A COMPUTER CONTROL SYSTEM FOR MOBILE ROBOT MANIPULATOR

Bai Xiaobo, Li Gang, Mao Shulin, Zhao Jingtun
(Shenyang Institute of Automation, Academia Sinica)

Abstract

This paper presents a computer control system used for the mobile manipulator, which is being used as a testbed in our laboratory. The robot system consists of a remote control station and a vehicle with a slave-arm.

In the remote control station, a Intel 8086 is used not only for receiving and processing signals and commands for joystick, master-arm and keyboard, but for receiving data and symbols referring to mobile robot environment on a graph- ter's terminal.

In the vehicle, multibus-based processor system is applied to controlling slave-arm, receiving and processing ultrasonic range information, local image feature information and completing navigation function based on local environment feature. The cable and radio transmission are used for communication between control station and vehicle.

1 Introduction

Recently, mobile robot techniques are being developed rapidly with the development of sensorial technologies such as sensor, micro-computer, artificial intelligence, manipulation, locomotion, control and etc [1], [2], [3]. These technologies provide powerful backing for an autonomous and self-reliant mobile robot, but it is a long way for us to get a practical autonomous and self-reliant mobile robot. So it is very important to build a test-bed for research and development of the advanced mobile robot [4]. In this paper, a prototype of the test-bed for mobile robot is presented. Based on the test-bed, we have been doing some experiments concerning computer system structure and application of some sensors, in our opinion, a open structure for the computer control manipulator is flexible and useful, because of the flexibility of coping with and adding some function units on the system. In addition, the system is hierarchic and multiprocessor system, and it has a series of standardization interface which can be connected with different kinds of input and output signal.

2 System configuration

A Hardware structure

The block diagram of the computer control system for the mobile robot is shown in Fig. 1. This hierarchical structure system consists of a remote control station and a vehicle. In the remote control station, a micro-computer system (Intel 8086) is used and it has the following function units system 80-386 (CPU, 8086, SMIC) with 1MB memory, 350 Mbytes of Winchester disk, 640 Kbytes of RAM, A-D and D-A converter board, communication system board. All of these boards are connected with multibus, A-D converter with 16 channels inputs the command signal of joystick and position signal of master-arm, and 12 bit D-A converter with 12 channels outputs the control signal to servo amplifiers for driving DC servo motors of master-arm. Communication system board with two single-chip micro-computers 8748 controls data transmission. Transmitter is controlled by one 8748, and receiver is controlled by another one. Fig. 2 shows the hardware block diagram of communication system board without using main computer. A graphic terminal is used to display the mobile robot environment. In the vehicle, as a main control computer, 16 bit Intel 8086/8087 single board computer based on multibus is applied, which has on-board serial and parallel I-O interfaces, 512 Kbytes of RAM and 32 Kbytes of EPROM. The vehicle computer control system has the following function units, A-D converter with 16 channels inputs the position signal of slave-arm, and 8 bit D-A converter with 8 channels outputs the control signal to servo amplifiers for driving DC servo motors of vehicle and slave-arm. Communication system board controls data transmission and this board is same as that one in remote control station.

A real time pipeline image processor, as an edge image detector, is connected with multibus. The edge image detector receives an image through a vision sensor and extracts the edge point pattern by a hardware differential process. The parameter of edge point pattern is stored in the computer memory in real time and is used to detect the contour by a modified Hough transformation.

A series of single-chip micro-computers 8748 are connected with parallel I-O interface of ISBC 86-12A single board computer. Some single-chip micro-computers 8748 of them receive and process ultrasonic range sensor signal. Two of them receive and process odometer signal of both left and right wheels. One of them receives and processes signal of infrared detector. The last one is I-O interface, which outputs signal to indication lights for displaying the states of the vehicle.

B Software

As the hierarchical multi-processor system based on Intel 8086 computer, such the operation software consists of control programs written by application programmer, and ISBC-86 operation system software which offers means of communication, direct remote control and monitor command of master-slave manipulator and vehicle motion. The operation software is called a supervise program of mobile robot manipulator.

The remote control station consists of 8086-386 computer and graphics terminal (VT-125). The supervise program consists of keyboard commands and monitor commands with arguments. Keyboard commands are listed below,

- KF: go forward
- KB: go backward
- K1: increase velocity
- KD: decrease velocity
- Q1: a step forward
- Q2: a step backward

477
We can flexibly and conveniently do some function experiments such as navigation based on the ultrasonic information and CCO camera information in PL-M-86 or Assembler language on BRKX 86. We debug and check the program on the 8086-380 in PL-M-86 or Assembler language and transmit it to the vehicle to run. We can check the running processing of the program by transmitting the state of the program to the control station. Some commands below are just used for this purpose.

TR xxxxxxx is used to start a program at address xxxxxxx on the vehicle.
TX xxxxxxxxxx is used to transmit the content of a block memory to the vehicle at address xxxxxxxxxx.
TV xxxxxxxxxx is used to transmit the content of block memory to the remote control station from the vehicle at address xxxxxxxxxx.
TF, DE, SC is used to order the vehicle to travel with speed V, distance S and direction D.

