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AUTONOMOUS MOBILE ROBOT YAMABICO AND ITS ULTRASONIC RANGE FINDING MODULE

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ABSTRACT

Autonomous mobile robot Yamabico and his newly developed ultrasonic range finding module(URF) are described. Yamabico is a self-contained autonomous robot for in-door environment. It has a modularized architecture, which consists of master module, ultrasonic range finding module, locomotion module, voice synthesizer module and console. Newly developed ultrasonic range finding module has a 68000 processor and Dual-port memory for communication. It controls the ultrasonic transmitters and receivers and calculate the range distances for 12-directiion, simultaneously within every 60 milliseconds.

1. Introduction

Autonomous mobile robot is a realization of the intelligent robot as a certain independent object, which has the all necessary functions to work in the real environment in his own entire body. Namely, it must have functions of the foot and/or arm(vechile, manipulator system), sensor and/or vision system, and brain(information processing) as well as the power source(battery). And it must be able to perform some action for specific purpose independently using his own capability.

A flexibility to meet with various environmental condition is very important for the autonomous robot which act an intelligent behavior. Also it is necessary for the intelligent robot to have the ability of recognizing his surrounding as well as the mobility to move himself. Therefore, the small and smart sensory system to know his environment is very important for the autonomous mobile robot.

In this paper, autonomous mobile robot Yamabico which is an experimental robot for research developed by the authors's group and his newly developed ultrasonic range finding module (URF) to recognize environment are discribed.

2. Autonomous Mobile Robot Yamabico

2-1 Yamabico

The Yamabico intelligent mobile robot project has been started at 1975[1]. And several types of the self-contained robots have been developed.

One of the main purpose of this project is the realization of intelligence on the autonomous mobile robot. Now, the authors are trying to implement the intelligence on Yamabico-M(Photo (1)), whose size is 31*31*38cm and weight is 8kgs, and Yamabico-B, which is about 80kgs heavy. Yamabico-M and Yamabico-B are constructed as a physical example of world-understanding machine intelligence.

Main features of these robots are ;

(1) They are multi-processor systems which consists of a master(brain), a locomotion module, a ultrasonic range finding module, a voice synthesizer module and a console and/or other functions.

(2) The robots have a world-understanding ability using map information to support intelligent tasks.

(3) The locomotion module has a command system as an interface protocol between itself and the master system and it provides smooth movement.

2-2 Modularized architecture[2]

The current Yamabico-M hardware has ultrasonic range finder as an environment sensory system, a locomotion system which drives two powered wheels with DC servo motor, and a voice synthesizer system to inform inside status of the robot. Each system has its own microprocessor system, and is realized as a modularized functional unit. Each module is equipped in one circuit board. There is a cental processor system called 'master' on which the user application programs are executed with controlling other modules.

To consider the over all system, the architecture of the Yamabico forms multiprocessors

Photo 1 Autonomous mobile robot Yamabico-M

system with star connection in which the master is centered. The construction of the Yamabico-M is shown in Fig.1. Yamabico-B has more modules like a manipulater or a force sensor in addition to the Yamabico-M system.

The main purpose for the modularization is to give a frame in order to develop gradually the Intelligence or function of the robot. Namely it is expected that the level of intelligence can be accumulated by addition of a new module or by improvement of functions within the module without reconstruction of other modules. Furthermore, modularization gives the effect of improving efficiency on development or maintenance by function distribution, and making plainness of the total system by regarding a module as a block-box.

