B.Sc. in Computer Science and Engineering Thesis

Mobile Video Transmitting Robot

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CERTIFICATION

This thesis paper titled **"Mobile Video Transmitting Robot"**, submitted by the group as mentioned below has been accepted as satisfactory in partial fulfillment of the requirements for the degree B.Sc. in Computer Science and Engineering on December 2013.

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CANDIDATES' DECLARATION

This is to certify that the work presented in this thesis paper is the outcome of the investigation and innovation carried out by the following students under the supervision of Lieutenant Colonel Md. Mahboob Karim, Instructor Class'A', Military Institute of Science and Technology, Dhaka, Bangladesh & co-supervision by Fahim Hasan Khan, Assistant Professor, Military Institute of Science and Technology, Dhaka, Bangladesh.

It is also declared that neither of this thesis paper nor any part thereof has been submitted anywhere else for the award of any degree, diploma or other qualifications.

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ABSTRACT

For more than a decade now robotics in education has gained a lot of attention from teachers, researchers, politicians, authorities and other stake holders. During the years a great number of methodologies, courses, projects, initiatives and competitions had been developed. The use of products from the market makes building robots possible at a very low-cost awakening the engineering nature of students and researchers. In this paper we present a low cost mobile robot which uses a normal android phone to guide itself. The low cost robot involves the use of one or more cameras to transmit visual data. Motors are from battery operated. The goal for this work is to build a large set of these robots, lend them to the engineering students.

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LIST OF ABBREVIATION

CSE : Computer Science and Engineering
LFR : Line Follower Robot
RF : Radio Frequency
LDR : Light Dependent Resistor
PPIC : Parallel Port Interface Circuit
RFID : Radio Frequency Identification
LED : Light Emitting Diode
I/O : Input Output
USB : Universal Serial Bus
RC : Remote Control
PDA : Personal Digital Assistance
P3 : Pioneer 3
CPU : Central Processing Unit
DSP : Digital Signal Processor
RAM : Random Access Memory
IR : Infrared Transistor
CMOS : Complementary Metal Oxide Semiconductor
PCB : Printed Circuit Board
A/D : Analog to Digital
BDT : Bangladeshi Taka
LAN : Local Area Network
DC : Direct Current
GPIO : General Purpose Input Output header
HD : High Definition
HDMI : High Definition Multimedia Interface

LIST OF SYMBOLS

mm : Millimeter

e : Euros

cm : Centimeter

MHz : Mega Hertz

MIPS : Microprocessor Without Interlocked Pipeline Stages

KB : Kilo Byte

ms : Millisecond

hz : Hertz

nm : nanometer

MP : Mega Pixel

CHAPTER 1

INTRODUCTION

1.1 Background

Robotics has come a long way. We have seen the transitions of computer systems of mainframe computing via workstations to PCs, which will probably continue with handheld devices for many applications. Same trend will happen with mobile robots. Mobile robots were controlled by heavy, large and expensive computer systems that could not be carried. Robots were linked via cables or wireless devices.

But today, robotics technology is introduced in education level. As a result low cost robot is necessary for education purpose so that students can use them for learning purpose.

Today, however, we can build small mobile robots with numerous actuators and sensors that are controlled by inexpensive, small, and light embedded computer systems that are carried on-board the robot. There has been a tremendous increase of interest in mobile robots.

Earlier robotics was used only for industrial purpose or scientists use them for important research work. But today robotics can be used not only for industrial improvement but also for education purposes. Nowadays, it is of the maximum relevance that computer, electric control, or mechanical engineering university program studies include the teaching of both theoretical and practical courses on robotics. Robotics challenges require working with multidisciplinary teams in order to successfully integrate different areas of knowledge. Practical work on robotics at the university level can help engineering students develop the needed communication and working skills for teamwork.

1.2 Present State

Students of Computer Science and Engineering (CSE) do Military Institute of Science and Technology (MIST) do group thesis on robotics. Students from other majors such as mechanical, electrical electronics and communication, and aeronautical engineering are also encouraged to do works on robotics, forming multidisciplinary teams. The main goals on robot design pursues are: to teach students about robotic design, get the students as close as possible to solving a real problem, and to show them how to integrate knowledge they gained in subjects taken in previous semesters.

Robotic design is taught by giving the students the hardware and software information they need to design, build, and debug their own robot. Emphasis is placed on mobile robotics because it is a much more challenging field than industrial manipulators.

Students are encouraged to propose their own ideas on the basis of useful projects, whether for industry, education, home, or entertainment applications. That is, they are motivated to think about proposing solutions to real problems and their social implications, develop the project requirements, evaluate the design parameters of the project, and implement an adequate work plan. Students have the space to apply knowledge about the subjects taken earlier in the whole graduation courses. Subjects are: Circuit design, Artificial intelligence, microprocessor, interfacing, programming languages.

This book is about mobile robot which is designed to transfer visual data of objects which are in front of it. To control the movement of the robot a software interface has been developed and a mini vehicle is designed and developed considering the cost in mind.

1.3 Objectives

The main objective is that designing and developing a low cost mobile robot for transmitting visual data considering the economic condition of our country which is though challenging but highly demanding.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Robotics is the science and technology of desigining, making and applying robots, including theory from many contributing fields. There are Military Robotics, Mobile Robotics, Industrial Robotics, Spatial Resoning, Artificial Intelligence.

Nowadays, robotic vehicles and mobile robots have become an increasingly important component of security operations and related activities. They can be used to gather information in areas where a human could not safely go and undertake tasks a human could not safely perform.

2.2 Line Follower Robot

The following article demonstrates a prototype development of an Intelligent Command Based Line Follower Robot (LFR) using Radio Frequency (RF) Technology. Mostly the LFR are build by using microcontroller chips. The chip is preprogrammed and embedded within the robot. But there is a problem with such LFR, as they are built based upon microcontroller chips, so they are preprogrammed. Because of preprogramming conditions LFR cannot take instructions and command from outside users in real time other than what is already fixed. The proposed system was [1] that the robot would follow the path and for this the robot would take information in real time from three Light Dependent Resistor (LDR) sensors via Parallel Port Interface Circuit (PPIC) connected to PC. The works of LDR is described in the following chapter. The robot should be programmed such a way that it can be controlled autonomously according to the received signals. A computer program was implemented in C-language [1] to accept user commands and also to control the robot. The second problem with LFR is wired connections, and the length of wire is the main constraint. As the length of a wire increases, the signal strength attenuate and along with signal strength attenuation delay in timings also increases. To overcome these problems, RF is used as it provides a convenient way of transmitting signals without conductors and hence eliminating the attenuation and time delay. The approach that solves the problem of controlling LFR with the added functionality is command mode. The command mode LFR is controlled using PC based instructions developed in C-programming language. Some work based on Radio Frequency Identification (RFID) systems has been reported. In these systems RFID tang is attached to receive and send information to and from a remote control device. The Strength of these RFID systems is that they can overcome line of sight problem as well as line loss and limitations.

2.2.1 Transmission

The direction of a robot was controlled by RF remote via PC. A transmission of robot is conformed to two wheels (i.e. left and right), coupled with two direct current motors separately.

Allowed moments are:

a. Forward direction

b. Backward direction

c. Right (clockwise)

d. Left (counter clockwise)

e. 360 degrees rotation

2.2.2 Direct current motor control

The robot movements involve two motors i.e. Left motor and Right motor. The power of these motors is controlled via RF transmitter which is connected at (Parallel Port Interface Circuit) PPIC. Speed and turning of the robot is controlled from PC using received information from LDR sensor values i.e. A, B, and C as shown in Table 2.2.

Table 2.1: Operation table for robot movement

A	B	C	FUNCTION
1	0	1	Forward
1	1	0	Right(Clockwise)
0	1	1	Left (Anti-clockwise)
0	0	0	Error
1	1	1	No Line Detection
0	1	0	White Track

Table 2.2: Operation Table of Motors

A	B	C	RIGHT MOTOR	LEFT MOTOR
1	0	1	1	1
0	1	1	0	1
1	1	0	1	0

2.2.3 Sensor Placement

It is found that sensors are placed at the front bumper of a robot. The main objective of the robot is to position its B (middle) sensor on the tape line and other two sensors A (left) and C (right) off the tape line. If the tape line ever ventures past these two extreme sensors, then the robot corrects by turning in the appropriate direction to maintain tracking. Sensors are positioned between 1/16" to 1/8" above the ground.

2.2.4 Sensor Spacing

The sensors of line follower robot [1] are arranged according to Fig.2.1 to get optimal results and this spacing work well for width tape lines.

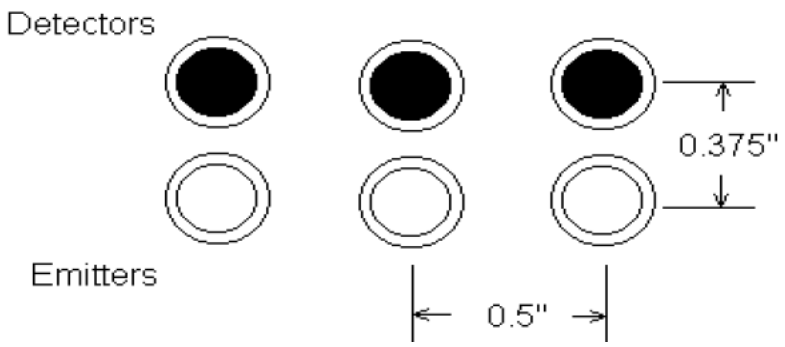


Figure 2.1: Sensor Spacing

2.2.5 Sensor Array

The sensor on the left is named as A, the middle sensor as B and the right sensor as C. When the sensor reads A=1, B=0 and C=1, then it is assumed that robot is on the tape at center point and ready to move the robot in forward direction.

The PC decides the next move according to the algorithm given below[1].

Table 2.3: Sensor Array conditions

A:LEFT	B:MIDDLE	C:RIGHT
1	0	1

Desired state A = C = 1 and B = 0.

2.2.6 Sensor Transmission

It was seen that the Red LED is used to transmit the light on the tape (line) and the LDR is used to sense the reflected light of LED. The output of the sensors is an analog signal which depends on the amount of light reflected back. This analog signal is sent by RF based transmitter which transmits these signals to sensor receiver circuit which is connected to PPIC.

