

Practical Development of an Experimental Autonomous System in Real Time Environment - C R U I

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Abstract

The paper presents the design, implementation of the a unique type of computer controlled circular mobile robotic unit equipped with intelligence. Building an experimental autonomous vehicle or robot, which has the ability to perform in real time environments is both a technical and scientific challenge and demands the development of systems for perception, modelling, planning and navigation. Within this scope, this paper describes the construction of a low cost mobile autonomous robot, intended for educational purposes. The work presented in this communication describes the mechanical structure of the vehicle, the electronic modules developed and the software modules implemented for the control and remote navigation. The work was undertaken as a sponsored consultation based project under the guidance of the author in the institute.

Keywords: Driver Units, Actuators, Visual Basic, Parallel Port Interface.

1. Introduction

Today, a mobile robot [1] can be designed in order to operate in a wide range of industrial, military, scientific, domestic, humanity and in educational applications. The important aspects of the design include the choice of the materials used in the vehicle framework, the kind of batteries, the type of sensors to assist the navigation, the choice of actuators and the steering system configuration. The user interface and the navigation software are also important. The relevance of these issues was shown in the development of CRUI, one of the advanced version of the mobile platform. In this version, it contains a working map describing the permanent and stationary obstacles like the walls, corridors, etc.,. An onboard controller performs the control of the vehicle.

The connection between the computer and its electronic systems is made through the parallel port using a lengthy interfacing cable. The use of external sensing systems, such as ultrasounds, limit switches and the infrared proximity sensors allows the vehicle to interact with its environment in a flexible manner, in order to move autonomously in the working area and avoiding detecting the unknown obstacles. This communication describes the design and implementation of a relatively low cost autonomous vehicle, named CRUI, totally indigenously developed and able to move in a semi structured environments, using a sensor based approach

for navigation. This project has its origin in our own fascination for the field of robotics. That, coupled with our genuine urge to build something substantial, led us to undertaking this endeavor.

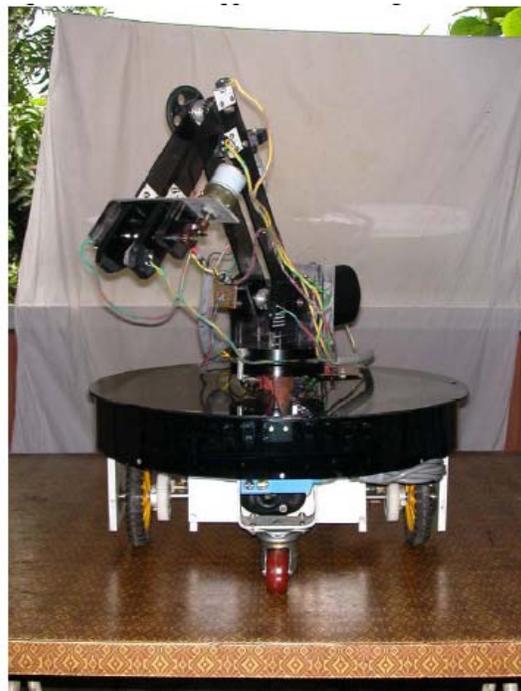


Figure 1 : The C R U I

Since robotics encompasses everything from mechanics to electronics to computer software, we had the opportunity to learn more than we could have otherwise. The whole of the city was roamed in search of components that matched our very stringent requirements. Nevertheless, we are mighty proud of our efforts and, more so, of the end result. Presenting – the “C R U P”. The main objective of this work is to design, fabricate each part, construct an educational model of a mobile robot with an arm and control it with a computer. The robot would move on a horizontal plane such as floor avoiding obstacles in its path of motion by making use of infra-red sensors.

2. Design and Implementation of the Mechanical Unit

The built autonomous vehicle [2] weighs 30 Kgs. with a circular base of 2 feet diameter and can travel at a maximum speed of 0.5 m/s. The sensorial system is composed of a pair of infra-red sensors, limit switches, encoders etc.,. This is a vehicle presenting a differential configuration, capable of operating in semi-structured environments, avoiding unknown obstacles. The operation is performed in various modes. The control architecture software was developed using modular approach implementing an optimized set of efficient routines both at the low level sensor and actuator signal management and at the high abstraction level to take care of the navigation problems and the communication protocol. The GUI implemented at the supervision station was developed using the Visual Basic Programming environment and provides the necessary facilities for the definition, simulation / execution of tasks required from the vehicle.

The mechanical system consists of three divisions.

- Robot Base Assembly (mobile trolley).
- Robot Arm Assembly.
- Robot Gripper Assembly.

2.1 Moveable base assembly (mobile trolley)

The base is made up of a brown hard hylam sheet of thickness 8 mm and of diameter 1.5 feet (circular in shape). Hylam sheet was chosen keeping in mind the following properties, viz., Good insulating medium, Light in weight, Can be easily cut into required shape and size and provides a platform for the arm and the entire structure including the electronic circuitries.