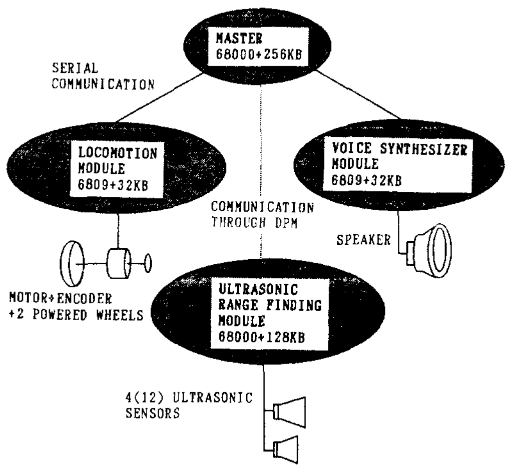

Fig.1 Modularized architecture of Yamabico-M

3. Ultrasonic Range Finding Module

3-1 Principle and the function of URF

For an autonomous mobile robot,an ability to understand its world is an inevitable requirement for executing sensible tasks.

There are two considerable sensors for understanding the environment by practical autonomous robots; image sensors and ultrasonic range sensors. Image sensors can get tremendous amounts of data in 2-D information at one time, but they consumes much time and processing power to detect some meaningful information. On the other hand, an ultrasonic sensor can get only one distance datum at one time, and take tens of milliseconds of time for data acquisition. It consumes, however, less power and less additional processing time[3].

It is also important for a mobile robot that a ultrasonic sensor with a control circuit weights far less than an image sensor with a control circuit. Therefore image sensors and ultrasonic sensors play complementary roles on mobile robot. That is the reason why some intelligent robots have utilized ultrasonic sensors as one of their basic functions.

An ultrasonic range sensor transmits the acoustic pulse as a norrow beam and receives its echoes from the reflecting object in its beam direction, and measures the time interval between transmission and reception. Since the acoustic velocity in normal air is about 340 m/sec, the distance between sensor and the reflecting object is calculated by

$$d\ [cm] = 1/2 * 340 * 100 * t\ [second]$$

where t is the time of flight.

The authors have developed a new ultrasonic range finding module for an intelligent autonomous robot, Yamabico-M and Yamabico-B. The characteristics of the new URF are as follows;

(1) In every 30 milliseconds, it transmits ultrasonic waves into 12 directions and receives the echoes, calculates the distance for each direction and keeps the latest values to answer the queries from the master.

(2) Communicate with the master system through the dual-port memory(DPM) using the technique for mutural exclusion of data collision.

The user functions to control this module and to use resultant data are listed in Table(1).

NAME	FUNCTION
see_dist(DIR)	To know the recent data for direction(DIR)
eye_mask(DIR)	To start and stop to transmit ultrasonic wave

Table(1) User functions for URF

3-2 Hardware

The hardware construction of URF is shown in Fig.2. This is a special purpose microcomputer system whose features are as follows.(See Table(2))

(1) The URF raughly consists of three parts, microcomputer part, communication part and analog circuits. Physically, the first two parts are mounted on a daughter board which is connected to a mother board with the Yamabico Bus- specification which is especially designed for Yamabico systems. The last part is mounted on a seperated small board.

(2) A processor 68000 is used with a 10MHz clock, to control the 12 directional ultrasonic sensors and to perform 12 directional diatance measurement simultaneously.

(3) To exchange the distance data, the communication between the master and URF is realized with very simple communication protocol by using Dual-port memory(DPM). URF always updates the distance data at specified address on DPM and the master can get always the newest distance data.

CPU	MC68000	10MHZ
PROGRAMMABLE TIMER	6340*3 (9 TIMERS)	FOR ECHO INTERVAL COUNTING
DUAL PORT MEMORY	ʃ dt7130 (1KB)	FOR COMMUNICATION WITH MASTER
COMMUNICATION INTERFACE ADAPTER	6350	FOR SERIAL COMMUNICATION
ROM	27256*2 (64KB)	
RAM	62256*2 (64KB)	

Table(2) Hardware feature of URF

(4) In order to measure the round propagation time of 12-direction's ultrasonic wave, URF uses three Programmable Timer Modules(PTM). Timer counts the time interval between sending and receiving wave with one microsecond accuracy. The ultrasonic transmitters and receivers are devided into two groups with each 6 transmitter/ receiver pairs. The one group of transducers sends ultrasonic wave simultaneously and count the round propagation time by timers of PTM. After 30 millisecond, the other group sends and counts. This is the way to reduce noise and number of PTMs.