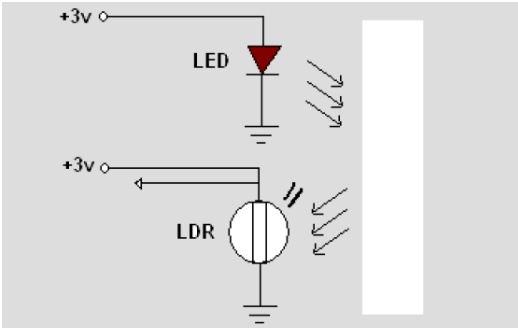


Figure 2.2: Circuit Diagram of Sensor circuit for the Red LED (Emitter) and LDR (Detector)

2.2.7 LFR Programming Description

To implement this section of prototype, a C-Programming language is used[1]. The program achieves three sensors monitoring, controlling robot movement and acceptance of user commands.

The flowchart for the software is shown in Fig following:

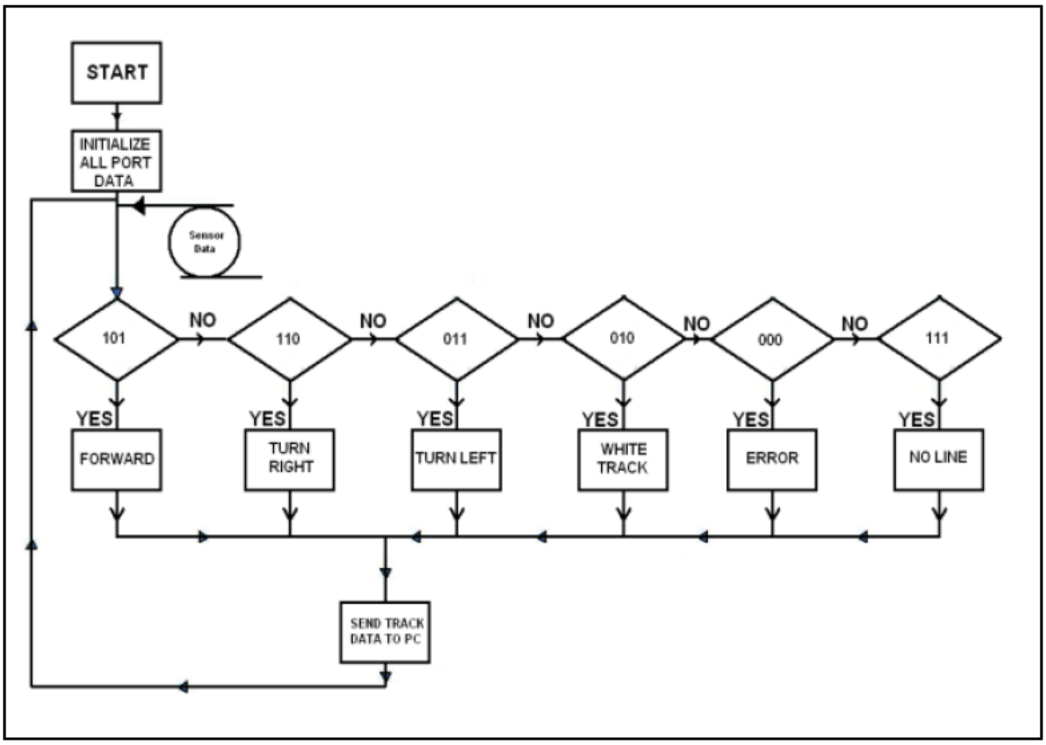


Figure 2.3: PC software flowchart

2.2.8 Prototype Algorithm for Autonomous Control

Following algorithm has been designed to control the robot autonomously [1] and decides the next move of the robot via received information from sensors.

1. IF A = left sensor which reads 1,
   C = right sensor which reads 1,
   B = middle sensor which reads 0,
Then Move in the Forward Direction.

2. IF A <= 0, B >0 and C >0,
   Then Move in Anti-clockwise (left)

3. IF A >0, B >0 and C <= 0,
   Then Move in Clockwise (right)

4. IF A >0, B >0 and C >0,
   Then output Line Lost

5. IF A <= 0, B <= 0 and C <= 0,
   Then output ERROR

6. Repeat step 1 to 5

2.3 Mobile Robots

Nowadays robots can help people. So it is a large field of research and education. But if the prices of robot is not reasonable robot will not be able to fulfill the desired task. So building low cost robot is crying need.

Robotics is widely used on education. The use of products from the market makes building robots possible at a very low-cost awakening the engineering nature of students and researchers.

In the following article a low cost mobile robot which uses a normal laptop to guide itself through a track is presented. The previous article was about a line follower robot also. The goal for this work is to build a large set of these robots, lend them to the engineering students. Moreover, along the years, the student integrates more and more knowledge in the robot allowing it to perform as better as their knowledge increases along the course.

In this article it is suggested to use these robots for education. University lends the robots to students to let them freely use their own laptops to control the robot, independently of classes, and join in the end of every semester for a local competition, like some competitions already existing in many universities [2]. Moreover, according to the level of the students, higher challenges are made to the students letting them feel how their increasing knowledge actually improves the robot performance.

This experience is being conducted in the Control, Automation and Robotics Group involving students both from Mechanical and Computer Science Engineering and follows some experience already acquired on building robots for competitions.

2.3.1 State of Mobile Robots

In the state of art of mobile robots morphology we may mainly find legged and wheeled robots [1]. Legged robots were always very challenging due to their likeness to living beings way of locomotion. Wheels for robots are briefly discussed in the following chapter.

Early in the 80s 3D Hopper [1] was an amazing one legged robot able to move and stabilize itself over a single leg.

Much simpler and easier to build and control, robots with wheels are the simplest for a beginner. Some topologies exist varying the number of wheels, the type of steering and driving. We may find four wheeled robots, but the simplest solution is to build two-wheeled robots which usually have two driven wheels near the center of the robot, along with a caster wheel. The two driven wheels are able to make the robot steer and drive in almost any direction. Robots with omnidirectional wheels are by far the most agile but somewhat more difficult to control. Varying the number of wheels, we may found different wheeled controlled robots which are discussed later.

2.3.2 Development of Low Cost Robot

As stated before, low cost was an important goal when building these robots. The processing unit is a normal laptop. Students use their own laptops to control the robots. Students complain less about the equipment when they use their own laptops, which in many cases are much updated and powerful than those the department could afford to them. They are responsible for damages so they pay a lot more attention to the programs they run. Hence, the laptop cost was not counted on the robots cost.

Moreover, the robot uses a normal webcam which the students usually already possess. Anyway they are very cheap and their cost was added on the robots cost. Software licenses cost was not included (Visual Studio, Matlab/Simulink, Labview, etc) because either campus or students licences were used.

In the following sections we present the several choices and costs. The cost depends on the choices of some components.

Lego Mindstorms are a common solution for low cost robots. However the number of I/O ports they provide is very limited and the processing capacities and languages available cant be compared, in number and in quality, to the languages and operating systems available for laptops. Tasks like image processing, visual servoing, PID tuning can be done with a normal laptop but are not straightforward or even impossible with actual Lego Mindstorms.

Small microcontrollers like Microchip or Atmega families provide a very interesting alternative, but again the programming capabilities are limited to the existing cross compilers available. Moreover they provide good solutions for analog or digital I/O ports but not for handling image processing cameras. It is actually possible to do that, but they are not as straightforward as connecting a webcam to a USB laptop port.

2.3.3 Morphology and Motors

Usually mobile robots are built by wheels for beginners and the movement of wheel is done by motors. Though there are several morphologies of robots, keeping in mind to make it simple three wheels was decided [1]. Two wheels provide differential driving and the other wheel is free (caster wheel). This simple structure allows a high mobility of the robot.

For building a low cost robot products are collected from local markets which enables to build the robot with a reasonable price. A differential driving robot will need two motors. Very likely it will need also a gear boxes to reduce the motors speed and increase the torque.

It will need batteries. Hence, a battery charger will also be needed to recharge the batteries. Bought individually, these components would lead to an expensive robot.

Fortunately, in the market, there are very low cost battery operated electrical screwdrivers, proving it all in a single set, which may be adapted to a low cost mobile robot.

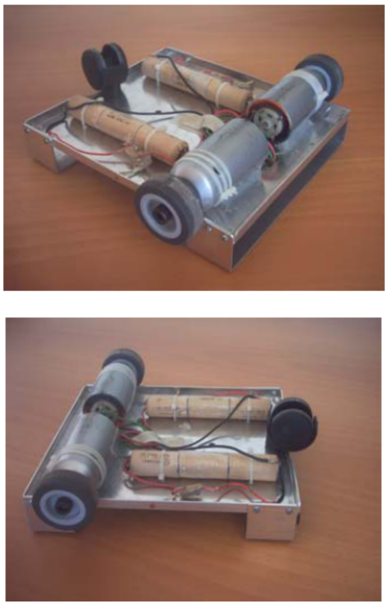


Figure 2.4: PC software flowchart

2.3.4 Data Acquisition and Control Card and Power Interface

Nowadays many students already have their own laptop computer. They have plenty of accessories, like webcams, which mainly interface the computer through USB ports which are rapidly replacing the old serial and parallel interfaces.

However, regarding data acquisition and control cards, usual PCI cards are not suitable for laptops and PCMCIA data acquisition cards are still very expensive.

Fortunately, new cards have recently been introduced in the market providing at a low cost, digital and analog inputs and outputs. These cards interface the personal computer through USB ports, allowing their use with common and portable laptops.

Figure 2.5: Example of a new USB card

Hence, we used a USB card to interface the laptop with the motors. There are plenty of free I/O ports in the acquisition card that might be used to cope with analog or digital sensors that may increase the ability of the robot to sense the environment.

2.3.5 Processing Unit

The processing unit is a normal laptop that is placed on the top of the robot. The advantage of using a normal laptop is that it is easy in a group of two or three students to find one with a laptop. Using their own laptops and interfacing it to the robot (which is lent to them), students may work with it at any place and hours independently of the availability of the laboratory.

But nowadays we see that mobile robots are controlled by using android phone.

2.3.6 Sensing

To sense the environment, students might use sensors that are widely available in the market, and could interface them to the USB card free I/O ports. Sensors are discussed in the Instruments of mobile robot chapter of the book. However, keeping it simple and challenging, the robot was guided through normal webcams, widely available at a low cost. The USB camera acts as a general purposed sensor to guide the robot through the environment.

2.3.7 Programming

Using a normal laptop we are not limited to specific languages. Any language available for PC with drivers for the USB card and able to read webcams might be used.