To drive the mobile trolley, we have used D.C. Servomotors which will give sufficient torque and at the same time sufficient rpm so that the robot can move at a particular speed. We have chosen D.C. servos because they have got only two wires (+ and -) and they can be easily driven from a simple driving IC chip and speed control is easier. Two D.C. Servomotors of 10 Kg - cm torque, 1.75A current rating, and 60 rpm, drive the mobile trolley on which all the electronic components and the mounted arm. The motors are mounted on the lower surface of the hylam sheet with

the help of brackets made from aluminium in order to reduce the weight.

The two wheels of diameter 12 cms, plastic made with a rubber tyre over it is coupled to the main driving motors using a chain of gearing systems and supported between two ball bearings. The motors are coupled to the wheels using aluminium shafts via the spur gears of 12 and 48 teeth's. Since the hylam base has to carry the entire weight of the robot, it was necessary for us to increase the torque rating at the wheel shafts. This was achieved by using spur hard nylon gears of 1:4 ratios.

The smaller gear attached to motor has 12 teeth's and the bigger gear attached to the wheel has 48 teeth's. The two driving wheels of 10 inches are placed along the diameter of the circular hylam sheet below it. The rubber tyre helps the robot better gripping of the surface. Two castor wheels one at the front and another at the back are attached perpendicularly to the diameter. These two castor wheels allow the robot free rotation of the castor resulting in a frictionless drag free motion of the robot. The view of the mobile trolley is shown in Figure 1.

2.2 Arm Assembly

The arm assembly is divided into arm base assembly and the two link arm which is attached to the base unit.

2.2.1 Arm Base Assembly

The base assembly of the 3 axis robot arm is at the center of the circular acrylic platform. It consists of two small circular plates one above the other (bottom plate being fixed and the upper one rotating w.r.t. the bottom) with a thrust bearing in between them to provide a smooth base rotation of 300° either in the clockwise or in the anticlockwise direction. A Big D.C. Servomotor is attached at the bottom of the acrylic platform.

A worm and a worm wheel assembly of 1:20 ratio is keyed to the D.C. Servo shaft in the horizontal plane. A central rotating shaft is attached to the big rotating worm wheel. This shaft is extended from the bottom of the platform to the top circular plate and is welded at the center. Limit switches are used at the extreme ends of the double plates. The entire arm (with the shoulder assembly, elbow assembly and the gripper assembly) is mounted on the upper rotating plate. The specification of motor used for Base are 12 V D.C, 60 rpm, 60db noise, Torque: 10 kg-cm, Weight : 1 kg, 0.5 A Current rating (Off Load), Up to 1.75 A as load increases.

2.2.2 Shoulder Assembly

The shaft is fitted with a pair of parallel Acrylic plates that move along with the shaft. These plates house the mechanisms that actuate the joint motion. On the other end of these plates is another shaft pin that rotates the outer arm along its axis, thus providing the revolute

motion for the shoulder joint. The plates for the inner and outer arms are made of Acrylic which is very light and strong, thus reducing the leverage of the two arms on the base and at the same time strong enough to sustain the weight of the motors and the mechanisms housed by them. The motion is actuated by a very compact mechanism of worm and worm wheel. The double helical worm is fitted on the motor shaft, while the worm wheel is fitted on the shaft, which provides elbow rotation. The speed ratio of this arrangement is 1:20, that is, the worm wheel makes one complete revolution when the worm makes 10 revolutions. The motor is fixed on the circular Acrylic Plate on the base assembly to the shoulder axis, first link of length 250mm .

Specification of Motor [4] used for Shoulder Assembly are 12 V D.C, 60 r.p.m, 60db noise, Torque: 10 kg-cm, Weight: 1 kg, 0.5 A Current rating (Off Load), Up to 1.75 A as the load increases. Limitation of the Shoulder motion is less than 90°. Opto-coupler is attached to the Shoulder joint axis. Working of the Opto-coupler is explained in later chapter. Main function of Opto-coupler is that it gives uniform count irrespective of varying load.

- Speed at which Shoulder Motor Rotates : 60 r.p.m.
- Gear Ratio of worm and worm wheel : 1:20
- Speed at which Axis of shoulder joint rotates : 3 r.p.m
- Rotation of Axis per second : $3/60 = 1/20$
- This states that one complete revolution of shoulder joint Axis moves arm by 360°.
- Therefore 1/20 revolution of shoulder joint axis moves arm by 18° at this time count at Rotating Disk is $90 / 20 = 4.5$ (For one rev count is 90 therefore for 1/20 rev count is 90/20)
- Hence, for every increment in the count there is $(18^\circ/4.5 = 4^\circ)$ rise in angle.

2.2.3 Elbow Joint Motion

The motion is actuated by a very compact mechanism of worm and worm wheel. The double helical worm is fitted on the motor shaft, while the worm wheel is fitted on the shaft, which provides elbow rotation. The speed ratio of this arrangement is 1:20, that is, the worm wheel makes one complete revolution when the worm makes 20 revolutions. The motor is fixed on the lower plate of the inner arm. The position of the motor is so adjusted that it does not obstruct the rotation of the outer arm. The plates of both the arms are coupled to the shaft with the outer arm plates inside the inner arm plates.