(5) Serial communication between the URF and terminal of host computer is realized by using Asynchronous Communication Interface Adapter (ACIA) 6350. This function is for development and debugging of this module.

(6) For the sensor driver, the 40KHz ultrasonic wave signal is produced by deviding 10MHz clock by 250.

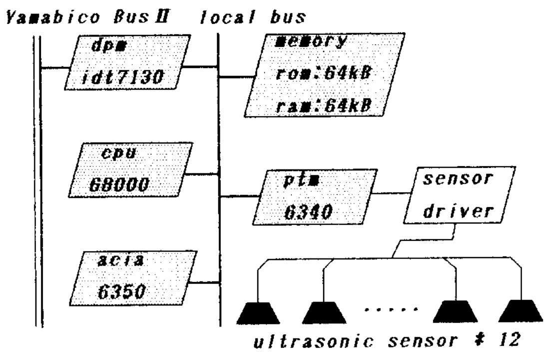

Fig.2 Hardware construction of URF

3-3 Software

The software of URF consists of three major routines; main routine, DPM interrupt routine and PTM interrupt routine. Software construction of URF is shown Fig.3.

At main routine, preparing interrupt tables of DPM and PTM, clearing flag for DPM/PTM and initialization of distance data area and variables, are excuted. After that, it is waiting for a interrupt request from DPM or PTM. If URF accepts command from master, DPM interrpt routine is activated as a current process, and interpretation of command and the corresponding routine are excuted. If URF accepts eye_mask(DIR) command, for exemple, URF brings to stop transmission ultrasonic wave of transmitter for the specified DIR. Every 30 millisecond, PTM interrupt routine is initiated. Three processes are excuted in this routine. They get time intervals of echoes from PTM calculate the distance and transmit ultrasonic pulses. The timing chart for PTM interrupt routine is shown in Fig.4.

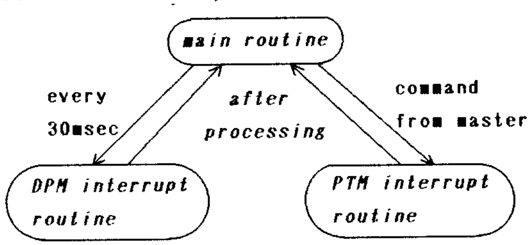

Fig.3 Software construction of URF

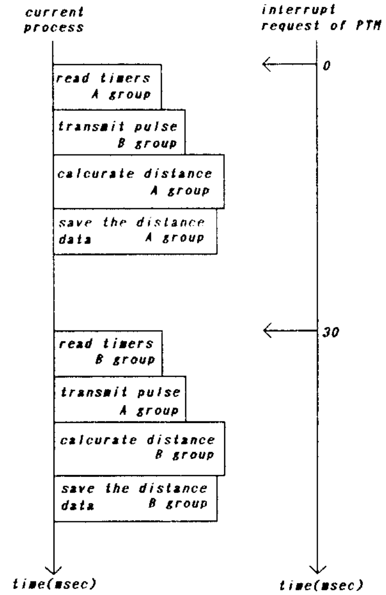

Fig.4 Timing chart of PTM interrupt routine

The software of URF is written in C language.

4. Experimental results

An experimental results of automous mobile robot movement using Yamabico-M with newly developed URF is shown. At this example, Yamabico-M moves at the following rules;

Go straight at a speed of 20cm/sec while measuring front distance. The distance to the wall of both left and right sides are measured for every 0.5 millisecond, if the front distance is bigger than the predefined threshold value. If the front distance is smaller than the threshold value, Yamabico-M stops and waits until the front obstacle disappears. After 100 distance data of each left/right are gotten, Yamabico ends his movement.

