IEEE International Conference on Advanced Robotics and its Social Impacts
Taipei, Taiwan, Aug. 23-25, 2008

Development of a Module Based Platform for Mobile Robots

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Abstract-**The paper develops a module based intelligent mobile robot system that has uniform interface. The core of these modules is HOLTEK microchip. The system contains many modules that are communication with master module using I2C interface. The master module is communication with main controller of the mobile robot using RS232 interface. The main controller of the robot system is industry personal computer (IPC). It can display status of these modules on the monitor. The user can add or remove the sensor module in any time, and the main controller can acquires sensor signals from these modules on real-time. Finally, we integrate these modules in the robot system that executes some scenario for the user.**

I. Introduction

With the robotic technologies development with each passing day, robot systems have been widely employed in many applications. Nowadays, robot systems have been applied in factory automation, dangerous environments, hospitals, surgery, entertainment, space exploration, forest, farmland, military, security system, and so on. Recently, more and more research takes interest in the robot which can help people in our daily life, such as service robot, office robot, security robot, and so on. We believe that robot will play an important role in our daily life in the future.

In the past literatures, many experts research in the mobile robot. Some research addressed in developing target-tracking system of mobile robot [1,2], such as Hisato Kobayashi et al. proposed a method to detect human being by an autonomous mobile guard robot [3]. Yoichi Shimosasa et al. developed Autonomous Guard Robot [4] witch integrate the security and service system to an Autonomous Guard Robot, the robot can guide visitors in daytime and patrol in the night. D. A. Ciccimaro developed the autonomous security robot – "*ROBART III"* which equipped with the non-lethal-response weapon [5,6]. Moreover, some research addressed in the robot has the capability of fire fighting [7,8]. These robots are complexity, and are not easy to maintain and repair, and the cost is very expensive. The development and adaptability of robot systems have limited. To increase their development and adaptability, the concept of the module-based robot system (MBRS) has been studied in the robotic field since 1980s. Many robot systems have been designed [9-13]. The research of MBRS contains many fields. In the paper, we focus on the module based sensory system and driver system of the mobile robot.

The paper is organized as follows: Section II describes the system the architecture of the module based intelligent robot. Section III explains the function of the detection and driver module, and it describes the principle of the sensor for these detection modules, and explains the driver method for the DC servomotor driver module. The user interface of the mobile robot is presented in section IV. Section V presents the experimental results for the remote supervise system of the intelligent security robot. Section VI presents brief concluding remarks.

II. SYSTEM ARCHITECTURE

The system architecture of the module based intelligent mobile robot is shown in Fig. 1. the system has some slave modules and one master module. The interface of these modules is I2C (Inter IC). These modules can use two-way communicate with master module, and the master module communicate with the main controller by series interface (RS232). These modules are connecting with the master module, and the master can detect which module to be connect, and transmit the module ID to the main controller. On the other hand the user removes the module from the system. The master can detect which module will be removed, and transmit the module ID to the main controller. The main controller of the module based intelligent robot can know how much modules on line and it can acquire data from these modules. .

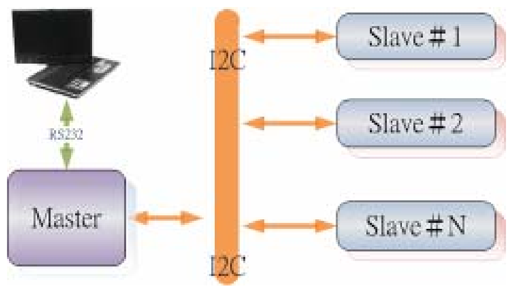


Fig. 1. The system architecture

The controller of these modules is HOLTEK microprocessor. The slave module has fire detection module, environment detection module, gas detection module, remote IR and wireless RF module, environment module, compass module, acceleration module, power detection module, obstacle detection module (IR sensors and ultrasonic sensors) and DC servomotor driver module. We arrange an ID to each module, and identify the module function by the ID. These modules can be equipped in the intelligent mobile robot. The prototype of the module based intelligent mobile robot is shown in Fig. 2.