The shaft moves in a pair of Brass bushes in the inner arm plates. Contact between the two plates is avoided by a pair of thrust bearings between them. The upper plate of the outer arm is pinned to the shaft motor. Actuating the motion is a DC tape motor; small in size with considerable torque and speed. The motor is light in weight (200gm) and easy to control, thus making it an ideal choice for actuation. In elbow axis, second link

is of length 140mm. The specifications of the elbow motor are, Type : DC Motor, Torque : 2kg-cm, Current rating : 0.5A., Direction : CW-CCW Motion, Elbow Motor Speed: 60 r.p.m. Limitation of the elbow motion is 120°. Limit switches are attached at the extreme ends of the elbow. An Opto-coupler is attached to the elbow joint axis performs same function as mention for Shoulder assembly.

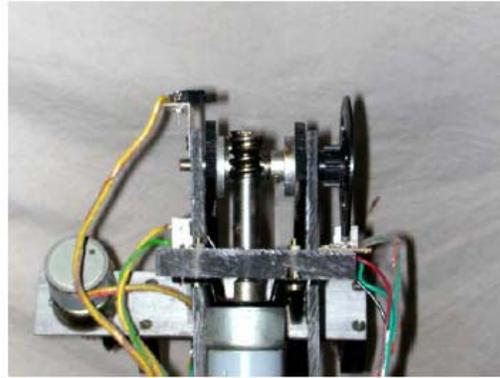


Figure 2 : Elbow Assembly Unit

2.3 Gripper Assembly

The robot being a PNP-type has a gripper as the end effector. The gripper is of parallel jaw type, which works on the principle of left-hand / right-hand screw. These jaws run on the LH / RH screw. The LH / RH screw is made by tapping a brass rod with LH die from one end and RH die from other end. This ensures that the gripper jaws move in the opposite direction, that is, the jaws move either towards each other to grip an object or away from each other to release it as shown in Figure 3.

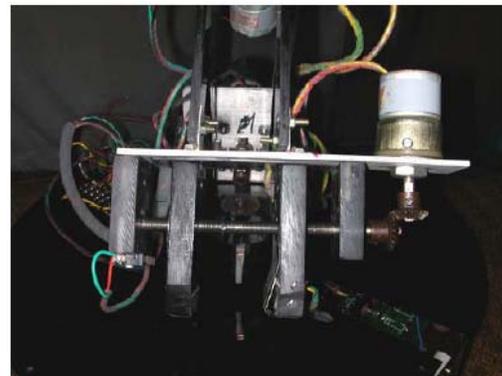


Figure 3 : Gripper Assembly Unit

The LH / RH screw is coupled to a small dc tape motor shaft (12V, 1A) via a bevel gear arrangement in the ratio 1:1 as shown in the Image. One limit switches are placed at the inner ends of the finger. This limit switch is connected to the controller card and is used to prevent the further closing of the fingers after the object has been gripper properly . Another limit switch is attached to the extreme end of the maximum opening of the gripper which is also connected to the controller card.

The maximum opening of the gripper is 75 mm. The gripper motor used has following specifications, viz., Type : DC Motor, Torque : 2kg-cm, Current rating : 0.5A, Direction : CW-CCW Motion.

3. SENSORS

Incorporation of proper feedback mechanism of sensory information to the robot can enable it to perform complicated tasks. Sensors perceive the environment and provide vital feedback information to the robot. Sensors are the eyes of the robot, i.e., they act as the vision system and make the robot very intelligent. Sensors are used to obtain the position and orientation of the robot arm and that of the obstacles in the surrounding environment in the 3D space. They are defined as the sensory data preceptors which detect the changes in the surrounding environment (detect the obstacles) and get adaptable to those changes (overcomes the obstacles, avoids collision and proceeds towards the destination). They are nothing but the feedback devices which are used to obtain the position and orientation of the object / obstacles and this information is fed to the robot system to properly configure the tool / gripper and reach for the object, avoiding all the obstacles in its path of motion.

3.1 Necessities of sensing

The main purpose of equipping robots with intelligent sensing [5] and vision is to enable them to work in nonstructural and random environments. A robotic gripper will always tend to grip an object that it was programmed to grip at a specified point. Then there might be an obstacle in its path. So the robot must intelligently sense the obstacle and move around it and reach the object and grip it. Therefore robots must be equipped with such sensing devices called sensors. Robots equipped with such sensors are called intelligent robots.

3.2 Sensors used in our work

1. Diffused scan sensor (EIR – 301).
2. Limit Switches.
3. Opto-coupler (Encoders)

1. Diffused scan sensor : We have used EIR 301 Scanning / Diffused scan Sensor that works on infrared for obstacle avoidance connected on front side of robot. General Specifications : Supply : 10-24V DC, Peak 30V, Standard Output, Mode / Current - PNP/100 mA, Switching Frequency : 25 Hz.