2.3.8 Programming The USB Card

The USB card comes with a so called universal library that allows programs written in many languages to be used. In particular, among others, it provides libraries for Visual Basic and C++, Borland C++, Delphi, Watcom C++ and .NET languages like VB.NET and C.NET. Drivers are also available for Matlab and Labview.

Using a wireless communication with the laptop the robot could be easily remote controlled. The robots laptop was connected to the internet through a wireless adapter (actually many laptops have, nowadays, built in wireless adaptors). With a normal desktop computer a remote desktop session was initiated in the robots laptop using windows XP standard features.

2.3.9 Image Acquisition

To let the robot sense the environment, a code which was already developed in C for acquiring the image to an array in C was used.

2.3.10 Image Processing

The simplest processing algorithm was the computation the centre of mass of the binary image, for which there are well known algorithms available on image processing literature.

2.3.11 Results

It is always expected to fulfill the required task by the robot. The minimal setup shown [2] allows the students to have a standard departure point that allows the robot to fulfill some of the tasks with little changes. However innovation is encouraged. Regarding innovations, students al-ready proposed solutions programmed in matlab, others proposed solutions with simulink and real time windows target, one proposed a microchip microcontroller version, with optical digital sensors, that was able to follow the line in a bang-bang manner, others used Labview and their image acquisition toolbox. So there is still space for innovation, mainly because the platform is generic and can support a large number of languages and operating systems.

2.4 A Low Cost Modular Robot Vehicle Design for Research and Education

In the following article the development of a low cost robotic vehicle for research and education is presented [3]. It was developed by Intelligent Systems and Robotics Laboratory of Department of Production Engineering and Management in Technical University of Crete.

Robotics is a multidisciplinary field. In research and educational needs mobile robots are necessary. During the last decade mobile robots of all kinds and sizes were developed. Robotics design for vehicle includes elements from vehicle/mechanism design electronics and artificial intelligence etc.

The vehicle was designed considering minimum cost and maximum capabilities. As a base for testing devices and different type of sensors, a commercially available vehicle was used and modified. Two different version of the prototype vehicle were developed accompanied by the proper software that allows the end user to operate the vehicles as an educational or research platform. The functionality of the vehicles was verified after extensive experimentation.

Research wise mobile robots are used to accommodate a wide area of scientific fields and educationally wise their usefulness in the academia is of no doubt. They provide all the necessary means for laboratory exercises in robotics, sensor technology, and basic electric and electronic circuits. Now days, the evolution of technology achieved a significant reduction in the cost of prototype robotic vehicles that introduce new and more sophisticated capabilities. Commercial robotic vehicles, as well as their components, from all around the world, are available at competitive prices to the contemporary research or academic institutions. The research and development in the category of mobile robots, during the last decade, resulted in the appearance of many new mobile robots in a wide price range.

In [3] a survey of more than 56 up-to-date commercially available robotic vehicles is presented. Based on this survey, some remarks about mobile robots are presented in the following paragraphs. Roughly 23% of the commercially available mobile robots are able to operate outdoors. This is due to the fact that most of the robots are used in educational and research activities which are conducted in a laboratory environment. This, along with the demand for low cost and relatively simple implementations, makes indoor robotic vehicles much more popular than outdoors. Low mass is another important issue in the design of robots. That is why the 59% of them weight less than 5kgr and only 27% weight more than 10kgr. As far as it concerns locomotion, the first choice of the vehicle designers is the differential drive as the 54% of them use two drive wheels and one or two castor wheels or points of contact with the ground. The ”brain” of the robots is a compact, personal computer unit in the 29% of the vehicles, while at the rest of them embedded microcontroller boards are used.

2.4.1 Disadvantages

The cost of these robotic vehicles as previously mentioned varies [3]. The majority of these vehicles share some considerable disadvantages:

- ▷ The vehicles construction and assembly is sensitive and their locomotion system is not accurate. Moreover they have certain limitations regarding their motion abilities.
- ▷ Their energy autonomy is limited, even for the basic research needs. Their operation time hardly reaches the one half of the hour.
- ▷ Their microcontrollers have low computational power and limited memory. They are able to manipulate only simple arithmetic variables and so they can not execute algorithms that use data structures like matrices, for example.
- ▷ There is no wireless communication of any kind.
- ▷ They have unreliable sensing ability, appropriate only for basic educational applications.

Many of the commercially available mobile robots managed to deal with the previous problems but with a significant cost rise. As a result, the cost of mobile robots that can accommodate both educational and research needs is more money. Apart from high costs, these robots usually require dedicated equipment, as usually there is no compatibility with off-the-shelf solutions. Moreover the programming, calibration and customization of the vehicle are not easy tasks and require advanced programming skills together with computer and electronics engineering knowledge. To our view, a major challenge today is the construction of mobile robots with a better cost-benefit ratio. Todays market offers a wide variety of choices concerning feasible, low cost solutions in almost all parts of mobile robotics technology. The microcontroller technology recently developed ready to use platforms specially designed for robotic applications. Several manufacturers presented powerful microprocessors in compact, low cost electronics boards, equipped with modern operating systems, high level programming languages and compatible with low cost sensing devices. Although their capabilities are inferior of a small PC, their low cost and power consumption as well as their ability to communicate with different types of devices are reasons that make microcontrollers an attractive solution for robotics applications. Further, the achievements in sensor technology reduce the price of suitable for robotic applications sensors. As result, sensors and motors are available in a low prices and yet reliable enough to use in almost all educational and research robotic applications. Wireless communication is also available in low prices via Local Area Network (LAN) or using point to point links. Thus the implementation of educational or research robotic vehicles with a price lower than 30000BDT is a feasible project.

The goal is to understand and focus the best cost-benefit ratio aiming at a user friendly yet reliable mobile robot, suitable for educational and research applications.

2.5 Expressive Low Cost Mobile Robot

Another robot is Trikebot [4]. The Trikebot is low-cost educational robot for secondary level education and home use. The following article describes some aspects of the Trikebot, including chassis and mechanism.

2.5.1 Physical Overview

The Trikebot chassis is a three-wheeled mobile robot base in a tricycle-like configuration, with a single driven steerable wheel and two fixed passive wheels. Its major physical features are a tall camera and two large payload areas. If payload low cost robot is necessary then one can follow the mechanism of Trikebot for designing. Altogether the Trikebot [4] has 4 control degrees of freedomdrive motor, steering, camera pan and camera tilt. That means Trikebot has 4 joints.

2.5.2 Mechanical Design Objectives

The Trikebot chassis has three primary functions. The goal was to place the camera at least 18 inches above the ground plane. This was part of a decision to make the Trikebot a floor-based robot which students could interact with more dynamically than a smaller table-top size robot.

We expect the Trikebot to operate indoors and on flat outdoor areas such as parking lots, sidewalks and lawns; it must be able to overcome obstacles such as electrical cables, door thresholds and gravel. To facilitate mobility in closed quarters, we required Trikebot to turn in-place within a 24 inch circle. To encourage student-robot interaction, the speed of the Trikebot was specified as comparable to a persons medium speed walk, 30 in/sec. As a worst-case payload requirement, the Trikebot is designed to carry a laptop computer, six Remote Control (RC) car battery packs and various onboard electronics.

Being assembled and maintained by students in a general classroom environment required that the majority of the components of the Trikebot be assembled using simple hand tools and that they be robust enough to handle rough treatment. Of course, cost is always an issue, so appropriate manufacturing techniques were chosen for the quantities of parts used.

2.5.3 Design Features

The following describes the basic design elements of Trikebot:

Wheel Configuration. A tricycle configuration with a single driven steering wheel gives the Trikebot very good agility using a single gear motor as its drive motor and a single high power servo for steering [4]. The servo can steer the driven wheel through 180 allowing the robot to turn nearly in place. We chose the tricycle design in lieu of the other common three-wheeled differential drive configuration to avoid several problems. One problem is that a trailing caster wheel can restrict the freedom of movement of the robot in certain situations. Furthermore, two driven wheels must match their speed profiles exactly in order for the robot to travel in a straight line. The tricycle design eliminates both issues. The single wheel forward arrangement was chosen for agility over obstacles. The driven wheel can more easily grip and climb over an obstacle at slow speeds, subsequently dragging the rear wheels over the obstacle. One final advantage of a three-wheeled design is reduced torsional stress on the chassis. In a four wheeled chassis, a single wheel can be raised above the others when traversing uneven terrain, twisting the chassis (and its payload). A three wheeled chassis undergoes less twisting, meaning the chassis can be simpler and lighter.

Wheels The Trikebot can drive over obstacles such as power cords, uneven sidewalks, and even gravel paths.

Camera Mast and Pan and Tilt The camera mast incorporates a pan and tilt [4] mechanism and elevates the camera to above its desired 18 inch minimum height. The positioning of the mast to the front of the chassis allows the camera to scan slightly in front of the front wheel while looking down. This facilitates activities such as line following or object-in-path detection.

Payload Area The Payload areas of the Trikebot are positioned low considering the center of gravity.

General Construction Most of the Trikebot chassis is constructed of [4] lasercut acetal (Delrin) sheets. Aluminum machined parts were used for a few items.

2.6 Existing Robots For Education

A wide range of mobile robots are available on the market [5]. In this section we survey the subset of them.

The **Khepera II** from K-Team is a redesign of the original Khepera robot [5]. With the same size of the original Khepera, it is compatible with its extensions, software, and scientific tools. The Khepera II is interesting because its size allows to use it on a desktop. It is expensive but is known for being reliable and well supported.

The **Hemisson** from K-Team is a cheap platform with a diameter of 120 mm. It only provides a limited computational power and few sensors in its basic configuration, but is extensible. It is a robust platform well suited for beginners.

The **IdMinds** circular GT kit is a similar platform slightly cheaper with a diameter of 150 mm. It has less standard extensions than Hemisson, but has more I/O available ports to connect self-made extensions. It is more suited for experimentation using custom self-made extensions.

Botn Roll is even cheaper, the platform is representative of a set of simple robots with few sensors that are excellent starting kits for beginners. This and the previous kit improve their accessibility by providing graphic programming environments.

The **Lego Mindstorms** RCX was the first robotic platform from the Lego company. The RCX is built around a small 8 bit processor and can manage only 3 inputs and 3 outputs (typically DC motors without encoder); but the combination with the Lego bricks makes it a fantastic tool to discover new robots shapes. The RCX has been replaced in 2006 by the Lego Mindstorms NXT. This newer version is equipped with more advanced sensors, including color and sound, and can drive motors equipped with encoders. It is a clear reference in the field because of its good computational power, its flexibility and interesting price .