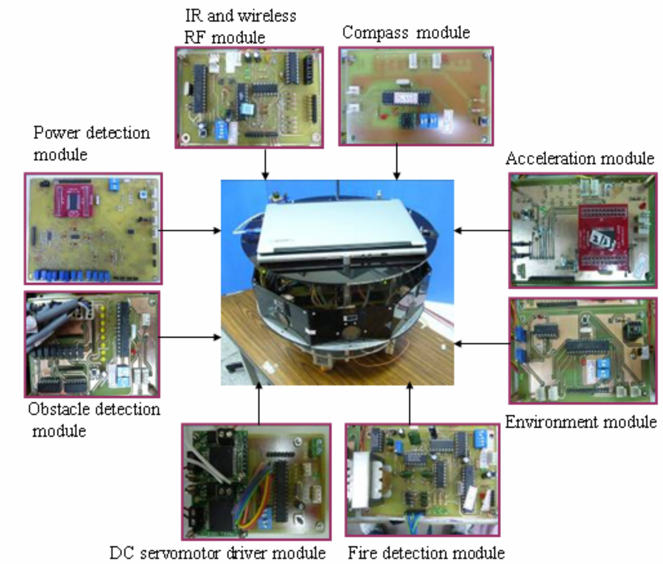


Fig. 2. The prototype of the module based intelligent robot

These modules can acquire sensory signal and processes these signal using amplifier and calibrate circuits and transmits sensory data to the master module using I2C interface. We list these sensors of the detection modules in Table 1.

Table 1 Sensors in these detection modules

Module	Sensors	Examples
Compass module	Compass sensor	HM55B
Acceleration module	Acceleration sensor	Memsic 2125
Environment module	humidity sensor	SHT1x
	temperature sensor	SHT1x
	illumination sensor	S1133
Fire detection module	Flame sensor	R2868
Obstacle detection module	IR sensor	SMC-60R
	Ultrasonic sensor	Polaroid 6500
Power detection module	Current sensor	LA-55P

III. DETECTION MODULE

The module based intelligent mobile robot has some slave module and one master module. The master module can communicate with each slave module using I2C series interface, and communicate with the main controller of the mobile robot by RS232 series interface. Some of the modules can calculate the exact measured value using multisensor fusion algorithm, and transmit signal to the master. The others can only transmit the measured value to the master module, too. We explain these modules as following:

- **Power detection module**

In the power detection module, we use four current sensors to measure the current variety of the mobile robot, and use two multisensor fusion methods (redundant management method and a statistical prediction method) to detect current sensor and voltage signals status. In the redundant management method and statistical signal method, we can get an exact measured value for power detection, and isolate faulty signal from current sensor and voltage signal. Then we can calculate the residual power of the mobile robot, and decide the residual time to work for the mobile robot.

The block diagram of the power detection module is shown in Fig. 3. The module can measure current and voltage values on the power variety of mobile robots. We use analog/digital interface to acquire these measured values by HOLTEK microchip (controller). The controller can decide the estimated values of current and voltage using redundant management method, and transmit results to the main controller of the mobile robot by series interface (RS232).

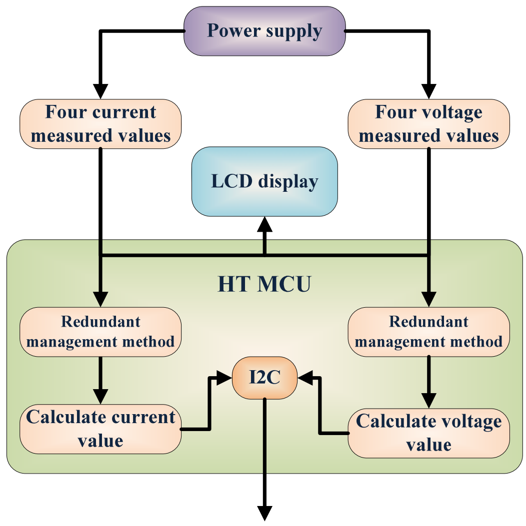


Fig. 3. The block diagram of the power detection module

In the intelligent power detection module, we use redundant management method to estimate the exact values on current and voltage on the power of the mobile robot. The value of the measured parameter is obtained by the following equation at that sample time k

$$\hat{x}(k) = \frac{\sum_{i=1}^{l} m_i(k) I_i(k_i)}{\sum_{i=1}^{l} I_i(K)} \qquad (1)$$