Supervise program, except commands mentioned above, contains other real-time application programs. On the remote control station, the supervise program contains a time interval process of transmitting information. Not only travelling distance and direction of vehicle and positions of obstacles can be drawn on the graphics terminal, but route sideline can be drawn on the graphics terminal.

On the vehicle, the supervise program is a real-time multitask program. When the vehicle is travelling, the vehicle is not only controlled and adjusted locally to avoid running into obstacles using ultrasonic information in real-time, but it is controlled and adjusted according to speed, direction and distance set by command. Operator can control it by watching graphics terminal. When some tasks need to execute at once, the supervise program will choose one according to the priority and the lower priority tasks can be interrupted by higher priority one.

1 Function experiments

The computer control system for the mobile robot is being used as a test-bed in our laboratory. Visual, ultrasonic, proximity, odometry and direction sensor are used and controlled by the computer control system. In the following sections, we shall describe some function experiments in our mobile robot using the computer control system.

A The application of ultrasonic range sensors

We use four ultrasonic range sensors in the vehicle and two sensors are fixed in the front of vehicle and another two are fixed respectively in right and left sides. The sonar devices are Patchroid ultrasonic ranging system and have a useful measuring range of 0.9 to 35 feet. Each one is controlled by a single-chip micro-computer 8748 respectively. Hardware block diagram is shown in Fig. 2. The computer control system of the vehicle gets a description about its environment by processing the distance information. Movement of the vehicle will be controlled according to the description and present program state. For example, when the remote control station orders the vehicle to move along the corridor, the navigation system based on ultrasonic sensors will work for guiding. Vehicle can move along wall, or in the middle of corridor by adjusting moving velocity of two wheels using distance information. Another useful and important function of the sonar system is to avoid obstacles and this function keeps the vehicle to be in safety. Fig. 4 is the software block diagram of this function. Of course, we can get environment map description in geometries using sonar information.

B The application of a real-time image processor

Fig. 5 shows a hardware block diagram of a real-time image processor connected with multibus of the vehicle computer control system. In the image processor, a hardware structure based on a pipeline image-processor with local parallel procession ability is applied, an edge image with directional feature is produced from input original grey image in 30ms. Every point of the edge image is represented by cartesian coordinates. All the points of the edge image are divided into eight group by directional feature and stored in eight segment RAM in real-time. The image processor provides powerful way of a rapid reduction of parameter to yield a line description of the environment of the vehicle. Fig. 6 shows the block diagram of extracting edge information of environment and objects from grey image. This system is a two level pipeline image processor with local parallel procession. The first level pipeline processor applies the smoothing operator to the original grey image to filter out noise. The second level pipeline processor extracts the edge pattern with directional feature by differential process.

In our vehicle, the visual sensor is a CCO TV camera (TN4000). Its digital signal can enter immediately the processor system mentioned above. Edge points are produced and stored in RAM in 30ms. After the edge image is obtained and stored in RAM, we apply a modified Hough-transformation to detect contour line. Fig. 7 shows the software block diagram of the Hough-transformation. We get a description of the environment and objects by a group of line segments and the description is transmitted to the control station. In the control station, we display the description of the environment on the graphics terminal. Making use of the description, we are going to do experiments of navigation based on local environment features, such as edges of objects, wall and route.

Conclusion

We have developed the computer control system for mobile robot manipulator as a practical use test-bed. We have done some function experiments. Experiments demonstrated its usefulness for researching new computer control system of robot and we will further develop and perfect the system in the fields of hight level control language and advanced multi-processor system.

References

[1] J. L. Crowy "Dynamic world modeling for an intelligent mobile robot using a rotating ultrasonic range de-
vice" pp 128-156 1985 IEEE ICRA

Fig. 1 Hardware block diagram of computer control system

Fig. 2 Hardware block diagram of communication system

Fig. 3 Hardware block diagram of I/O interface

Fig. 4 System block diagram of a real-time iconic image processor

Fig. 5 Block diagram of extracting edge point
calculate $p(q)$ of all point $(i,j)$ and get $p-q$ table of one direction

find local maximum in P-Q table

find and store end points of all times

\[ \text{yes} \rightarrow \text{finish} \]

\[ \text{no} \rightarrow \text{all directions} \rightarrow \text{next one} \]

Fig. 6 Block diagram of modified Hough-transformation

\[ \text{distance} \rightarrow \text{no} \]

\[ \text{front two distance} \rightarrow \text{stop} \]

\[ \text{distance} \rightarrow \text{turn} \rightarrow \text{go forward} \]

\[ \text{distance} \rightarrow \text{turn} \rightarrow \text{turn} \]

\[ \text{stop} \rightarrow \text{distance} \]

\[ \text{yes} \rightarrow \text{distance} \]

Fig. 7 Block diagram of ultrasonic avoiding obstacles