DEVELOPMENT OF A SMALL MOBILE ROBOT

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Key words: Mobile robot, sensors.

ABSTRACT

An intelligent small mobile robot that will be used as a member of a mobile robot team has been developed. The main features of the robot are to navigate in safely in the environment, search for target objects and avoid obstacles. The robot's brain is an on-board Z80 microprocessor. Infrared sensors are used for navigation. Object recognition is accomplished by a CMUCAM. A PIC-based sensor card is developed in order to collect data from IR and/or ultrasonic range sensors. Locomotion system of the mobile robot consists of two stepper motors and a PIC-based stepper motor drive card. A pan tilt unit is designed for the camera system.

I. INTRODUCTION

Mobile robots are used in applications which are dangerous for human beings, for example collecting toxic waste, planetary exploration, extinguishing fire, finding land mines, search and rescue missions [1]. Use of a team of robots instead of a single robot may increase the effectiveness of the system [2]. For example in an exploration task, two or more robots may divide the area and explore quickly than a single robot. But due to their size and capabilities, some robots cannot reach certain places. In this case a smaller mobile robot with adequate capabilities may be used. In our laboratory, we designed and implemented a small mobile robot, named Junior. We plan to use this robot as the smallest member of a mobile robot team. It will navigate in the environment and collect information where other members of the team cannot reach. Main design requirements of this robot can be summarized as follows:

i. Robot should have on-board computation capacity,
ii. Should be able to navigate safely in the environment,
iii. Locomotion system should give information about distance traveled by the robot,
iv. Should be able to collect data and recognize objects in the environment,
v. Should be able to communicate with other members of the team.

To accomplish the above requirements, following modules are designed and implemented:

i. A Z-80 microprocessor board is used for on-board computation.
ii. Navigation system is equipped with infrared range sensors array and a sensor reading card.
iii. Locomotion system consists of two stepper motors. We use stepper motors, because they are easy to drive and counting number of pulses gives information about the traveled distance.
iv. To recognize the objects in the environment, a CMUCAM is used. A pan-tilt unit is designed for the camera.
v. Communication with the other members of the team is accomplished through rf transmitter/receiver system.

This paper is organized as follows: Section II explains the overall system, section III explains navigation system and sensor reading card, camera system is explained in section IV, locomotion system is explained in section V. Conclusion is given in the last section.

II. OVERALL SYSTEM

The block diagram of the overall system is shown in Figure 1.

The brain of the system is a Z-80 microprocessor unit. All computations and decisions are done by this unit. A 12-V battery pack is used to drive all the units in the system. Four modules are connected to the Z-80 unit: CMUCAM and sensor control card are connected to the Z-80 unit through serial ports, pan-tilt unit and stepper motor driver card are connected to the Z-80 unit through parallel ports.

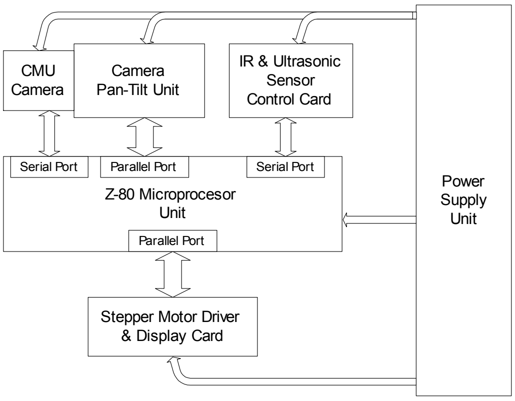

Figure 1. Block diagram of the overall system

III. NAVIGATION SYSTEM AND SENSOR READING CARD

Navigation system is equipped with an IR range measuring array consisting of 8 Sharp GP2D02 [3] infrared range measuring sensors. GP2D02 gives range information between 10 and 80 cm. A sensor reading card is designed to read the range values from each sensor. The layout diagram of the card is shown in Figure 2. As seen from the figure, Devantech SRF04 [4] ultrasonic range sensors, which gives range information between 5 and 300 cm, could also be connected to the sensor card. Two dipswitches are used to indicate whether a sensor is connected to an input and the type of sensor connected to the input. These two dipswitches should be adjusted before operation. A 16F877 PIC is used to control sensor card and to communicate with the Z-80 unit. Depending on range information request from the Z-80 unit, sensor reading card fires the necessary sensors, retrieves the range information and sends the requested range information to Z-80 unit over serial port.

IV. CMUCAM AND PAN-TILT UNIT

A CMUCAM [5] is used for object recognition. To increase the capabilities of the robot, a Pan-tilt control card is designed. The robot may inspect relatively wide area by moving its camera with pan-tilt control unit. The pan-tilt unit has mechanical and electrical parts.