Where I_i is a weight for the each measurement m_i and at the given sample time k. So we can define indicator function Ii is

$$Ii=\sum_{j=1}^{l} f\left[\left|m_i(k)-m_j(k)\right| \le \left(b_i(k)+b_j(k)\right)\right] \quad i=1,2,\cdots l \tag{2}$$

$$f[*]=\begin{cases} 1, & if \quad * \quad is \quad true \\ 0, & if \quad * \quad is \quad false \end{cases} \tag{3}$$

- **Fire detection module**

We use three flame sensors to detect fire event in the fire detection module. Flame sensors look for characteristic emissions of either infrared or ultraviolet light from the frame. We use the ultraviolet sensor to detect the flame. Its peak wavelength is 220 nm and sending wavelength is 185 ~ 260 nm. We want to get more reliable and have high accuracy in the detection capability. In order to enhance the detection capability, we use weighted average method to obtain the high reliable result in the fire detection. In the weighted average method, the weighted average of n sensor measurements x_i with weights $0 \le \omega_i \le 1$ is

$$\bar{x}=\sum_{i=1}^{n} \omega_i x_i \tag{4}$$

$$\sum_{i=1}^{n} \omega_i = 1 \tag{5}$$

And $\omega_i = 0$ if x_i is not within some specified threshold. The weights can be used to account for the differences in accuracy between sensors, and a moving average can be used to fuse together a sequence of measurements from a single sensor so that the more recent measurements are given a greater weight.

- **Environment detection module**

The environment detection module contains humidity detection, illumination detection and temperature detection. The sensor element of the humidity and temperature detection is SHT1x, and the sensor element of the illumination is S1133. The environment information can be extracted using equation (6) to (9). The humidity measurement value is RH_{true} , and the temperature measurement value is T .

$$T_C = 0.01(SO_T)-40 \tag{6}$$

$$RH_{linear} = -0.28\times10^{-6}(SO_{RH})^2 + 0.0405(SO_{RH})-4 \tag{7}$$

$$RH_{true} = (T_C-23)(0.01+0.00008(SO_{RH}))+RH_{linear} \tag{8}$$

$$T = -40+0.04(SO_T) \tag{9}$$

- **Compass module**

The compass module uses the dual-axis magnetic field sensor (Hitachi HM55B). The features of the compass module have sensitive to microtesla variations in magnetic field strength, and simplify direction by resolution magnetic field measurements into two components axes. It can use 30 to 40 ms to transmit X axis and Y axis data between start measurement and data-ready with simple synchronous series interface, and we can calculate the angle of the mobile robot using equation (10). The block diagram of the compass module is shown in Fig. 4.

$$\text{angle}\ \theta = \tan^{-1}(-y/x) \tag{10}$$

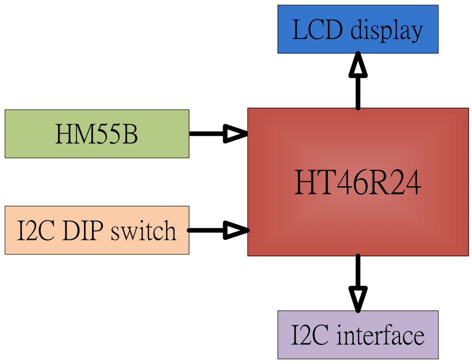


Fig. 4. The block diagram of the compass module

- **Obstacle detection module**

The obstacle detection module uses ultrasonic sensors and infrared reflection sensors to detect obstacles and reconstruct the surrounding environment by using the multisensor fusion and integration technique. Ultrasonic sensor is one of the most common forms of distance measurement used in the mobile robot and a variety of other applications. The principle is simple to understand, a transducer is used to emit a short burst of sound (ping). The sound wave travels through the air and reflects off an object back to the transducer (echo). By measurement the time of flight between ping and echo detection, we can calculate the distance between the object and transducer.

There are 16 Polaroid 6500 ultrasonic range sensors are distributed around the mobile robot for environment exploration. The firing rate and sequence of the ultrasonic sensors are controlled by HOLTEK microprocessor. The beam width for each sensor is 22.5 degree, and the range to an object is determined by the time of flight of an acoustic signal generated by the transducer and reflected by the object. The robot can use the sensors to detect the distance from 40cm to 1000cm. the block diagram of the ultrasonic sensor module is shown in Fig. 5.