The **Palm Pilot** Robot Kit (PPRK) is a commercially available platform2 from Carnegie Mellon University combining a mobile base and a personnel digital assistant (PDA), originally a Palm Pilot. The PDA provides the computational power and the user interface and controls the sensors and the actuators through a serial connection with a PIC processor. The result is a compact Omnidirectional platform with three distance sensors . Furthermore, the availability and the maturity of Palm development tools makes this platform an interesting starting kit.

The **Cye** platform is a medium-size robot equipped with special wheels that ensure a good odometry. Designed for indoor domestic environments, Cye can carry extensions such as a vacuum cleaner and can navigate in indoor environments.

The **Khepera III** from K-Team is a research oriented platform much larger than the Khepera II (120 mm of diameter). It is adaptable to specific research requirements through extensions, for instance the korebot board which provides an XScale processor. Flexible, efficient, and powerful with respect to its size, this robot is also quite expensive as an educational robot. (around 2000 e in basic configuration).

The **ER1** from Evolution Robotics4 is a simple aluminum frame kit supporting a laptop (not included) and equipped with wheels. The laptop provides the computational hardware, which improves the performance / cost ratio of the kit (the basic configuration costs around 230 e). The motor wheels controller has some free inputs/outputs but provides limited computational power. This low-cost kit comes with a sophisticated but expensive software environment for navigation and vision.

The **KHR-1** from Kondo 5 has been the first humanoid robot with good mobility capabilities (17 DOF) for a price under 1000 e. The Pioneer 3 (P3) is the latest version of the Pioneer robot by ActivMedia. It is a large (44_38_22 cm) solid platform on which the user can install custom processors, sensors, and actuators. The AmigoBot of the same company is a cheaper version (1550 e) of the same concept. The Garcia from Acroname6 is a small robot frame (25_18_10 cm) designed to be controlled by a companion XScale board. The size of Garcia makes it suitable for experiments in compact environments. Its price is around 1360 e in the basic configuration.

Robotino from Festo7 is a modern mobile robotic platform for education. Robotino runs a real time Linux kernel and is built around industrial standards. These features make this robot powerful in term of computational power but also expensive (about 4500 e). Robotino is well suited for technical schools that want to approach technical problems using robotics.

Roomba Create from iRobot is an educational/research version of the roomba vacuum cleaner. Devoided of the cleaning module, this platform provides low cost mobility (100 e). Its sensors, designed for vacuum cleaning tasks, offer a good support for reactive navigation. The limited internal processor, dedicated to the low-level robot control, is programmable by simple scripts. Any advanced programming or supplementary I/O requires an additional main processor.

2.7 e-puck Hardware (Basic Configuration)

To understand the features of mobile robot one can go through the existic mobile robos features. The following article briefly discuss about e-puck hardware.

2.7.1 Microcontroller

The electronic structure of the e-puck is built around a Microchip dsPIC microcontroller. This microcontroller complies with the educational criteria of flexibility because it embeds both a 16 bit processor with a 16 entry register file and a digital signal processor (DSP) unit. This CPU runs at 64 MHz and provides 16 MIPS of peak processing power. The instruction set is mostly orthogonal8 and rich; in particular, it contains multiply-acccumulate and hardware repeat instructions suitable to drive the DSP unit, for instance to efficiently compute scalar products and fast fourier transforms. Finally, this processor is supported by a custom tailored version of the GCC C compiler. For the e-puck, we chose a microcontroller version with 8 kB of RAM and 144 kB of flash memory.

2.7.2 Sensors and Actuators

To ensure a broad range of experimentation possibilities, the e-puck contains various sensors covering different modalities:

- ▷ Eight infrared (IR) proximity sensors placed around the body measure the closeness of obstacles or the intensity of the ambient infrared light. These are typical sensors for simple navigation in cluttered environments.
- ▷ A 3D accelerometer provides the acceleration vector of the e-puck. This vector can be used to measure the inclination of the e-puck and the acceleration produced by its own movement. It can also detect collisions and if the robot falls. This sensor is rarely included in miniature low-cost mobile robots. We decided to include it because it allows a rich set of experiments.
- ▷ Three microphones capture sound. Multiple microphones allow the e-puck to localize the source of the sound by triangulation. The bandwidth of this signal is much larger than the one of the accelerometer or of the infrared sensors, making the microphones, because of their larger computational demands, the ideal tools to learn how to use the DSP unit.
- ▷ A color CMOS camera with a resolution of 640_480 pixels in front of the e-puck enables experimentation in vision. Only a sub-part of the image can be grabbed: the

size of acquisition is limited by the memory size of the dsPIC and the rate is limited by its processing power. Any format of sub-image is acceptable, providing these two constraints are fulfilled. For instance, the e-puck can grab a color image of 40_40 pixels at 4 frames per second; the frame rate is doubled in gray-scale. This limitation shows to the students the impact of high bandwidth sensors such as cameras.

2.7.3 e-puck Provides The Following Actuators

- ▷ Two stepper motors. They control the movement of the wheels with a resolution [5] of 1000 steps per wheel revolution.
- ▷ A speaker, connected to an audio codec. Combined with the microphones, the speaker can create a communication network with the ability to detect the direction of peers. It is also an excellent output device for human interaction.
- ▷ Eight red light emitting diodes (LED) placed all around the e-puck. These LEDs are covered by a translucent plastic and the e-puck can modulate their intensities. They provide a visual interface with the user; furthermore, another e-puck can observe them with its camera which allows mutual visual interactions.
- ▷ A set of green LEDs placed in the transparent body. By lighting the body, they improve the interactions with the user.

  _ A red front LED placed beside the camera. This LED generates a focused beam that projects a red spot on objects in front of the e-puck. Combined with the camera, this spot allows distant measurements at longer range than the infrared proximity sensors.

2.7.4 User Interface

The e-puck also contains several devices to interact with the user and to communicate with other equipments:

- ▷ Two LEDs show the status of the battery: One indicates whether the robot is powered on, while the other indicates a low battery condition.

- ▷ A connector to interface to an in-circuit debugger, to program the flash memory and to debug code.
- ▷ An infrared remote control receiver, to control the epuck with standard television remote controls.
- ▷ A classic RS232 serial interface to communicate with a desktop computer.
- ▷ A Bluetooth radio link to connect to a desktop computer or to communicate with up to 7 other e-pucks.
- ▷ A reset button.
- ▷ A 16 positions rotary switch to specify a 4 bit number, which can be used, for instance, to select among preprogrammed behaviors or parameters.

2.7.5 Mechanics

The robot has a diameter of 75 mm [5] and a height which depends on the connected extensions. The mechanical structure of the e-puck consists of injected plastic parts. This manufacturing technique reduces the unit price of the robot for sufficient quantities. The robot structure is simple, being made of only four injected plastic parts: the main body, the light ring, and the two wheels. The main body is the core of the mechanical structure and encloses the battery. The user can extract the battery from the bottom of the e-puck. The two motors are simply laterally screwed onto the main body, with the wheels directly attached to the motor axis. The main printed circuit board (PCB), containing most of the electronics, is screwed on top of the main body. A light diffusion ring and a default extension board are mounted over this main PCB; the user can replace the default extension board with application specific boards, as illustrated by some examples in the next section. All mechanical parts are transparent and allow to observe all components.

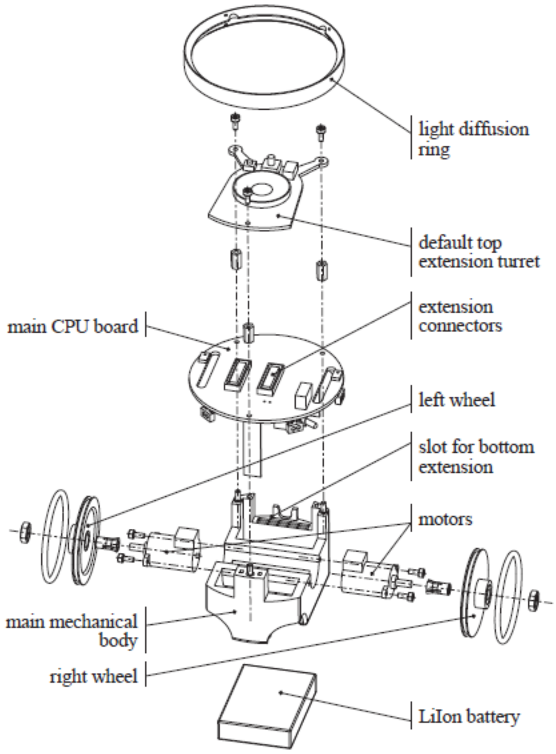


Figure 2.6: The Mechanical Structure of an e-puck in an exploded view

2.7.6 e-puck simulation

Several simulators support the e-puck. Among them, we use Webots and Enki. Webots is commercial and supports three-dimensional physics through the ODE library. Enki is open source and provides fast 2D physics, which, for instance, makes it suitable for evolutionary robotics experiments .

2.8 Robot Design For Engineering Education

Most of the aforementioned products are exclusively either efficient mobile robots or good educational tools. However, being both implies the following criteria:

Desktop size: A robot that can evolve on the desk near the computer improves drastically the student efficiency during experimentation. We consider that for a good mobility, the experimentation space should be 10 times the diameter of the robot. On a table, this implies a robot diameter smaller than 80 mm [5].

Wide range of possibilities from an engineering and educational point of view: To exploit this tool in various fields of education such as signal processing, automatic control, embedded programming, or distributed intelligent systems design, the robot should provide a wide set of functionalities in its basic version.

User friendly: The user interface has to be simple, efficient, and intuitive. This is an important point for the acceptance of the system by the students.

Low cost: The broad introduction in engineering classes requires a large number of robots. Knowing that the budget of many schools is constant or decreasing, this is only feasible by reducing the cost of an individual robot.

Open information: This robot has to be shared among faculty members, laboratories, schools and universities. An open source hardware/software development model is an effective way to achieve this goal. None of the platforms available on the market is respecting these criteria. Most robots are large and thus need to operate on the floor. The smallest robots are either expensive or have limited functionalities. Very few are open source.

2.9 Related Research

Research on robotics is going on in every corner of the world and so workshops and conferences. These workshops and conferences had a strong focus on robotics education. There is a list of related research [5]. Please note that this list is obviously not complete and represents just samples. Within this section we like to highlight the focus and content of some of those events.

