HUMANOID ROBOT DEVELOPMENT

Dr. V.BALAJI
Principal, Sapthagiri College of Engineering, Periyanahalli Dharmapuri *India*
emailid : balajieee79@gmail.com

***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 paper.**

***Keywords*— Robot, Automation, Humanoid, Qrio, Asimo.**

I. 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

II. Background

A. *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 RossumsUniversal 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.

B. *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). he 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 centre 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. .

C. 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.

Fig. 1 Commercial Robot (Qrio)

Fig.2 Commercial Robot (ASIMO)

D. 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 cannot 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.

III. 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

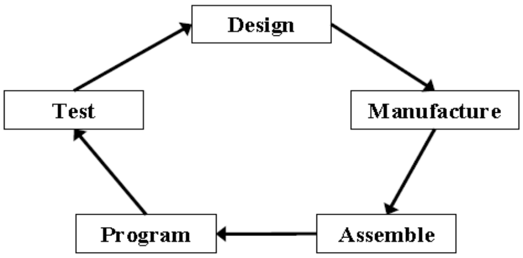

Fig.3 Methodology Flowchart

A. 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 analysing the Robot Club's walking robot the team created a list of Pros and Cons with regards to the aim of our project:

TABLE I CURRENT HUS ROBOT PROS AND CONS

S.No	Pros	Cons
1.	Can walk on two legs	Doesn't walk smoothly or straight
2.	Has 10 degrees of freedom	Has no upper body
3.	Corrects hip placement	Shakes (Motor vibrate, screw loose)
4.	Capable of tuning	Motor relax easily

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 analysed, however it had some differences. The major differences were the placement of the ankle motors and the orientation of the motors in the hips .

B. 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 aluminium stock which were 25mm x 50mm and 50mm x 50mm, each having a thickness of 1.2mm and 2mm, respectively.

C. 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.

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.

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) 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.

D. 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.

IV. RESULTS AND ANALYSIS

A. 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.

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 (Fig 4). 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 (Fig 5). 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 (Fig 6). 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.

Fig. 4 MG995 Motor

Fig. 5 Esky Motor

Fig. 6 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 Fig 7 below for a SolidWorks image of the leg design.

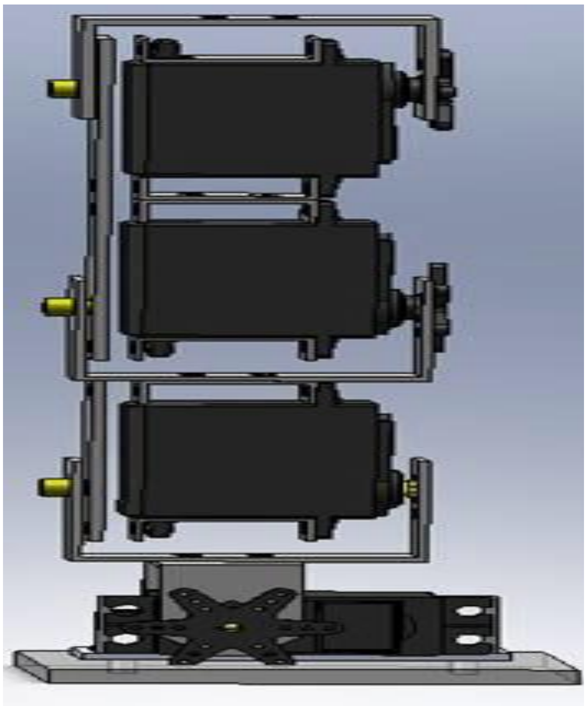

Fig. 7 Team 5 Leg Design

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 Fig 8 below for the SolidWorks image of the upper body design.

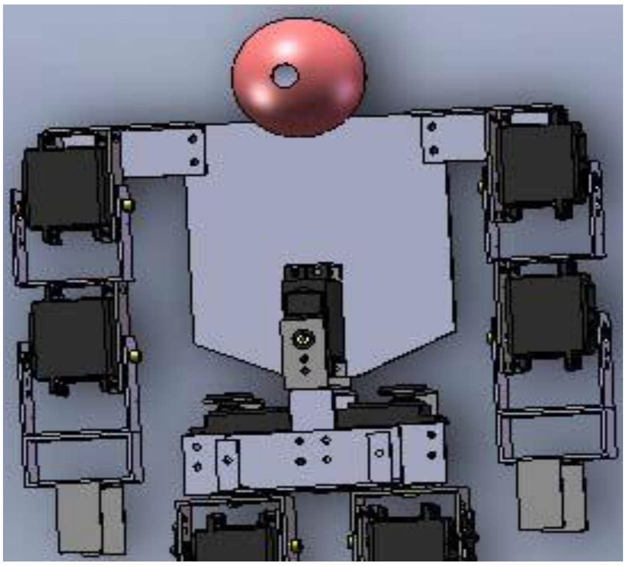

Fig. 8 Team 5 Upper Body Design

B. The Developing Board

After doing much research on the internet the team decided to purchase an AT2440EVB-I board (See Fig 9). 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.

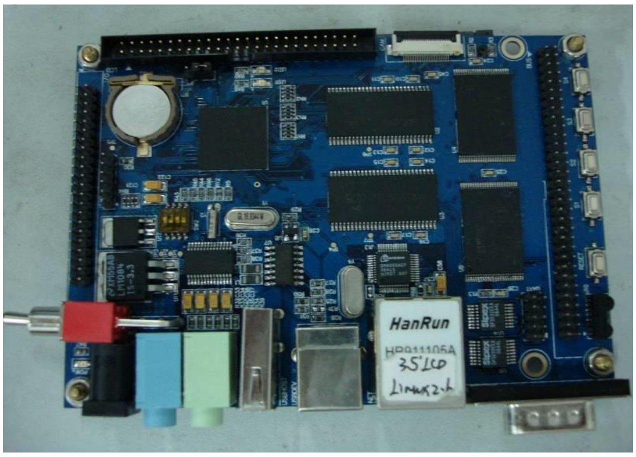

Fig. 9 The AT2440EVB-I Developing Board

1) 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.

2) 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.

D. 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.

V. CONCLUSIONS

This team was charged with the task of creating a humanoid robot that would improve on the currently designed and created robot, Some of these improvements were to include adding an upper body and improving the walking motion of the robot. 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

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ABOUT THE AUTHOR

Dr. V.BALAJI has 13 years of teaching experience. Now he is working as a principal in Spathgiri College of Engineering, Dharmapuri. His current areas of research are model predictive control, process control, and Fuzzy and Neural Networks. He has published 30 research papers in national and international journals and conferences. He is a member of ISTE, IEEE , IAENG, IAOE and IACSIT. He serve as editorial board / Reviewer members in many of the reputed journals.

