member of the Robot Club said would work with the team's program. Once the motors were exchanged the program was again tested and still did not work.

These setbacks lead the team to believe that they would not be able to finish the walking program. This fear was crushed when, after some more adjustments to the program, the robot began to move. The robot did not walk as the team had hoped, but it was moving. The team then sat down to adjust the program in order to make the robot walk.

The first program which allowed the robot to walk had a few problems. The first problem was that the robot did not maintain its balance and needed to be guided by the operator's hand in order to assure it did not topple over on itself. The program had the arms attempting to coordinate with the legs in order to help it walk in a fashion matching that of a human; however, the two motions were not coordinated as well as anticipated. The second, and final, attempt at programming the robot was more successful. The robot maintained its balance and walked, however its movements were very rapid. Due to a lack of time that program was the final product that was demonstrated.

4.3.3 Vision Program

The vision program was completed after much trial and error. The first concern the team had was which camera to use. The first camera the team purchased was not the correct type of camera and would not output the data in a form that the developing board required. After consulting with a graduate student who had done a lot of work in this field it was determined that the team needed to purchase a new camera. The second camera was a much better product for the task we wanted it to accomplish. The program was able to be written with assistance from professors in the Image Center as well as the company through which the camera was bought.

The total vision program was broken down into two major parts: the data receiving program and the image processing program. The data receiving program was created to do exactly what it would appear to, receive data from the camera. It could receive an image picture by picture, potentially allowing our robot to respond to a boundary in time. Its disadvantage was the impossibility to present the stable image. The image processing program was broken down into five steps: get the array data, clear the image, transfer from colorful image into monochromatic one, provide a HIGH or LOW value to every unit of the image, and detect the line by ratio of HIGH value (large ratio if distance is close enough). What this meant is that the image is taken from a color image and turned into a black and white one. The program then analyzes the picture by breaking it up into smaller parts and determining if they are black or white. The program then counts the height and width of the number of consecutive white pieces and if the number is high enough the robot will know to either turn around or stop.

4.4 Testing the Robot

Once the robot was assembled and programmed it could finally be tested. The standards the team set forth to determine whether or not the robot was successful were as follows:

1. Does the robot maintain its balance?
2. Do the motors all function simultaneously?
3. Does the robot walk smoothly?
4. Does the upper body move?
5. Does the camera move?

Following the analysis or the robot, it was determined that the robot did: 1. Maintain its balance, 2. have motors that functioned simultaneously, 3. The robot walked relatively smoothly, however very rapidly, 4. The robot's upper body moves in order to allow it to maintain it's balance as well as letting it appear more like a human. Regardless of the fact the camera was not attached, the project was considered a success because the robot walked, which was the initial purpose of our project.

5 Conclusions

This team was charged with the task of creating a humanoid robot that would improve on the currently designed and created robot built by the Huazhong University of Science and Technology (HUST) Robot Club's robot. Some of these improvements were to include adding an upper body and improving the walking motion of the robot.

After over four months of hard work researching, preparing, and completing this project, the team was able to put together a final product that achieved several important aspects of the goal that the team set. When the final product was completed, the body had two legs, a torso, a head, and arms. This allowed the robot to have an appearance similar to that of a human.

The programming and walking of the robot proved to be more difficult. The team had little prior programming experience which led to some of our major problems when the team was creating brand new programs for the robot. The final walking program allowed the robot to move in a fashion similar to that of a human, however its movements were very rapid and not 100% accurate. The vision program was completed with a little more success; however the program was not translated in order to allow it to be applied to the robot.

6 Recommendations

Following the determination of the projects success, the team brainstormed ways in which the project could be improved in future years. As previously mentioned, the ideal use of this robot was to compete in robotic soccer matches. In order for it to compete in these competitions the robot will need to be modified in three major ways.

The first major modification that the robot would require would be the addition of the actual camera onto the robot. Once the camera is securely mounted to the robot, it will become one step closer to competing in robotic soccer competitions. In addition to mounting the camera, the program for the camera needs to be converted into a language that the developing board supports. Another potential program that could be added to the robot was one that allowed the robot to recognize the ball.

After completing the aforementioned tasks, the robot's walking program would need to be adjusted in order to allow it to turn around as well as kick the ball. The turning program would run when the robot detected a white line meeting a certain criteria with regards to length and width. When kicking the ball, the robot would need to maintain its balance on one foot and at the same time swing the other foot, allowing it to kick the ball. By combining these walking programs and the vision program, the robot will be able to play soccer in a fashion physically similar to that of a human.

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