By using see_dist(DIR) function, programmer can get distance in user process.

Since Yamabico can run forward straightly at a constant speed by the function of locomotion module, URF can recognize the flat walls and corners, and measured the distance sucessfully. The program for this experiment which is written in the style of ROBOL/0 language developed by the author's group[4] is shown Fig.5, where mchi() is the function to give the commands for locomotion module of Yamabico[5]. And resultant range data for left and right sides is illustrated in Fig.6.

5. Conclusion

The ultrasonic range finding module(URF) is presented which is implemented for autonomous mobile robot Yamabico. Improvement and development for URF is realized without reconstruction of the total system, because of Yamabico's modularized architecture. The experimental result shows that URF is a useful tools to recognize his environment for autonomous mobile robots.

```
#define OBST 40

MODESDEF
  mchi(MVEL,20);
  mchi(MGO,0,0,0,0);
  mchi(MSTRT);
  talk(0x10);
  eye_mask(NON_MASK);

MODE go_straight
  WAIT
     WHEN (see_dist(FRONT)<OBST)
            EXEC mchi(MSTOP0); NEXT stop_wait
     WHEN (count<100)
            EXEC interval(); record_dist(); CONTINUE
     WHEN (count>=100)
            EXEC talk(0x16); NEXT endmode
MEND

MODE stop_wait
   set_timer(30);
   timer_wait();
  WAIT
     WHEN (see_dist(FRONT)>=OBST)
            EXEC restart(); NEXT go_straight
     WHEN (see_dist(FRONT)<OBST)
            EXEC do_nothing(); NEXT stop_wait
MEND

MODE endmode
   mchi(MSTOP0);
   exit();
MEND

MODESEND

record_dist()
{
  unsigned short   dist_left, dist_right;

  dist_left = see_dist(LEFT);
    adrs_ldata->ldist_data[count] = dist_left;
  dist_right = see_dist(RIGHT);
    adrs_rdata->rdist_data[count] = dist_right;

  count++;
}
```

Fig.5 An example program for the experiment

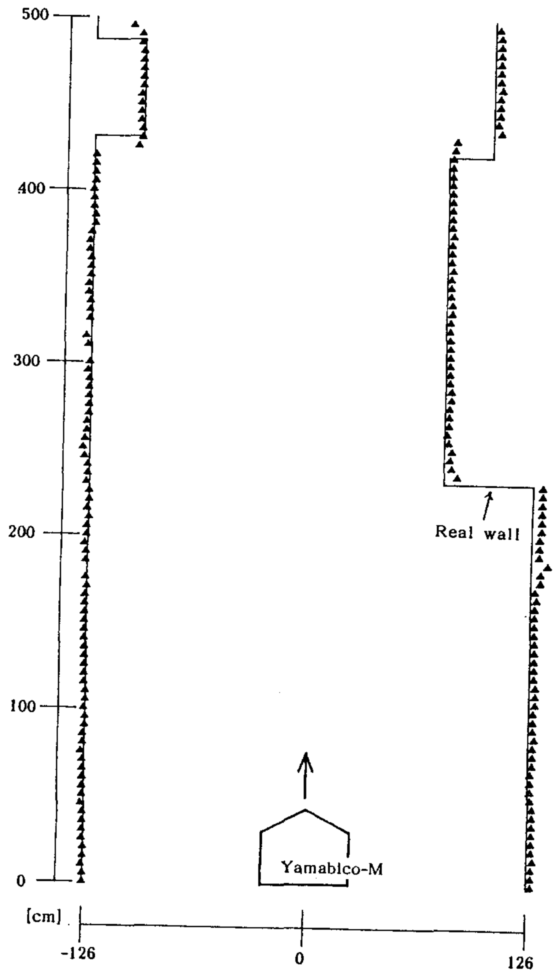

Fig.6 Memorized distance data in an experiment

6. Acknowledgement

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7. References

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