The selected conferences and workshops are the following:

1.AAAI Spring Symposium on Accessible Hand-On AI and Robotics Education, 2004

2.AAAI Spring Symposium on Robots and Robot Venues: Resources for AI Education, Stanford University, CA, USA, 2007

3.Research and Education in Robotics - EUROBOT 2008, Heidelberg, Germany, 2008

4.Teaching with robotics: didactic approaches and experiences, Workshop at International Conference on Simulation, Modeling and Programming for Autonomous Robots (SIMPAR), Venice, Italy, 2008

5.AAAI Spring Symposium on Educational Robotics and Beyond: Design and Evaluation, Stanford University, CA, USA, 2010

6.First International Conference on Robotics in Education, Bratislava, Slovakia, 2010

Unfortunately, the major fraction of these conferences and workshop show common sub-optimal properties which are:

1.The presented publications are related to a single institution or small region

2.The presented publication show just example of diverse small education project

3.Results are usually justified by a very small population from a single class

4.Publications are usually made from people coming from computer science and robotics but not from the obvious related fields of educational sciences, pedagogy or psychology

5.The approaches are not condensed to a common standardized methodology

6.The publications contain repetitively trivial technical descriptions of yet another educational robot platform or setup

7.The conferences and workshops are too closely coupled to a particular event, competition or initiative

CHAPTER 3

INSTRUMENTS OF MOBILE ROBOTS

3.1 Introduction

In this chapter necessary instruments for designing and building mobile robots are discussed. If one wants to do a project on robotics he/she must know the instruments which are the necessary to build a robot. A better design is half-done of a project. For beginners, like us, some of the necessary instruments are discussed here:

3.2 Wheel

There are many types of mobile robots. Such as: wheeled robots, legged robots, flying robots and underwater robots. But for beginners it is necessary to think about the simplest case. The simplest case of mobile robots are wheeled robots. Wheeled robots comprise one or more driven wheels and have optional passive or caster wheels and possibly steered wheels. Most designs require two motors for driving a mobile robot.

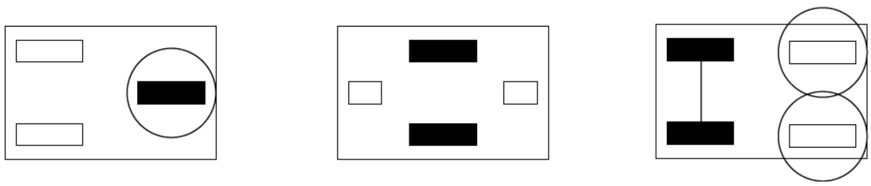


Figure 3.1: Wheeled Robots

A single driven wheel can be also steered. In the above figure it is shown in the left side. A single driven wheel requires two motors because of turning and also for driving the wheel. The advantage of this design is that the driving and turning actions have been completely separated by using two different motors. A disadvantage of this design is that the robot cannot turn on the spot, since the driven wheel is not located at its center.

In mobile robot designs, differential drive is used most of the time. The robot design in the middle of Figure is called differential drive. As it is a combination if two driven wheels, the robot can be driven straight, in a curve, or turn on the spot. Another advantage of this design is that motors and wheels are in fixed positions and do not need to be turned as in the previous design. This simplifies the robot mechanics design considerably.

Finally, on the right-hand side of Figure is the so-called Ackermann Steering, which is the standard drive and steering system of a rear-driven passenger car. We have one motor for driving both rear wheels via a differential box and one motor for combined steering of both front wheels. It is interesting to note that all of these different mobile robot designs require two motors in total for driving and steering.

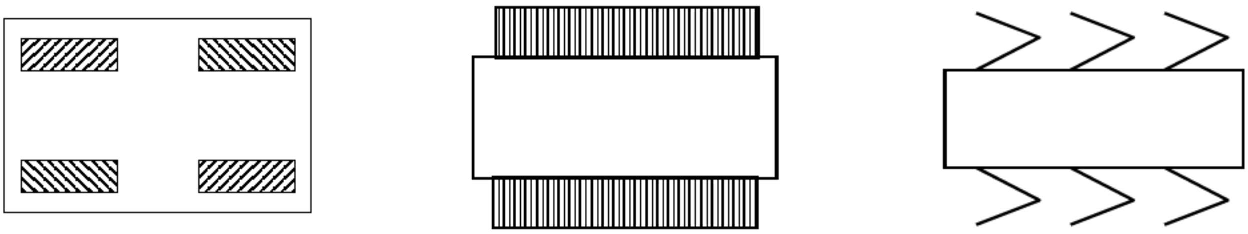


Figure 3.2: Omni-directional, tracked, and walking robots

3.2.1 Omnidirectional

A special case of a wheeled robot is the omnidirectional robot in the Figure left. It uses four driven wheels with a special wheel design.

3.2.2 Tracked Robots

Tracked robots are more flexible and can navigate over rough terrain. However, they cannot navigate as accurately as a wheeled robot. Tracked robots also need two motors, one for each track. A tracked mobile robot can be seen as a special case of a wheeled robot with differential drive. In fact, the only difference is the robots better maneuverability in rough terrain and its higher friction in turns, due to its tracks and multiple points of contact with the surface.

3.2.3 Disadvantages

One disadvantage of all wheeled robots is that they require a street or some sort of flat surface for driving.

3.3 Sensors

For designing a low cost robot, it is necessary to find the right sensor for a particular application. There are a vast number of different sensors being used in robotics. These sensors apply different measurement techniques and use different interfaces to a controller. Choosing right sensor involves the right measurement technique, the right size and weight, the right operating temperature range and power consumption, and of course the right price range.

Data transfer from the sensor to the CPU can be either CPU-initiated (polling) or sensor-initiated (via interrupt). In case it is CPU-initiated, the CPU has to keep checking whether the sensor is ready by reading a status line in a loop. This is much more time consuming than the alternative of a sensor-initiated data transfer, which requires the availability of an interrupt line. The sensor signals via an interrupt that data is ready, and the CPU can react immediately to this request.

3.3.1 Sensor Categories

From an engineers point of view, it makes sense to classify sensors according to their output signals. This will be important for interfacing them to an embedded system.

From a robots point of view, it is more important to distinguish:

Local or on-board sensors(sensors mounted on the robot) & Global sensors (sensors mounted outside the robot in its environment and transmitting sensor data back to the robot)

For mobile robot systems it is also important to distinguish:

Internal or proprioceptive sensors(sensors monitoring the robots internal state) & External sensors (sensors monitoring the robots environment)

A further distinction is between:

Passive sensors (sensors that monitor the environment without disturbing it, for example digital camera, gyroscope) & Active sensors (sensors that stimulate the environment for their measurement, for example sonar sensor, laser scanner, infrared sensor)

Analog versus Digital Sensors:

A number of sensors produce analog output signals rather than digital signals. This means an A/D converter is required to connect such a sensor to a microcontroller. Typical examples of such sensors are:

1. Microphone
2. Analog infrared distance sensor2
3. Analog compass
4. Barometer sensor

Digital sensors on the other hand are usually more complex than analog sensors and often also more accurate. In some cases the same sensor is available in either analog or digital form, where the latter one is the identical analog sensor packaged with an A/D converter.

However, a number of typical sensor systems are selected and discussed their details in hardware and software, here.

3.4 Sonar Sensor

In robotics distance measurements sensors are wildly used. Measuring distance is an important feature for mobile robots. For decades, mobile robots have been equipped with various sensor types for measuring distances to the nearest obstacle around the robot for navigation purposes.

In the past, most robots have been equipped with sonar sensors (often Polaroid sensors). Sonar sensors use the following principle: a short acoustic signal of about 1ms at an ultrasonic frequency of 50kHz to 250kHz is emitted and the time is measured from signal emission until the echo returns to the sensor. The measured time-of-flight is proportional to twice the distance of the nearest obstacle in the sensor cone. If no signal is received within a certain time limit, then no obstacle is detected within the corresponding distance. Measurements are repeated about 20 times per second, which gives this sensor its typical clicking sound.

Sonar sensors has a very powerful sensor system. Though it has some disadvantages. There are vast number of published articles dealing with them. The most significant problems of sonar sensors are reflections and interference. When the acoustic signal is reflected, for example off a wall at a certain angle, then an obstacle seems to be further away than the actual wall that reflected the signal. Interference occurs when several sonar sensors are operated at once. Here, it can happen that the acoustic signal from one sensor is being picked up by another sensor, resulting in incorrectly assuming a closer than actual obstacle. Coded sonar signals can be used to prevent this, for example using pseudo random codes.

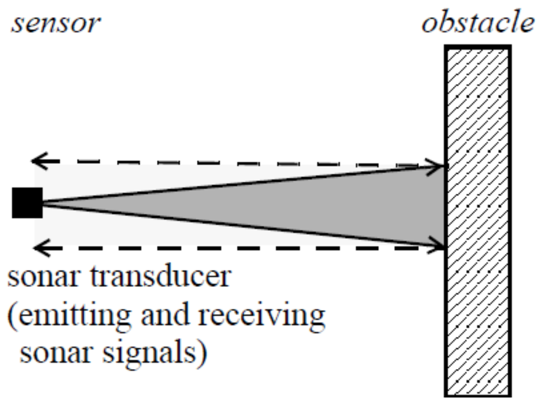


Figure 3.3: Sonar Sensor

Today, in many mobile robot systems, sonar sensors have been replaced by either infrared sensors or laser sensors. The current standard for mobile robots is laser sensors that return an almost perfect local 2D map from the viewpoint of the robot, or even a complete 3D distance map. Unfortunately, these sensors are still too large and heavy (and too expensive) for small mobile robot systems.

3.5 Infrared Sensor

Another type of sensor is infrared sensor. It is one of the most commonly used sensors in robotics. But infrared sensor do not follow the same rules and working principle as sonar sensors. The time-of flight for a photon would be much too short to measure with a simple and cheap sensor arrangement. Instead, these systems typically use a pulsed infrared LED at about 40kHz together with a detection array. The angle under which the reflected beam is received changes according to the distance to the object and therefore can be used as a measure of the distance. The wavelength used is typically 880nm. Although this is invisible to the human eye, it can be transformed to visible light either by IR detector cards or by recording the light beam with an IR-sensitive camera.

