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A Vision Based Mobile Robot Travelling Among Obstructions

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Abstract This paper presents a mobile robot that travels employing visual information. The mobile robot is equipped solely with a TV camera as a sensor, and views from the TV camera are transferred to a separately installed micro computer through an image acquisition device. An acquired image of a view is processed there and the information necessary for travel is yielded. Instructions based on the information are then sent from the micro computer to the mobile robot, which causes the mobile robot next action. Among several application programs that have already been developed for the mobile robot other than the entire control program, this paper focuses its attention on the travelling control of the mobile robot in a model environment with obstructions as well as an overview of the whole system. The behaviour the present mobile robot takes when it travels among obstructions was investigated by an experiment, and satisfactory results were obtained.

1. INTRODUCTION

A mobile robot is an autonomous robot equipped with some sensors and wheels. Unlike the existent industrial robot that is fixed at an individual location, it moves to its destination employing the information on its surroundings which the attached sensors provide. Because of its potential applicability in various fields such as factory automation, patient-aids in hospitals, autonomous traffic systems, *etc.*, researches have been made vigorously toward the realization of a mobile robot of the kind.

Most of the mobile robots under development are basically equipped with a TV camera and the difficulty of real-time image processing is covered by the employment of a range finder or other sensors, or both[1]. Mori *et al.*[2] develops an outdoor land vehicle which has a TV camera and subsidiary sensors attached to it to realize smooth travel of the vehicle. The mobile robot proposed by Matsumoto *et al.*[3] employs four range finders instead of making use of a TV camera. Taken it into consideration that more than 70% of the information we obtain from the outside through our sensory organs are visual information, realization of an intelligent mobile robot largely depends on to what extent it can utilize the image data acquired by a TV camera. Therefore, though a range finder offers quick acquisition of range data, we stick to the employment of a TV camera as a sensor.

The mobile robot presented in this paper has been developed in a model environment so as to study basic techniques necessary for a mobile robot to travel to its destination. This mobile robot is equipped solely with a TV camera as a sensor, and moves forward employing the visual cues the front views taken by the TV camera provide. Until now, several algorithms have been developed for making the mobile robot travel on the instructed way in a model environment to its destination: It detects the middle part of a road and moves on it[5]; It also recognizes the shape of the junction in a front view where it might make a turn[4]: These functions are employed repeatedly until it finally reaches the destination.

This paper focuses its attention on the travelling control of the mobile robot in a model environment with obstructions. The first part of this paper gives an overview of the whole mobile robot system, and the technique for travelling among obstructions is presented in the second part along with an experimental result.

2. SYSTEM CONFIGURATION OF THE MOBILE ROBOT

We aim at developing a mobile robot which travels based on image processing. The present mobile robot is equipped with a TV camera and no other sensors are installed in it in order to utilize the image information the TV camera provides as much as possible. The mobile robot is rather small-sized for the use in a model environment and realizes its move by a pair of wheels driven independently by stepping motors. The rotation of the TV camera is also controlled by two stepping motors; one for panning and the other for tilting. The appearance of the present mobile robot is shown in Fig.1.

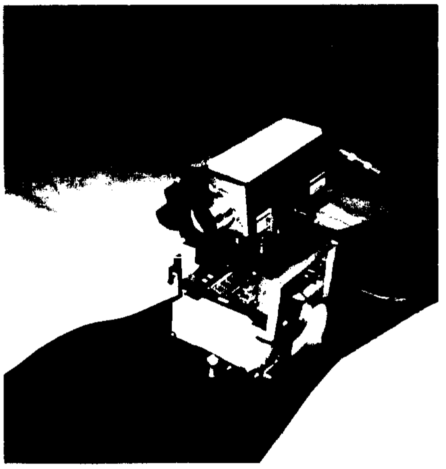

Fig.1. The vision based mobile robot developed in the present study.

Figure 2 shows the system configuration of the present mobile robot. The whole system is controlled by a 16-bit micro computer separated from the mobile robot itself. A view from the TV camera is transferred to the micro computer through an image acquisition device which transforms the view into a 256×256 pixels digitized image of the 16-level gray scale. The digitized image is processed in the micro computer, which yields the information giving the situation of the mobile robot in the environment. Employing this information, the micro computer produces the instruction that gives next desirable move of the mobile robot and sends it to the robot through the communication interface board.