Conditions of working : Standard Temperature max 50 C, Clear to sight dust laden atmosphere, Protection IP 44 / IP 40. The Option to Standard Features are : Output NPN, Higher Switching frequency.

2. Limit Switch : The Limit switches are normally connected so as to detect extreme ends of motion of Links. It has three terminals C, NO, NC stands for Common, Normally Open and Normally Close. The

Common terminal is connected to GND while V_{cc} (+5V) is directly applied to NO through resistance, also NO is connected to one of connector of 1: 8 Multiplexer on controller card.

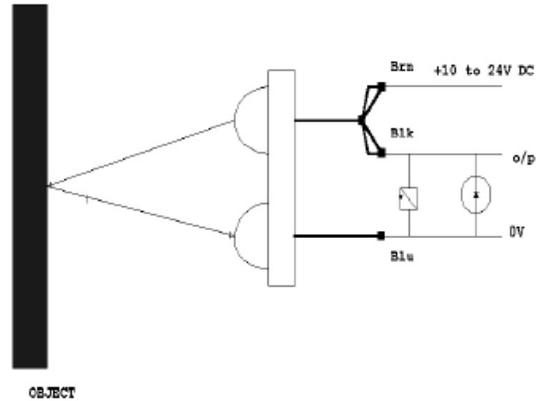


Figure 4 : Working of Diffused scan sensor

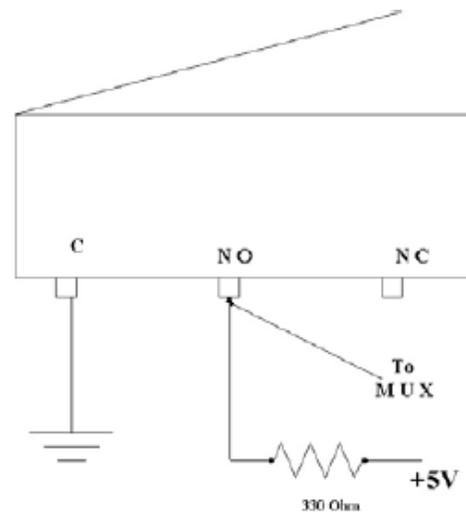


Figure 5 : Limit Switch

When mechanical Limit reaches, NO gets Logical GND (NO physically gets connected to C through strip) which is read by software running at background and immediate action is taken.

3. Opto-coupler : It works on infer-red. Opto-coupler has two sections Emitter and Collector. Emitter is nothing but a Photo-Diode that emits infra red after receiving proper voltage and current. Note that small Register is used to drop down current to the Anode of Diode. Register is necessary because if current at Photo diode is higher it will burn out. Collector is Photo-transistor; emitted light falls on base of transistor. Depending on the intensity of light base current varies. A situation comes when rise base current moves transistor from cut-off to saturation. With Transistor is in ON state, indicates Logic 0 at the output, (One of the output terminal is directly connected to connectors J1 to J5 present on the controller card) read by the software that polls output of opto-coupler at regular interval.

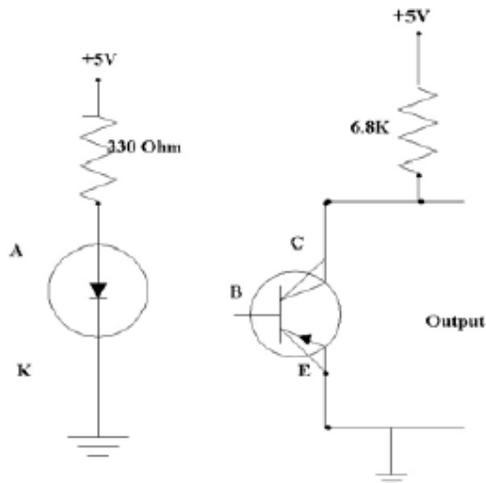


Figure 6 : Optocoupler (Encoder)

4. Electronic Subsystem

Electronic Subsystem [4] is the interface between Mechanical assembly and the PC. The Electronic System consist of the Power Supply Unit and the Control Unit.

4.1 Power Supply Unit

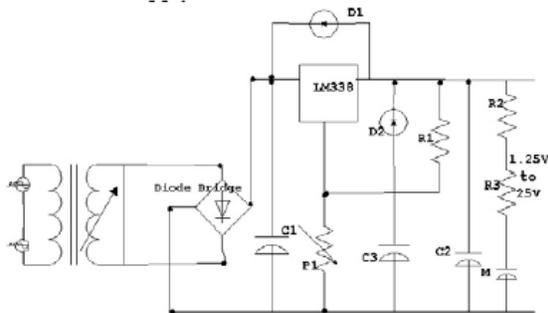


Figure 7 (a) : Power Supply Circuit

Values : of the PS unit are Capacitor C1 = 1000 μ F / 25V, Regulation Capacitor C2 = 330 nF, Regulation Capacitor C3 = 10 nF, Transformer Secondary = 7Vrms.