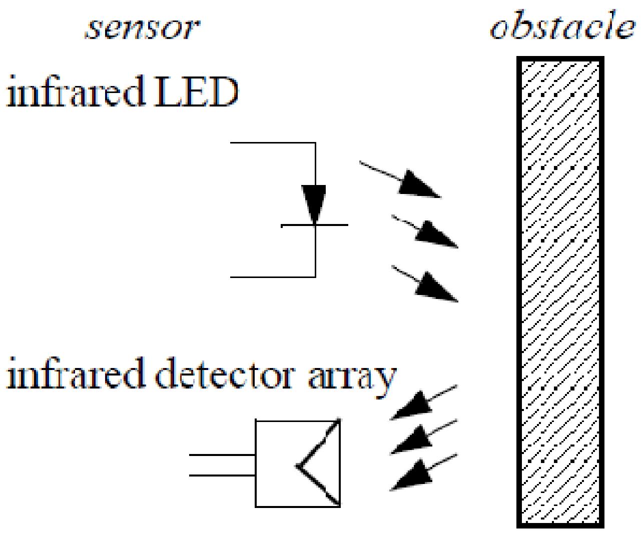


Figure 3.4: Infrared Sensor

3.6 Digital Camera

Digital cameras are the most complex sensors used in robotics. Digital camera is needed in surveillance mobile robots. Most of the time CMOS camera is used.

For most applications for small mobile robots, a resolution of 6080 pixels is sufficient. With such a small resolution, detection of colored objects or obstacles in the way of a robot is possible.

The simplest camera interface to a CPU is shown in the previous figure. The camera clock is linked to a CPU interrupt, while the parallel camera data output is connected directly to the data bus. Every single image byte from the camera will cause an interrupt at the CPU, which will then enable the camera output and read one image data byte from the data bus.

Camera chip development advances so rapidly. For a robot application program, the routines to access image data are:

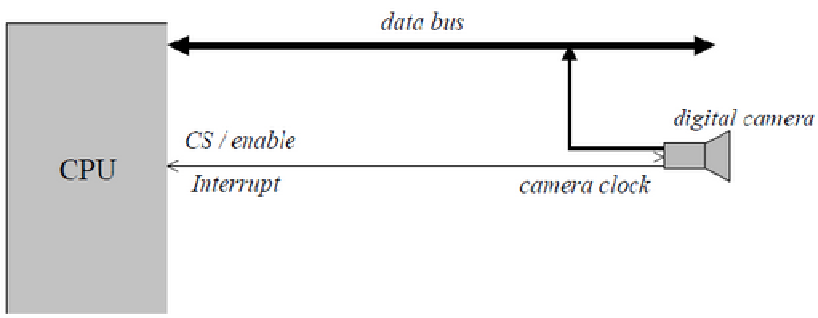


Figure 3.5: Camera Interface

1. Initializes camera, independent of model. Older camera models supported modes different to normal.

2. Disable camera.

3. Read a single grayscale image from the camera, save in buffer.

4. Read a single color image from the camera. If convert equals 1, the image is immediately converted to 8bit grayscale.

5. Set camera parameters. Parameter meaning depends on camera model

6. Get camera parameters. Parameter meaning depends on camera model

3.6.1 Focus

The first important step when using a camera is setting its focus.

3.6.2 Auto-Brightness

The auto-brightness function adapts a cameras aperture to the continuously changing brightness conditions. If a sensor chip does support aperture settings but does not have an auto-brightness feature, then it can be implemented in software.

3.7 Motors

Motors are the most common and important instruments of mobile robots. The following article discuss the motors generally used in mobile robots. To interface motors with the microcontroller l239D IC is needed.

3.7.1 DC Motors

For locomotion of the mobile robot DC motors are widely used. To interface motors with the microcontroller one l238D IC is needed. One DC motors can be used to drive the two wheel.DC motors are clean, quiet, and can produce sufficient power for a variety of tasks. They are much easier to control than pneumatic actuators, which are mainly used if very high torques are required.

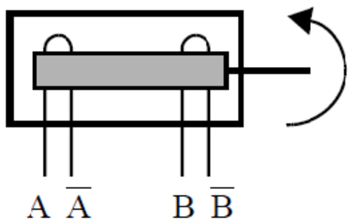
The first step when building robot hardware is to select the appropriate motor system. The best choice is an encapsulated motor combination comprising a: DC motor, Gearbox, Optical or magnetic encoder

Using encapsulated motor systems has the advantage that the solution is much smaller than that using separate modules, plus the system is dust-proof and shielded against stray light. The disadvantage of using a fixed assembly like this is that the gear ratio may only be changed with difficulty, or not at all. In the worst case, a new motor/gearbox/ encoder combination has to be used.

3.7.2 Stepper Motor

There are two motor designs which are significantly different from standard DC motors. These are stepper motors discussed in this section and servos, introduced in the following section.

Stepper motors differ from standard DC motors in such a way that they have two independent coils which can be independently controlled. As a result, stepper motors can be moved by impulses to proceed exactly a single step forward or backward, instead of a smooth continuous motion in a standard DC motor. A typical number of steps per revolution is 200, resulting in a step size of 1.8. Some stepper motors allow half steps, resulting in an even finer step size. There is also a maximum number of steps per second, depending on load, which limits a stepper motors speed.



Switching Sequence:

Step	A	B
1	1	1
2	1	0
3	0	0
4	0	1

Figure 3.6: Stepper Motor its switching sequences

Above figure demonstrates the stepper motor schematics. Two coils are independently controlled by two H-bridges (here marked A, A and B, B). Each four-step cycle advances the motors rotor by a single step if executed in order 1..4. Executing the sequence in reverse order will move the rotor one step back. The switching sequence pattern resembles a gray code.

One l239D IC is needed to interface a stepper motor with the microcontroller. If two steeper motor is required then two l239D is needed.

Stepper motors seem to be a simple choice for building mobile robots, considering the effort required for velocity control and position control of standard DC motors. However, stepper motors are very rarely used for driving mobile robots, since they lack any feedback on load and actual speed (for example a missed step execution). In addition to requiring double the power electronics, stepper motors also have a worse weight/performance ratio than DC motors.

3.7.3 Servo Motors

A servo, on the contrary, is a DC motor with encapsulated electronics for PW control and is mainly used for hobbyist purposes, as in model airplanes, cars, or ships.

Figure 3.7: Servo Motor

A servo has three wires: VCC, ground, and the PW input control signal. Unlike PWM for DC motors, the input pulse signal for servos is not transformed into a velocity. Instead, it is an analog control input to specify the desired position of the servos rotating disk head. A servos disk cannot perform a continuous rotation like a DC motor. It only has a range of about 120 from its middle position. Internally, a servo combines a DC motor with a simple feedback circuit, often using a potentiometer sensing the servo heads current position.

The PW signal used for servos always has a frequency of 50Hz, so pulses are generated every 20ms. The width of each pulse now specifies the desired position of the servos disk. For example, a width of 0.7ms will rotate the disk to the leftmost position (120), and a width of 1.7ms will rotate the disk to the rightmost position (+120). Exact values of pulse duration and angle depend on the servo brand and model.

Like stepper motors, servos seem to be a good and simple solution for robotics tasks. No l239D IC is needed to interface servo motors with the microcontroller.However, servos have the same drawback as stepper motors: they do not provide any feedback to the outside. When applying a certain PW signal to a servo, we do not know when the servo will reach the desired position or whether it will reach it at all, for example because of too high a load or because of an obstruction.

3.8 Driving action

Following is described the driving action.

3.8.1 Multiple Motors Driving Straight

The way that a robot vehicle is constructed, how- ever, shows us that a single motor is not enough . All these robot constructions require two motors, with the functions of driving and steering either separated or dependent on each other. In the design on the left or the design on the right, the driving and steering functions are separated. It is therefore very easy to drive in a straight line (simply keep the steering fixed at the angle representing straight) or drive in a circle (keep the steering fixed at the appropriate angle). The situation is quite different in the differential steering design shown in the middle of Figure which is a very popular design for small mobile robots. Here, one has to constantly monitor and update both motor speeds in order to drive straight. Driving in a circle can be achieved by adding a constant offset to one of the motors. Therefore, a synchronization of the two motor speeds is required.

3.8.2 Single Wheel Drive

Having a single wheel that is both driven and steered is the simplest conceptual design for a mobile robot. This design also requires two passive caster wheels in the back, since three contact points are always required.

Linear velocity and angular velocity of the robot are completely decoupled. So for driving straight, the front wheel is positioned in the middle position and driven at the desired speed. For driving in a curve, the wheel is positioned at an angle matching the desired curve.

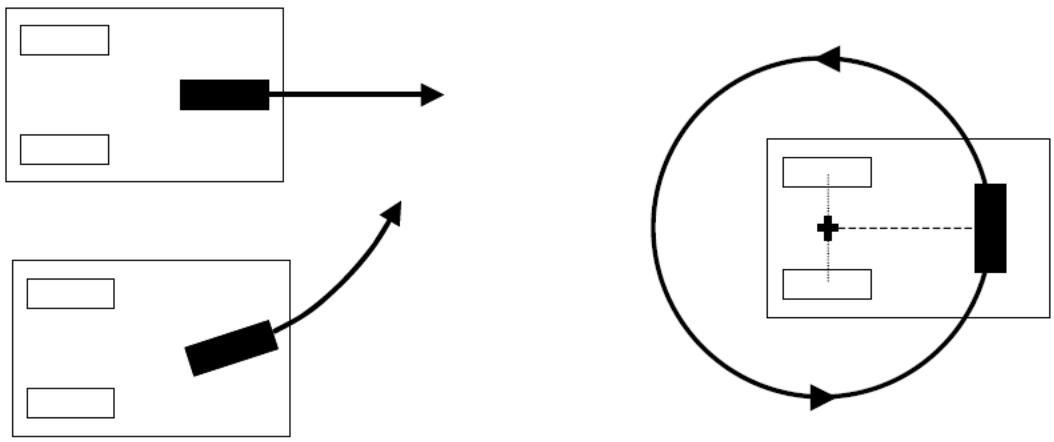


Figure 3.8: Driving and rotation of single wheel drive

Figure above shows the driving action for different steering settings.

3.8.3 Differential Drive

The differential drive design has two motors mounted in fixed positions on the left and right side of the robot, independently driving one wheel each. Since three ground contact points are necessary, this design requires one or two additional passive caster wheels or sliders, depending on the location of the driven wheels. Differential drive is mechanically simpler than the single wheel drive, because it does not require rotation of a driven axis. However, driving control for differential drive is more complex than for single wheel drive, because it requires the coordination of two driven wheels.