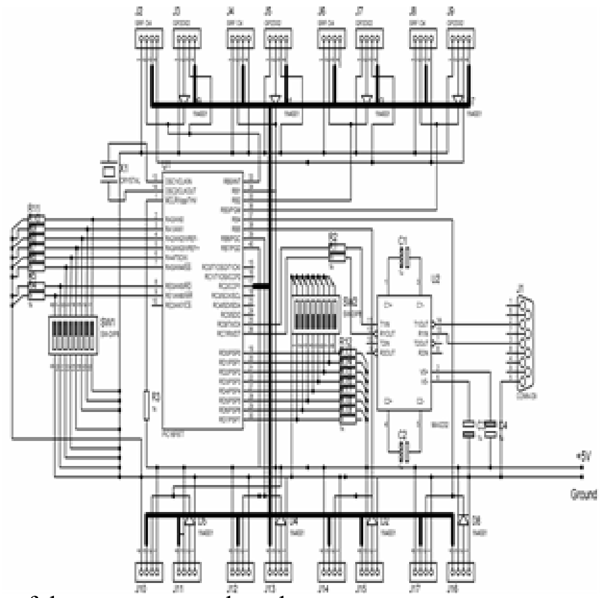
Figure 2. Layout Diagram of the sensor control card

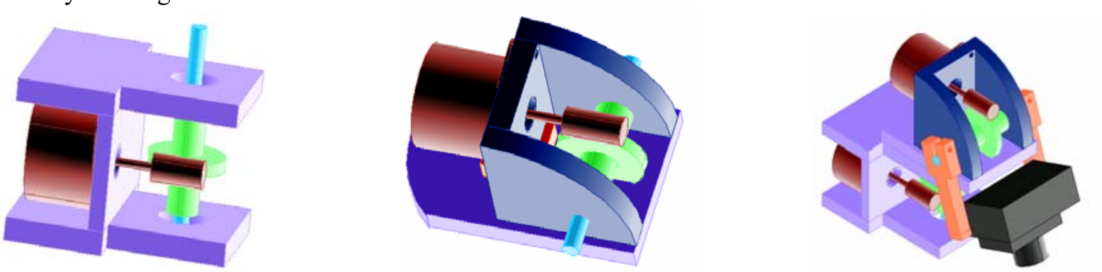
(a) **(b)** **(c)**

Figure 3. (a) Pan Unit, (b) Tilt Unit, (c) Overall Pan-Tilt Unit

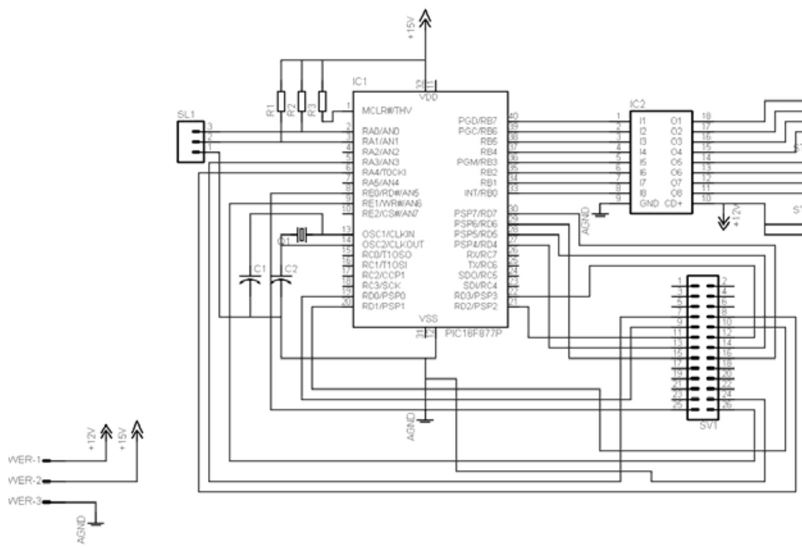

Figure 4. Circuit schematic of the Pan-Tilt controller card

MECHANICAL DESIGN

In the unit, two stepper motors, two gears, and four bearings are used. AutoCAD drawing of the unit is given in Figure 3. Tilt angle range is from -60^o to +90^o, pan angle range is from -90^o to +90^o.

ELECTRICAL DESIGN

The pan-tilt unit is driven by two stepper motors and uses two micro switches to check limits. An ULN2803 Darlington transistor array IC is used to drive the stepper motors. A PIC16F877-based control card is designed to produce the required pulses to drive the motors. The circuit schematic is given in Figure 4. Structure of the commands to control the pan-tilt unit is:

Command Bit Stream:

X	X	R	T	P	D	d	d

d	d	d	d	d	D	d	d

R = Reset Position (0 = Sending Data, 1 = Sending Reset Command)
T = Command type (0 = Relative, 1 = Absolute)
P = Pan-Tilt (0 = Pan, 1 = Tilt)
D = Direction (0 = Positive, 1 = Negative)
d = Relative rotation (the amount of rotation between 0 – 660 steps)

V. STEPPER MOTOR DRIVER AND DISPLAY UNIT

This unit is developed to drive stepper motors and monitor capabilities of the mobile robot system. The block diagram of the unit is given in Figure 5. Z-80 microprocessor uses a set of drive commands, such as go forward, go backward, turn left with degree, etc. to drive the stepper motors.