The DC Motors employed in the project are 12V DC motors, which need 12 V to get energized and start rotation. The Controller card needs 5V supply for various IC's in the circuit. Thus we have designed 12V at 5A and 5V at 1A power supply cards. A 5V / 12V supply is designed, because the cumulative current drawn when all the motors are energized is around 4A. Thus as a safety measure, a 5A supply is selected. The power supply consists of the a line fuse of 5A, a multi-secondary winding step down transformer, the C filter circuit to remove the ripples, the bridge rectifier and the regulator circuit. The regulator circuits are designed using 78L05 IC – which provides a 5V / 1A and a LM338 IC – which provides a 12V / 5A stabilized dc output voltage. The various parts of the power supply are shown in the Figure. All the regulators in the 78L series will deliver a maximum current of 100 mA

provided the input/output voltage differential does not exceed 7 volts, otherwise excessive power dissipation will result and thermal shutdown will occur. This occurs at a dissipation of about 700 mw ; however the metal can version can dissipate 1.4 Watts if fitted with a heat sink.

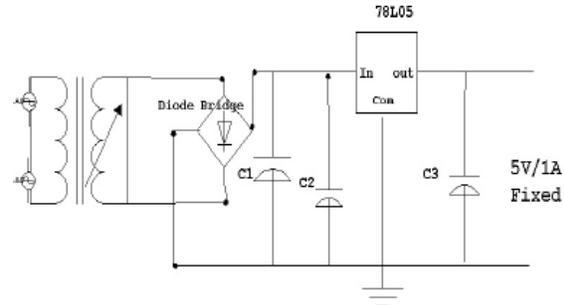


Figure 7 (b) : Power Supply Circuit

Values : Conventional Filter capacitor C1 : 4700 μ F/ 40V, Regulation Capacitor C2: 1 μ F/ 40V, Regulation capacitor C3 : 10 μ F/ 40V, Potentiometer P1 : 2 K Ω and resistors R1, R2, R3 of 120 Ω , 220 K Ω , 27 K Ω

4.2 Control Unit



Figure 8 : Controller Cards

The Control Unit consists of :

25 Pin D Male Connector : This connects the driver circuit to the PC through the parallel port. The program sends the byte combination to energize the desired motors, which reaches the driver circuit through the 5-meter Data Cable to the input of the driver circuit.

Output Expansion circuitry : Here, we designed a circuit that controls up to 64 TTL or CMOS compatible outputs.

Working of the circuitry is as follows. The simple parallel port has got 25 pins and is used as the interface between the robot and the controller. The PNP operation of objects is carried out using 16 by just calling 16 routines with appropriate counts as shown in the Table 1 above. H-bridge using P and N channel MOSFET's Unit is being designed, fabricated and used to drive all the actuators used in the system and is as shown in Figure 9.

Signal	Description
TMLCW	Trolley Motor Left CW
TMLCCW	Trolley Motor Left CCW
TMRCW	Trolley Motor Right CW
TMRCCW	Trolley Motor Right CCW
TMLRCW	Trolley Motor Left / Right CW
TMLRCCW	Trolley Motor Left / Right CCW
TMLCWRCW	Spin in clockwise
TMLCCWRCW	Spin in Counter Clockwise
BMCW	Base Motor Clockwise
BMCCW	Base Motor Counter Clockwise
SHMCW	Shoulder Motor Clockwise
SHMCCW	Shoulder Motor CCW
ELMCW	Elbow Motor Clockwise
ELMCCW	Elbow Motor Counter clockwise
GMCW	Gripper Motor CW (Open)
GMCCW	Gripper Motor CCW (Close)

Table 1

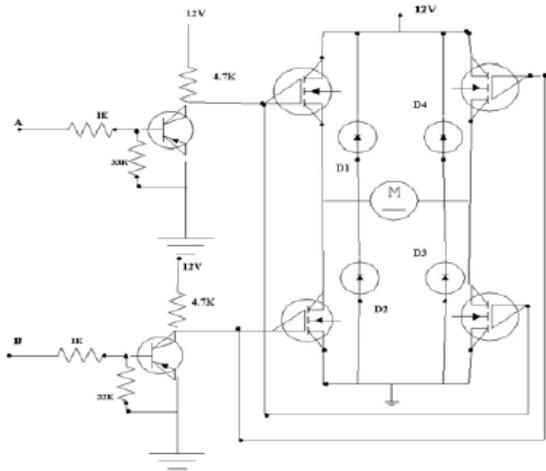


Figure 9 : Schematic of the H-bridge

MOSFET's are extremely static sensitive but more important is that if the Gate is left open (no connection), the MOSFET can self-destruct. The Gate is a very high impedance device ($10 + M\Omega$) and noise can trigger the MOSFET. Resistors have been added specifically to stop the MOSFET from self destructing. The resistors pull-down the Gates and turn off the MOSFET's, not to mention adds some static protection. Back EMF protection is provided by diodes D1 to D4 via route, back EMF from the motor back to the power supply. Q1 and Q2 are NPN transistors that control DC motor action.