The minimal differential drive design with only a single passive wheel cannot have the driving wheels in the middle of the robot, for stability reasons. So when turning on the spot, the robot will rotate about the off-center midpoint between the two driven wheels. The design with two passive wheels or sliders, one each in the front and at the back of the robot, allows rotation about the center of the robot. However, this design can introduce surface contact problems, because it is using four contact points.

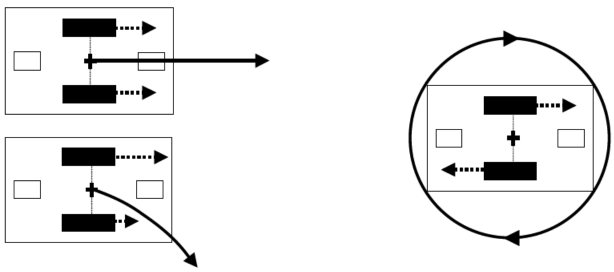


Figure 3.9: Driving and rotation of differential drive

Above figure demonstrates the driving actions of a differential drive robot. If both motors run at the same speed, the robot drives straight forward or backward, if one motor is running faster than the other, the robot drives in a curve along the arc of a circle, and if both motors are run at the same speed in opposite directions, the robot turns on the spot.

3.9 Raspberry Pi Features

- Ethernet connectivity: Can be able to connect to internet. Standard Ethernet connector available.
- USB 2.0: This module support USB 2.0 bus. This module has two USB headers.
- RCA Video OUT: To output the video to an RCA video compatible device (such as television), this module has an RCA Video OUT port.
- Audio OUT: To output the audible data, this module supports audio out port.
- JTAG header: This module has an in-built JTAG header. So this module can be tested/debugged while keeping the connection intact.
- GPIO header or General Purpose Input Output header: This pinsallows to make any custom hardware module that directly uses the processing power of the Raspberry Pi module.
- SD Card compatibility: SD card slot is available to this device, so that SD card can be possible to use to store the operating system.
- SAMGSUNG 325 700MHz processor: For the processing power, this device includes a Samsung 325 700 MHz processor.

CHAPTER 4
DESIGN APPROACH & IMPLEMENTATION

4.1 Introduction

The use of products from the market for robot components, together with some engineering spirit, enables the emergence of low-cost robots for many application areas. University lends the robots to students to let them freely use their own laptops to control the robot, independently of classes, and join in the end of every semester for a local competition, like some competitions already existing in many universities.

4.2 Mobile Robots

In the state of art of mobile robots morphology we may mainly find legged and wheeled robots. Legged robots were always very challenging due to their likeness to living beings way of locomotion.

Much simpler and easier to build and control, robots with wheels are the simplest for a beginner. Some topologies exist varying the number of wheels, the type of steering and driving. We may find four wheeled robots, but the simplest solution is to build two-wheeled robots which usually have two driven wheels near the center of the robot, along with a caster wheel. The two driven wheels are able to make the robot steer and drive in almost any direction. Robots with omnidirectional wheels are by far the most agile but somewhat more difficult to control.

Here, a design approach was given for a mobile robot which will transfer visual data of object which is in front of it.

4.3 Hardware & Development

As stated before, low cost was an important goal when building these robots. An android phone can be used to control the robot. They are more and more common among university students. It is very common that among two or three students in a group, at least one has an android phone. So the students use their own phones to control the robots. Hence, we did no count the laptop cost on the robot cost.

We did not include the costs of the software licenses (Visual Studio) because we use either campus or students licenses. The cost depends on the choices of some components but the overall cost of the robot is under 12000 BDT.

Small microcontrollers like Microchip or Atmega families provide a very interesting alternative, but again the programming capabilities are limited to the existing cross compilers available. Moreover they provide good solutions for analog or digital I/O ports but not for handling image processing cameras.

The advantage of such a simple robot is that it becomes possible to lend the robot to the students freeing the laboratories occupancy and providing a new challenging and unusual peripheral for the students own smart phones.

Raspberry Pi was decided to use. Raspberri Pi's camera module and reason for selecting it are included in this chapter.

4.4 Working Approach

Working approach is divided into three sub division: 1.Hardware design 2.Software design 3.Selecting Electronic Devices

4.4.1 Hardware design

Hardware design part consisting of the design of the 3D design, then convert it into a real prototype. In this project, solidworks software was used to design the 3D part which gave us the insights about the robot to be built.

4.4.2 Software Design

For this project, a software is needed for monitoring and controlling. A graphical user interface for this project is needed. Qt software bundle is choosen for the project. This is an appropriate tool to build a controller and user interface within limited amount of resource.

This software bundle has a lot of library. So it is quite easy to build an interface. Also it has a lot of open source library for data communication that we used in our interface.

4.4.3 Electronics and Communication

Choosing the right hardware was a great challenge. Finally a decision was taken to work with Rapsberry Pi board. This is an embedded linux board with a lot of facility in it including HDMI port support, USB support and so on. We also used a camera module connected to the Raspberry Pi board. On the desktop part, we used a wifi router. The raspberry Pi is also connected with another wifi module. This two makes the communication part.

4.5 Working Procedure

The implementation of the robot is consisted of three different parts. These are

- ▷ Hardware Development
- ▷ Software Development
- ▷ Implementing the communication

4.5.1 Hardware Development

The device is made of plastic wood. It is easier to use, light weighted and flexible for experiment. In this portion, the hardware design is implemented. This phase is splited up into two parts. First, designing the simulation model. Second implementing it on real.

For designing the 3D model, Solidworks was used as a 3D modeling tool. This tool is used for designing the robot chassis with exact dimension. Thus, it helped to find the correct material and the stress analysis.
The following article is about the pictorial view of the low cost robot.

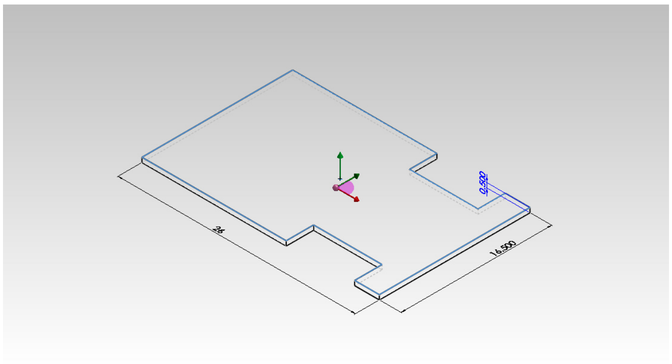


Figure 4.1: Bottom sheet of the robot

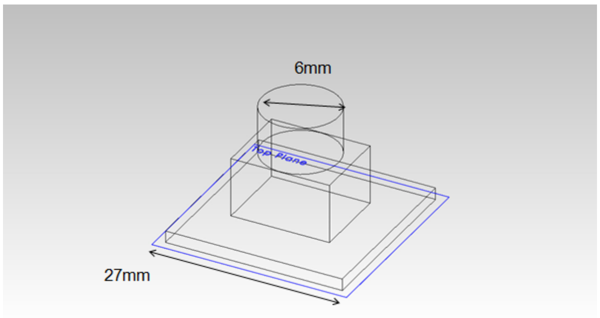


Figure 4.2: Dimension of the camera

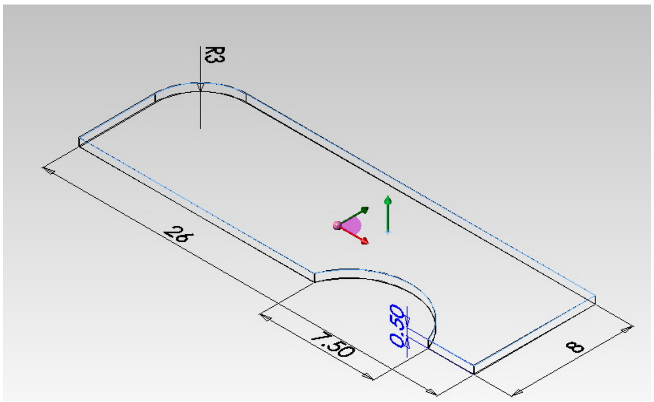


Figure 4.3: Chassis Side View

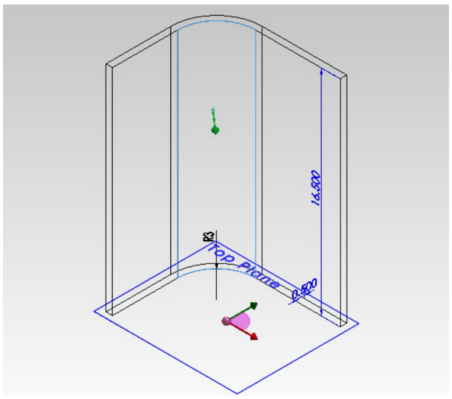


Figure 4.4: Front Panel

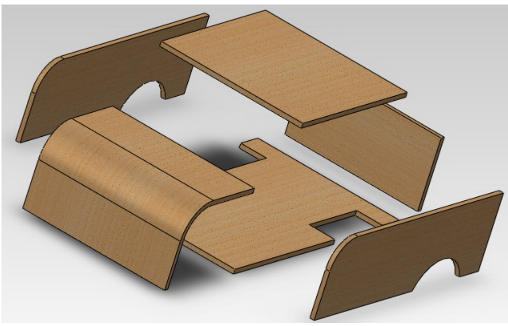


Figure 4.5: Disassembled View

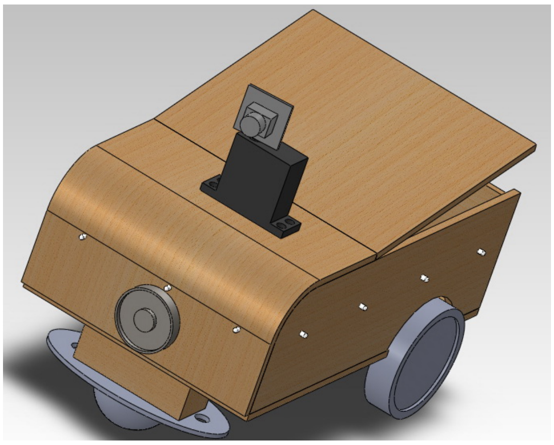


Figure 4.6: Assembled View

4.5.2 Software Development:

It involved two different approach.

a.It is already stated before that Qt software bundle was used for the controller software implementation. The reason for choosing Qt over Microsoft Visual Studio is that it is open-source. Moreover this tool has good features to build a graphical user interface.

b.For the software on the robot-end, shell script and python was used to capture and receiving the control command. Raspberry Pi module has a good operating system naming Raspbian. This system is equipped with some linux shell command for image capturing and networking. To create a bundle of operation linux shell script was used. To create the data communication and command receiving module, python language was used.