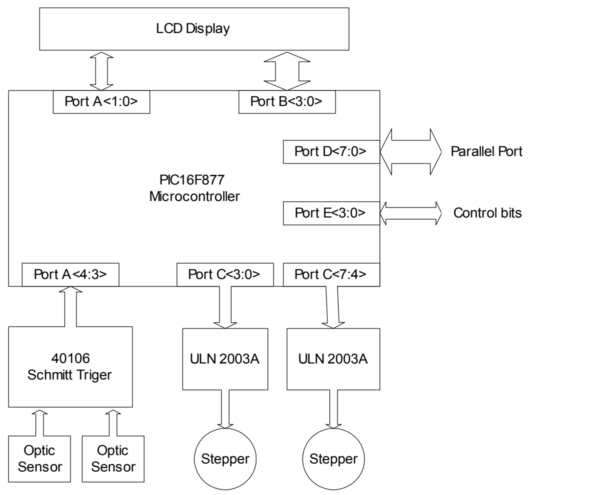

Figure 5. Block diagram of stepper motor driver and display unit

The back wheels are the main driving units and the front wheels are used for steering. The unit drives the stepper motors according to commands received over parallel port. The relative rotation of the robot can be calculated by counting the steps applied to front stepper motor. However, the initial position of the front wheels must be known. For this purpose, two optical sensors are placed to the appropriate positions on the gear of the drive mechanism. Initially, the driver unit brings the front wheels of the robot to the straight position. Then, the rotational position of the front wheels is calculated relative to this straight position. The unit also has a 1x16 LCD display. The display is useful for monitoring the system states. The schematic of the unit is given in

Figure 6. Pictures of the stepper motor and display unit are given in Figure 7.

VI. CONCLUSION

In this work, some control units for small mobile robots were developed. In the near future, small size mobile robots may have many capabilities with the developments in the sensor technology. It is easy to assemble thermal and colored vision sensors, different types of range sensors, orientation sensors, smoke sensors, etc. to a small-sized mobile robot. However, increasing the number of sensors assembled to the robot may cause computational problems for a single microprocessor. At this point, PIC-based microcontrollers may be used to share the computational load of the microprocessor.

A step motor control unit, a pan-tilt unit, a navigational system and a sensor control unit for small mobile robots were developed using PIC microcontrollers. Each unit performs low level processes using some predefined commands. Thus, the microprocessor works on processing of the high-level decision methods instead of struggling with communication protocols of the sensors and actuators.

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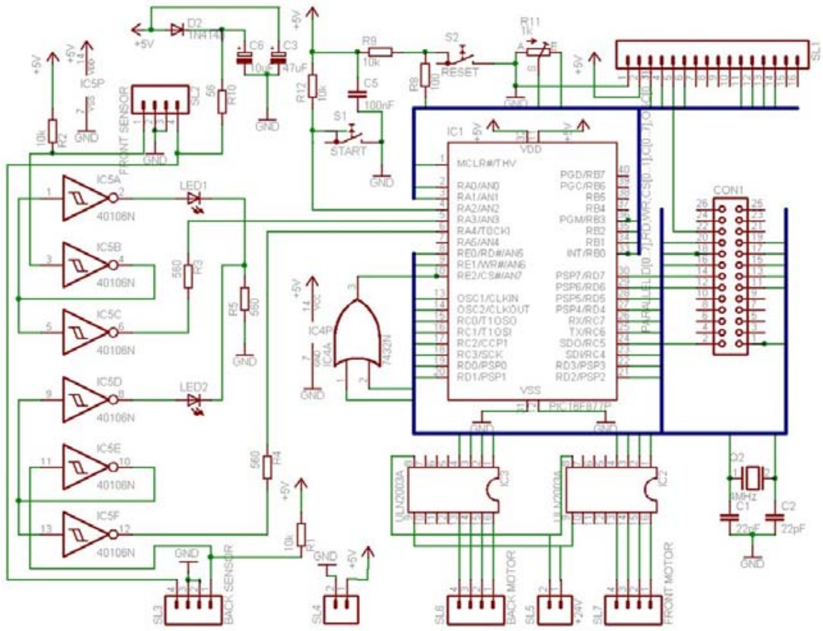

Figure 6. Schematic diagram of the stepper motor driver & display unit

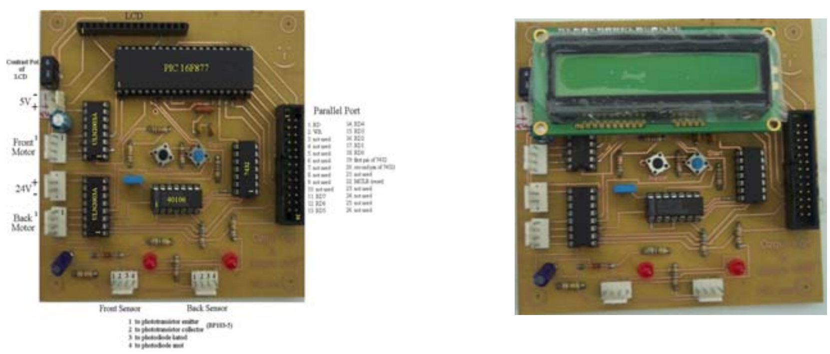

Figure 7. The stepper motor driver & display unit