The obstacle detection module uses 16 SMC-60R infrared reflection sensors. The principle of the reflection infrared sensor is following. There is one transmitter and one receiver in the sensor. The transmitter always launches light signal. When the receiver receive the signal, it means the sensor detect an object. The infrared sensors signals are connected to the I/O of the controller, and the sensors can detect the distance that is less than 60 cm. The controller is HOLTEK microprocessor, too.

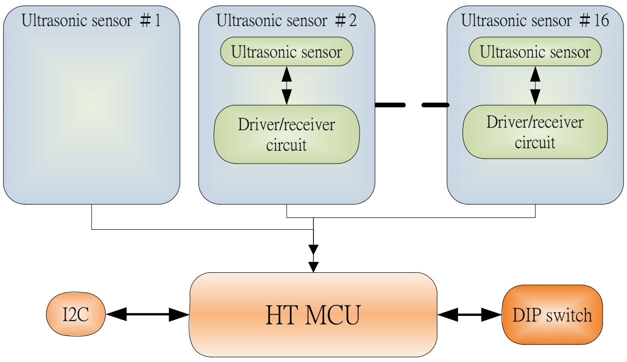


Fig. 5. The block diagram of the ultrasonic sensor module

- **DC servomotor driver module**

The DC servomotor uses the Pololu high-power motor driver (VNH3SP30) to drive motor. The driver includes pull-up and current-limiting resistors and a FET for reverse battery protection, and has maximum current ratings of 30A continuous. The block diagram of the DC servomotor driver module is shown in Fig. 6. The user must use two motor driver modules to control the mobile robot by differential drive method. In the module based mobile robot, we use a motor control module order command to the motor driver module using I2C interface. The motion master module can receive environment status from the obstacle detection module. The obstacle detection module contains ultrasonic driver module and IR driver module. Finally, the motion master module can communicate with controller of the mobile robot (PC) using RS232 interface. The relation of the motion control structure is shown in Fig. 7.

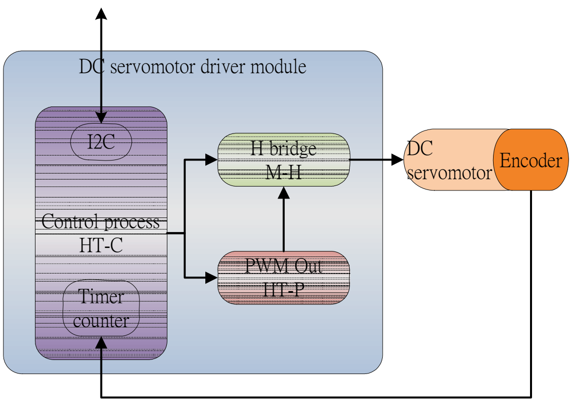


Fig. 6. The block diagram of the DC servomotor driver module

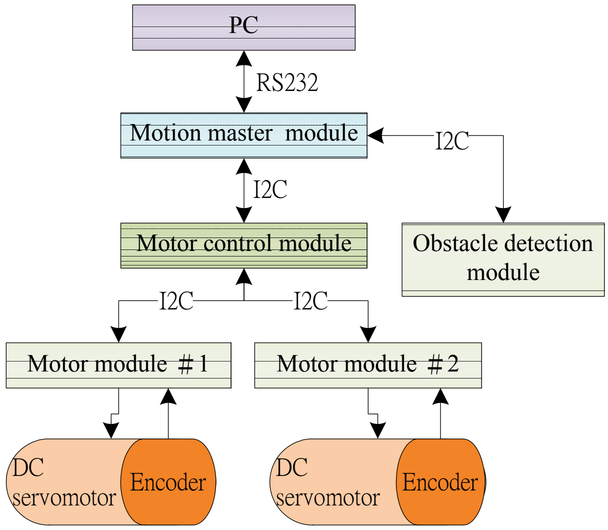


Fig. 7. The relation of the motion control of the module based mobile robot

The mobile robot is constructed using aluminium frame. The contour of the robot is cylinder. The diameter is 40 cm, and height is about 60 cm. The main controller of the mobile robot is personal computer. The hardware devices have touch panel, ultrasonic and IR sensors, sensor and driver module, batteries, DC servomotors and wireless RF interface. Fig. 8 is the structure of the mobile robot.