The Following is the user interface that has been developed to control the robot.

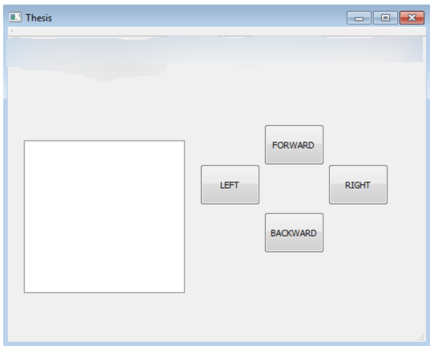


Figure 4.7: Software Interface

4.5.3 Implementing the Communication

For the communication task, the design is planned with wifi communication. There is a wifi dongle planned to be attached with the USB hub of the Raspberry Pi board. This wifi will communicate with the command-end.

4.6 Working Methodology

- ▷ Raspberry Pi needs 5V DC supply. As a result a voltage regulator is used. 12V DC supply is connected with the voltage regulator. The voltage regulator is connected with the Raspberry Pi.
- ▷ The Raspberry Pi is connected with the motor driving IC, L293D. Then it is connected with the motor. And thus the motor is rotated.
- ▷ The camera module is directly connected with the Raspberry Pi.

4.7 Raspberry Pi

It consists a camera module which captures the video/ images of the robots front.

4.7.1 Raspberry Pi Camera Module

Following is the figure of Raspberry Pi camera module.

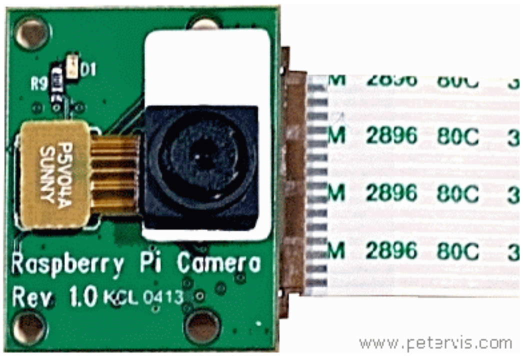


Figure 4.8: Raspberry Pi Camera Module

4.7.2 Features of Raspberry Pi Camera Module

- ▷ 5MP resolution: This module supports 5Mega pixel camera module.
- ▷ Video resolution: This module supports 1080 HD quality video capturing.
- ▷ Image resolution: This module supports2592 x 1944 pixel of image resolution at maximum.
- ▷ This module takes power directly from raspberry pi board.

4.7.3 Raspberry Pi Actual Module

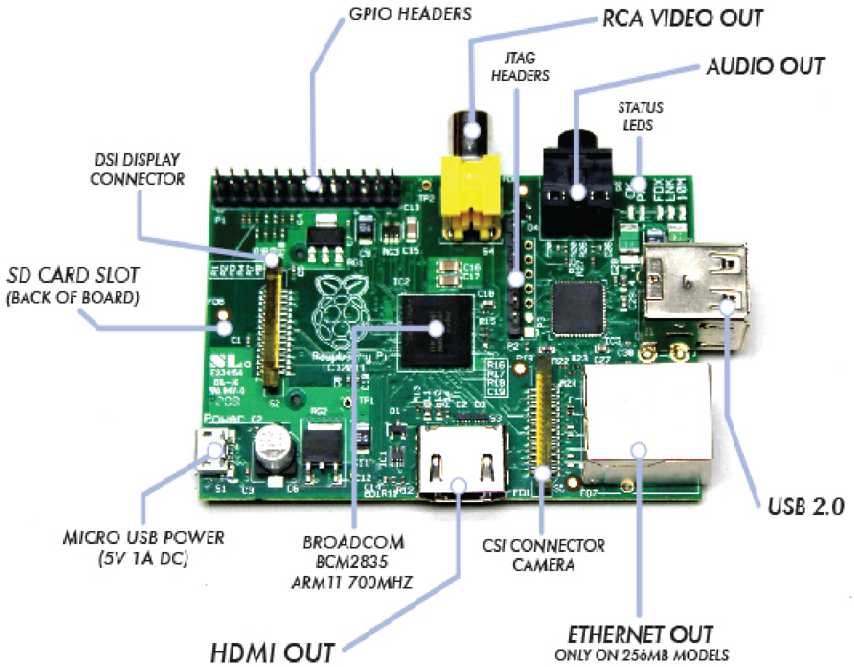


Figure 4.9: Raspberry Pi- actual module with different parts demonstrated

4.7.4 Raspberry Pi Schematic

This device is the minicomputer for the robot. Raspberry Pi has its own operating system. Raspbian operating system is used on this device.

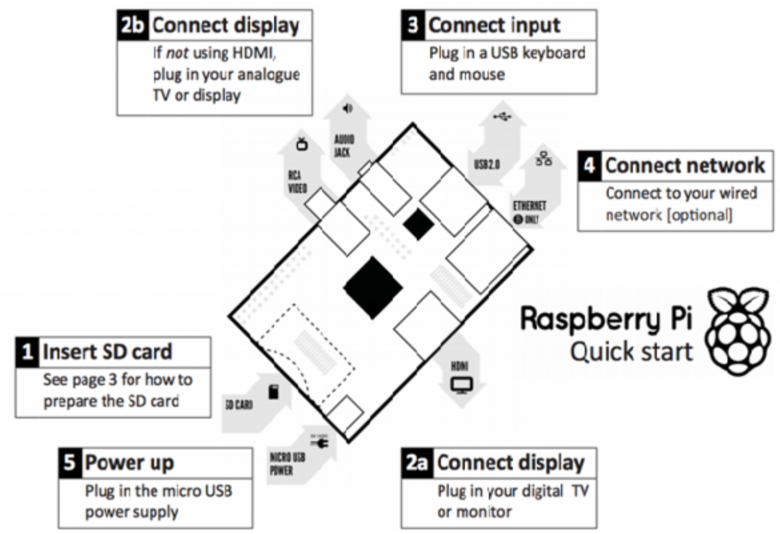


Figure 4.10: Raspberry Pi Schematic

4.8 Reason For Selection of Raspberry Pi

Choosing the right hardware board was a challenge. Raspberry Pi was choosen finally.

The possible candidates are Raspberry Pi, Arduino board, Custom design, Beagle bone etc. Follwing are the short features of these candidates.

4.8.1 Beagle Bone

- ▷ This is an extra-ordinary board that should fit our purpose. But this module doesn't support a dedicated camera module like the Raspberry Pi does.
- ▷ Beagle bone are a little costlier than the raspberry pi.

4.8.2 Arduino Board

- ▷ Very easy to start and work with, but not enough processing power.
- ▷ Cannot handle an image to capture and process operation.
- ▷ Memory is too much short for our purpose.

4.8.3 Custom Design

- ▷ Details implementation takes a lot of time.
- ▷ Many items are not available to Bangladesh.
- ▷ Too much sophisticated for our purpose.
- ▷ Too much costly.

4.8.4 Raspberry Pi

- ▷ Feasible to our needs and technical complexity.
- ▷ Lots of resource on the internet.

- ▷ This module also maintain a dedicated camera module that can be easily implementable on Raspberry Pi board.

4.9 Morphology and Motors

As we showed there are several morphologies of robots. It uses low cost motors, batteries and chargers of disassembled low cost electrical screwdrivers.

Trying to keep it simple, we decided to build a robot with three wheels. Two wheels provide differential driving and the other wheel is free (caster wheel). This simple structure allows a high mobility of the robot.

The use of products from the market enables the construction of low cost robots. DC gear motor was decided to use.

The gear ratio is 1:16.

4.10 Power System

12V DC power supply was used here. Lead acid battery. Lower internal resistance giving sudden current surge.

CHAPTER 5

CONCLUSION & FUTURE EXPANSION

5.1 Conclusion

Robotics is the science and technology of robots and their design, manufacture and application. It is commonly defined as a mechanism that can sense its environment, process what is senses, and act upon its environment based on that processing.

The minimal setup shown allows the students to have a standard departure point that allows the robot to fulfill some of the tasks with little changes. However innovation is encouraged (otherwise it would be just reinventing the wheel all the time). So there should be still space for innovation.

A low cost robot is fabricated with locally available materials and components. A suitable mechanical control system is necessary to perform fine manipulation. Installing a robot won't work or solve all quality problems unless the robot is programmed correctly, that they have a shorter reach and can only work with smaller parts. A strong multi-discipline team with good engineering base is necessary for the development and refinement of robotics.

Technology is no doubt important but success on the way of thinking and applications without bringing unnecessary complexity.The device explained in this report is able to transmit visual data and it can be seen in the monitor. It is expected that flexible automation and robotics technology in particular, will play an important part in the revolutionizing progress of technology.

5.2 Future Works

With the change of time, change of requirement, improvement of technology there is a modification in every creation. So, there is still room for improvement.For future works, we can integrate various types of sensors to guide the robot. However, more features can be added like track following, obstacle detection, distance measuring, object detection and so on. For further perfection and to increase the efficiency of the device the following recommendations are put forward on the basis of experience gained out of the thesis work and investigation:

i. Making the robot communicating with other robot.

ii. Making the robot controllable with multi user command end.

iii. Making the robot designed with bluetooth system.

iv. Making the robot designed with the ability to carry payload in a destructive environment for the mankind.

v. Making the robot designed with the camera being movable.

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APPENDIX

APPENDIX

COMPUTER PROGRAMMING FOR ROBOT CONTROL

```
#include <QtGui/QApplication>
#include “mainwindow.h”
int main(int argc, char *argv[])
{
	QApplication a(argc, argv);
	MainWindow w;
	w.show();
	return a.exec();
}
```

Controller Software:

```
#include “mainwindow.h”
#include “ui_mainwindow.h“
MainWindow::MainWindow(QWidget *parent) :
QMainWindow(parent),
ui(new Ui::MainWindow)
{
	ui->setupUi(this);
}
MainWindow:: MainWindow()
{
	delete ui;
}
```