4.2.1 Modes of Operation :

Inputs	Output of P Q EXOR	Output of AND	Output of NOT	Input to H-Bridge
0 0	0	0	1	5V 5V
0 1	1	0	1	5V 5V
1 0	1	1	0	0V 5V
1 1	0	0	1	5V 5V

STOP Mode : When A= 0 and B = 0, the motor is stopped.

REVERSE Mode : When A = 1(+5) and B=0 , the motor is in reverse. Q1 is turned on as Base-emitter voltage crosses 0.7V that ensures 0V at gate of first and third MOSFET pair. Q2 is turned off by the voltage at B. Since Q2 is off gate terminals of MOSFET pairs . Second and Fourth gets +12V that provides low resistance path for current to flow through it and through Motor windings. Upon getting sufficient voltage and current Motor start rotating in counter clockwise direction.

FORWARD Mode : When A=0 and B=1(+5), the motor is in forward. Q2 is turned on as Base-emitter voltage crosses 0.7V that ensures 0V at gate of second and fourth MOSFET pair. Q1 is turned off by the voltage at B. Since Q2 is off gate terminals of MOSFET pairs first and third gets +12V that provides low resistance path for current to flow through it and through Motor windings. Upon getting sufficient voltage and current motor start rotating in counter clockwise direction.

NOT ALLOWED Mode (or fuse test mode) : Condition A=1 and B=1 will turn on all MOSFET's which shorts out the power supply among other things - Not recommended. This care is taken by the short circuit prevention circuitry.

Miscellaneous Information : Motors make a lot of electrical noise from the brushes when running and huge electrical spikes when stopping, starting and especially changing direction. C1 and C2 try to suppress the noise spikes. Negative spikes are shorted to either ground or the power supply by D1 to D4.

4.3 Input Applications :

Because Parallel port's most common use is to send data to printer, you might think that port is useful only for sending information from a PC to a peripheral. But you can also use the parallel port as an input port that reads information from external devices. SPP have five status inputs and four bi-directional Control lines, and on many newer ports (PS2), you can use the eight data lines as input as well. It was decided to use five status input so as to read status of motors and Sensor. Since every motor has two limit switches and opto-coupler to read it's status, then for 6 motors we must have 18 input lines and also one for Sensor interface. Hence, we have implemented circuit that could read 3 Bytes (24 Bits) of input.

4.4 Working of the Control Circuit

U13, U12, U11 are 1:8 Multiplexers (Data Selectors) that selects three out of twenty four lines, which are then directly connected to status input lines S0, S1, S2.

Each Multiplexer has Three select lines (A, B, C). Combination of three select lines chooses one of eight lines ranging from (I0 to I7). I0 to I7 of each IC are connected to 8 Pin connectors J1 to J5 which are used to take feedback from Motors.

The Data Path D0-D2, through 74HCT374 latch connected to each multiplexers select lines in parallel.

NO of limit switches are directly connected of the inputs of Multiplexers.

Opto-coupler is four terminal device, whose on of the output terminal is directly given to Multiplexers.

Sensor Interface: It operates in the range of 10 to 25V DC supply. It has three colored wires; Blue is Grounded, Brown is connected to 12V and output is taken between Black and Blue as explained in previous sections.

The two constraints are defined by manufacturer.

Object not Sighted : Output Low (0V).

Object Sighted : Output High (10V).

As the control unit operates on TTL logic must supply +5V for Logic High and 0V for Logic Low. On detection of opaque object, Output high (10V) signal is passed through 7805 voltage regulator and 7486 NOT IC converting it into Logic High and then into Logic Low. This Active Low on the line is detected by software and both trolley Motors are immediately stopped. The range can be easily adjusted with small screw provided at back.

Function Table :

- EP : Encoder Pulse (From Opto-Coupler)
- USW : Upper Limit Switch
- LSW : Lower Limit Switch
- UpSDn : Up side Down Limit Switch
- DnSup : Down Side Up Limit Switch
- TMLSP : Trolley Motor Left Sensor Pulse
- TMRSP : Trolley Motor Right Sensor Pulse
- GPCL : Gripper Close Limit Switch
- GPMW : Gripper Maximum Width Limit Switch.

4.5 Design Features of Control Unit

Control Circuitry works on TTL Logic : Since output from PC's port is in the TTL form, The control Unit designed accordingly. The TTL Short Circuit Prevention Logic : This circuit, a part of the Control section, is a protection mechanism, employed by us to ensure that the motor does not receive 12v signal on both the CW and CCW inputs which may cause the motors to get stalled. The H-Bridge has 2 direction Inputs for each motor, which should be activated exclusively and not simultaneously. The TTL Short Circuit prevention Logic makes sure that if both signals (CW and CCW) for a motor are low simultaneously then the input to the Bridge on both the direction lines will be Logic 1. This is because Logic 1 as Input, to both Inputs of Level shifter (Level shifter Implemented by using simple BJT in self bias mode) will give 0V to input of all MOSFET pairs , that keeps motor off.