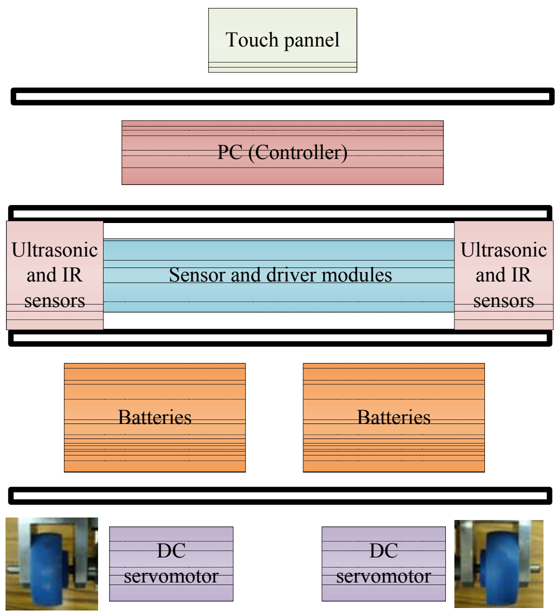


Fig. 8. The structure of the mobile robot

IV. USER INTERFACE

The user interface of the module based intelligent mobile robot is shown in Fig. 9. The user interface can acquire data of these modules, and display on the monitor of the supervised computer. The upper of the left side can display fire signal, power status, environment measured value, compass signal and acceleration value (two axes). The upper of the right side can display power measured value. It contains current and voltage estimated values, maximum and minimum values and mean values. The bottom of the left side can control the mobile robot forward, backward, turn right, turn left and stop. The user can speed up and slow down to the mobile robot. The bottom of the right side can display the status of obstacle. It can display the data from remote IR sensor and wireless RF, and the direction of the mobile robot by compass sensor, and display the measured values for eight ultrasonic sensors and eight IR sensors.

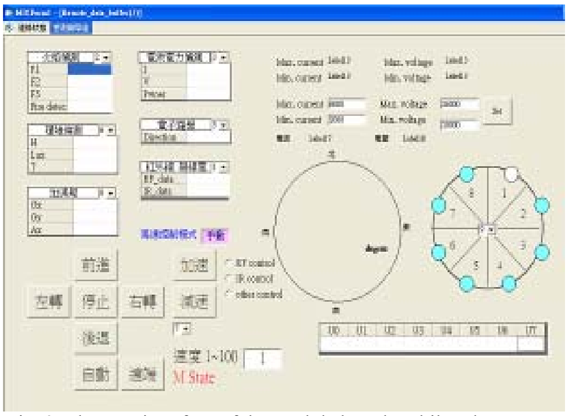


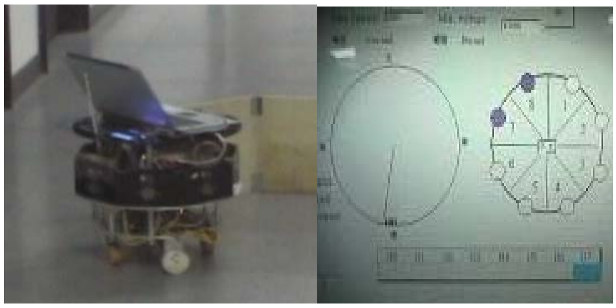
Fig. 9. The user interface of the module based mobile robot system

V. EXPERIMENTAL RESULTS

In the motion control experimental scenario of the mobile robot, we can select autonomous mode or wireless control mode. In the autonomous mode, the mobile robot can move according to environment state using IR sensors and ultrasonic sensors. In the wireless control mode, we can supervise the mobile robot for walking forward, walking backward, stop, rotation, turn right and turn left through multiple interface system (wireless RF interface or wireless RS232 interface). The mobile robot can uses IR sensors and ultrasonic sensors to construct environment. It can avoid state dynamic obstacle, and move in the free space. In the state avoiding, it uses the obstacle detection module to detect obstacle on the front side of the mobile robot. The experimental result is shown in Fig. 10. In the Fig. 10 (a), it shows the mobile robot to detect the obstacle in left side. It can turn right to avoid obstacle, and move to the preprogramming path. The experimental scenario is shown in Fig. 13 (b-c). The user interface can display the position of the obstacle to be shown in Fig. 10 (d).

In the motion planning experiment, we program the motion path is rectangle (100cmX100cm). The experimental scenario of the mobile robot is shown in Fig. 11. First, the robot start to move forward to the first goal (Fig 11(a)).if the robot move to the first goal and turn right, and it move to the second goal. The experimental scenario is shown in Fig 12(b-c). Next it turns right and move to the third goal (Fig 12(d)). The robot moves to the third goal, and turn right to move start position. Finally, the mobile robot arrives at the start position, and it must stop. The experiment result is shown in Fig.11 (e-f). We can see the error between the final position and the start position to be about 3cm (Fig. 11(g)).

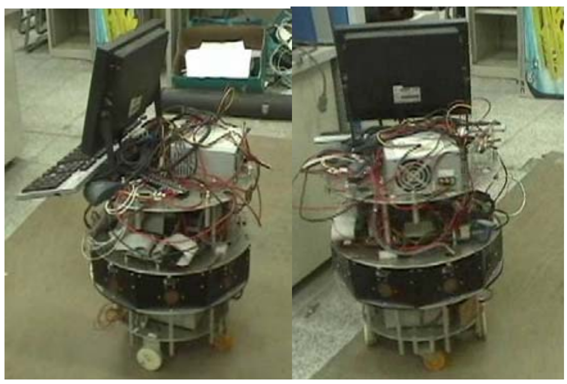
(a) (b)



(c) (d)

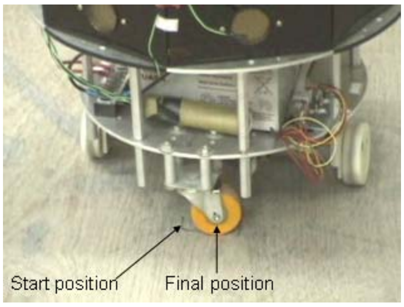
Fig. 10. The motion control of the mobile robot

(a) (b)



(c) (d)

(e) (g)



(g)

Fig. 11. The motion planning of the mobile robot

In the fire detection, the mobile robot uses three flame sensors to detect fire source. The mobile robot can use voting method to decide the fire event. The three flame sensors detect fire source, and display "1" on the monitor of the main controller. Otherwise the monitor displays "0" to present no fire source. Then it can decide the fire event to be true. The experimental scenario is shown in Fig. 12.

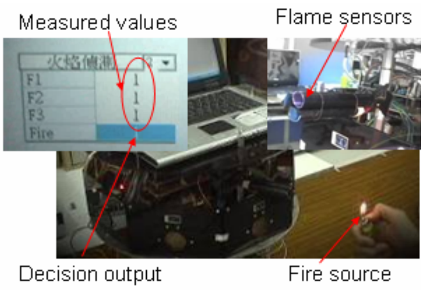


Fig. 12. The fire detection for the mobile robot

VI. CONCLUSION

We have presented a module-based mobile robot. These modules have IR and wireless RF module, compass module, acceleration module, environment module, fire detection module DC servomotor driver module, obstacle detection module and power detection module. These modules contain detection modules and driver modules. We develop a user interface for the mobile robot. The controller of the mobile robot acquires environment status from these detection modules, and order command to control two DC servomotor using driver modules. The user can add or remove these modules which you want in any time. In the experimental results, the mobile robot can move in free space, and avoid obstacle using obstacle detection module (ultrasonic and IR sensors). The user can control the module-based mobile robot using wireless RF interface and IR remoter through IR and wireless RF module, and program the motion trajectory on the monitor for the mobile robot. In the future, we want to develop new modules to enhance the function of the mobile robot, and program intelligent man-machine interface for user.

ACKNOWLEDGMENT

This work was supported by the project "The Development of Integrated Robotics System" under DOIT TDPA of Taiwan, R. O. C. 95-EC-17-A-04-SI-054.

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