Control unit is designed in such a way that 8 Motors can be controlled. Slight enhancement in the circuit will allow to control maximum Twenty Four motors.

5. Design of the software algorithm

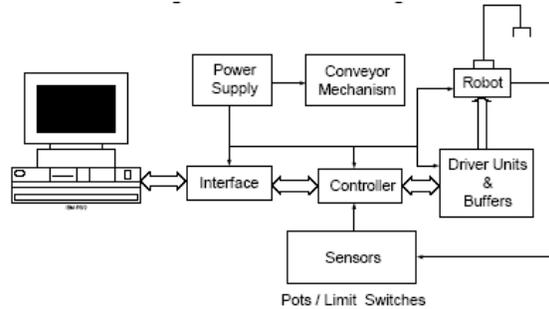


Figure 10 : Block Diagram Of Mobile Robotic System

CRUI employs a sophisticated application-controlling interface created in visual basic 6.0 as it is a fantastic programming language for any application software development. The software is designed for maximum Robot control & working efficiency. It is so designed that the user can have complete control over each movable part of the Robot. Also the user can easily maneuver the Robot & make it traverse a path towards the object to be picked. He can then manipulate the different limbs of the Robotic arm so that the gripper comes closer to the object & eventually picks it up. VB is selected as it is a simple, yet powerful, windows platform based programming language, which provides us with a complete set of tools to simplify complex rapid application development.

Visual refers to the method used to create the GUI. BASIC stands for Beginners All Purpose Symbolic Instruction Code. VB is a combination of these two. The best part of VB is that it is an object oriented event driven language which means that we write code specific to only desired events of an object. The object written in VB6 does not respond to events that are not coded by us and hence there is a less chance of errors. The software module to be developed in order to control the robotic system to do successful manipulation tasks will be consisting of the following features.

1. Manual mode control,
2. Programming mode of control,
3. Dynamic home position reset facility,
4. Facility to loop operation to do the same task again and again.
5. Teach mode,
6. Parallel Port Interface.

In 1, the system is controlled manually by pressing a computer key. Each key is assigned for a particular operation.

In 2, the user writes a application program for the robot to do a PNP operation using the built-in sub-routines and execute it.

In 3, the system comes to the reference home position once the reset button is pressed. All the angles, distances will be measured from this reference / resetted home position.

In 4, the robot can perform the same task again and again repeatedly by looping the program 'n' number of times.

In 5, the user teaches the robot how to do a particular task. Once he is teaching the robot how to do a particular task, all the instructions will be stored in the memory. Once taught, the robot can perform the same task again and again.

In 6, the PC interface to the system is done through a parallel port as it is a powerful platform for implementing projects dealing with the control of real world peripherals (Robots and its accessories) and multiple bits can be transferred in and out of the system at once and as a result of which multiple actuators can be controlled at the same time. This reduces the on-time of the motors, thus saving the power of the power supply. The Robot basically works in two modes. Programming Mode. Manual Mode.

5.1 Programming Mode

In this mode of working the robot is fully controlled by the user's commands. It accepts the commands for the various motors from the input interface. The software provides the user full control of manipulating any movable part of robot. Each and every command works on feedback system. The software provides the user with the ability to write his / her own programs using the commands provided. The programs written by the user employ the intelligent path decision feature of the application. This feature highlights the ability of the program to calculate the various angles associated with the robot and take a decision about enabling one or more motors simultaneously to save on time and power consumed in reaching the destination point specified by the user.

FEATURES : It is the start up screen for the software application ; Features a complete HELP file, which can be invoked from the menu provided ; Has a menu, which enables the user to select different options ; Simple yet powerful interface ; Ability to loop operations ; Cut - copy - paste Instruction function ; Facility to save current program ; Facility to save current program with different name ; Insert function ; Minimization of typing ; Editing of program is possible by use of up / down buttons.

ABOUT THE SCREEN CODE box : The program loaded / generated by the user is displayed in code box.

PROGRAM Commands : The screen provides the user with following commands in the form of buttons which are discussed as below :

MOVE : On clicking the move button, the user is required to select the motor (Trolley motor Left or Right) and the distance in meters is to be specified in the combo boxes provided for the same. MOVE [Motortname, Distance]

ROTATE : On clicking the rotate button, the user is required to select the motors (Trolley motor Left or Right, base, Elbow, Gripper with Direction) and the

angle in degrees is to be specified in the combo boxes provided for the same.

ROTATE [Motortname with direction, Angle]

OPEN : Command given to open the gripper

CLOSE : Command to close the gripper

SPIN : On clicking the Spin button the user is required to select the motors (Trolley motor Left or Right) as specified in the combo boxes provided for the same. SPIN [Motortname with direction]

INSERT : Command to insert a blank line of code between any two instructions in the program.

DELETE : Command to remove a line of code from the program

RUN : Command to invoke the run screen where the loaded program is executed

MENUS : The screen features the following menus :

FILE Menu : This menu has options related to handling of files and exiting the application. They are NEW (Ctrl + N), OPEN (Ctrl + O), SAVE (Ctrl + S), SAVE AS (Ctrl + A), CLOSE (Ctrl + L), EXIT (Ctrl + X).

EDIT Menu : This menu facilitates cut copy paste operations in the program such as CUT (Ctrl + X), COPY (Ctrl + C), PASTE (Ctrl + V), MODES (MANUAL MODE, PROGRAMMING MODE), HELP.

5.2 Manual Mode

This interface allow user to select individual Motor and activate it for any particular time period until it stops automatically by receiving command by computer that violation has taken place or on a user wish. This screen allows direct control of each motor employed in CRUI . The screen is invoked from the programming mode screen when the user selects it from the menu bar.

The screen features : Manual control of each motor, Fine positioning of the base, rack, elbow and roll, Facility to rotate the motors clockwise and counterclockwise, Automatic RESET function to bring the robot to the reset/home position on startup, Dynamic reset function to allow the user to bring the robot to the reset position at any instant.

ABOUT THE SCREEN

MOTOR SELECTION LIST BOX : The screen features a list box, where the user selects the desired motor. The user selects the motor by double-clicking on the motor name in the list box.

MOTOR SELECTED TEXT BOX : The selected motor is then highlighted and displayed in the motor selected textbox.

DIRECTION OPTION BUTTONS : The clockwise option button is enabled by default. The user can change the direction of rotation prior to pressing the start button. The user is required to click on the option button for selection of the direction.

START BUTTON : The START button, when clicked, enables rotation of the desired motor. On clicking the start button, all the remaining components on the screen except the stop button are disabled as a precautionary measure.

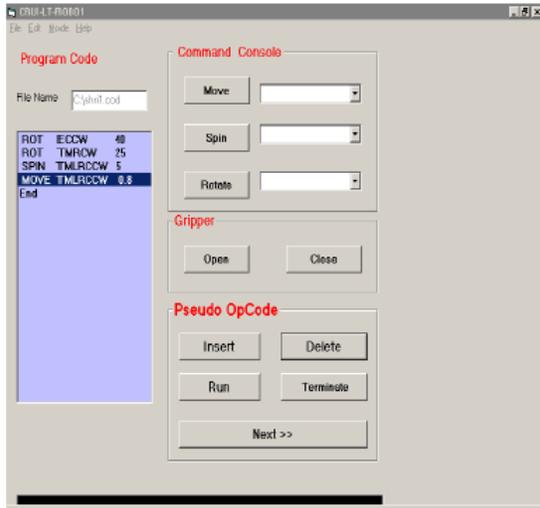


Figure 11 : Screen Layout - Programming Mode



Figure 12 : Screen Layout - Manual Mode

STOP BUTTON : The STOP button, when clicked, disables rotation of the desired motor by sending byte 0 to the port. On clicking the Stop button, all the components disabled by the start button are re-enabled.
MESSAGES : The messages are an indication, to the user, of the motor selected, the direction of rotation.

5.3 The Logic Algorithm

The application makes use of visual basic's timers. The main function of the program is to calculate the various movement angles and movement distances associated with the robot from the user given data. The movement angles and distances are then converted into time. A calibrated value of time taken to move through one revolution, that is, 360 degrees, is known. This time will be different for the base motor shaft, elbow motor shaft and roll motor shaft since this time will not only

depend on the speed of the motors but also on the gear ratios and loads. These values are pre-calibrated and loaded into the reference variables of the software. A feature to change these values in the software, in the event that the motors are replaced is also provided.

The program calculates the angles associated and then calculates the different time intervals corresponding to these angles. These intervals are then loaded into the timers used in the program. The program then sends the necessary byte to the parallel port to turn on the desired motors and then the timers are started (that is, the timers are enabled). After a timer's interval elapses, the respective timer raises a timer event, which the program uses as a cue to stop the desired motor. The program sends a byte to the parallel port to stop the necessary motor while at the same time not affecting the status of the other motors.

5.4 Sample Application

In the teach method, Select manual mode of operation. By selecting Trolley Motors with proper direction move robot towards the object, this is possible by simply pressing START button. After Robot reaches to specific position press STOP button. Then by selecting individual motors and direction make movements of links such that Gripper should reach to the object. Close Gripper motor and move object to desired position. In the programming method [1], select the programming mode of operation. Write set of instructions that will move robot towards object grip it properly and place it to given position.

6. Conclusions

A design and implementation of a low cost mobile robot was described. It implied the choice of several alternatives such as materials, motors, programming, sensors, controllers and so on. Experiments were conducted to demonstrate its utilities. A user friendly GUI was developed. The vehicle presented is a good experimental robotic base for the future development of algorithms and paradigms for the navigation, mapping, trajectory planning and task planning. A brief kinematic analysis of the robot was also carried out. A number of pick and place operations were successfully performed by the developed robot by using teaching mode, manual mode and programming modes.

6. References

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