The mobile robot itself has an 8-bit micro processor contributing to its wheel control. The block diagram of the robot hardware system is shown in Fig.3. (Detail description of the diagram is given in [6].) The main part is composed of a communication unit, a drive unit,

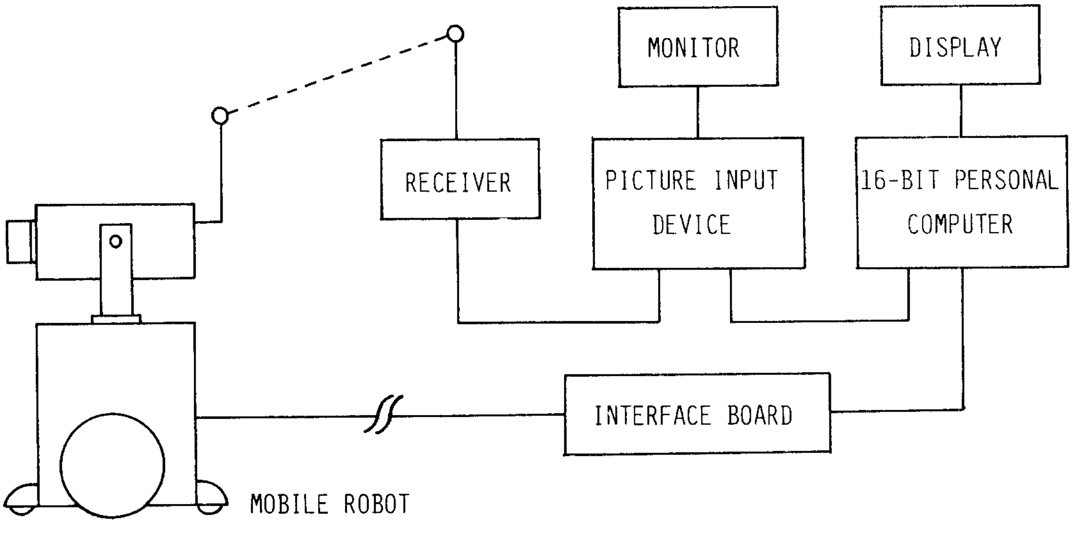

Fig.2. Configuration of the present mobile robot system.

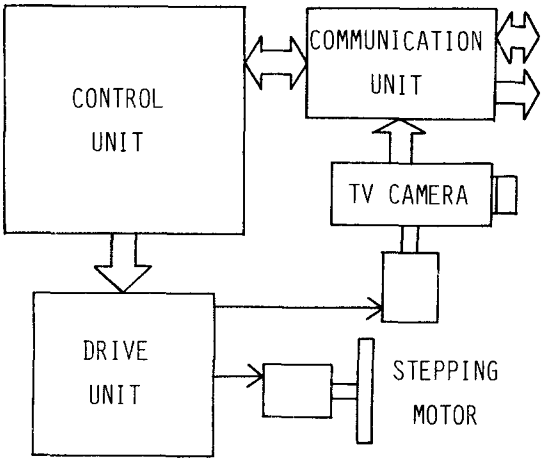

Fig.3. Block diagram of the hardware of the mobile robot.

and a control unit which contains the 8-bit micro processor. The communication unit sends video signals to the image acquisition device and receives control signals from the main micro computer. The drive unit supplies pulses produced by a pulse generator to the stepping motors. Along with these units, the control unit contributes to the travelling control of the mobile robot in the following way: the control signals sent from the micro computer are received by the communication unit and transferred to the control unit after an acknowledge signal is returned to the micro computer; by decoding the control signals, the control unit chooses the stepping motors to be driven and their rotational directions; then it instructs the drive unit to start sending the number of pulses indicated by the control signals to these stepping motors; after this stepping motors driving process, the control unit finally sends an acknowledge signal to the main computer telling the normal end of the process.

Since the micro processor installed in the mobile robot operates independent of the main micro computer, the micro computer is able to process the acquired images while the micro processor controls the travel of the mobile robot. This contributes to realizing real-time processing of those successive images.

3. AVOIDANCE OF OBSTRUCTIONS

3.1. The Model Environment

It is indispensable to a mobile robot to avoid obstructions on the way to its destination. This avoidance problem relates itself to the route planning problem of a mobile robot[7]. In case that the location and the shape of those obstructions are known in advance, the shortest (or some optimum) route can be planned that makes a mobile robot avoid the obstructions and leads it to its destination[8]. Such a case is, however, uncommon in a real situation, and the desirable route should be searched in a heuristic manner employing successive views from a TV camera on the mobile robot.

In principle, the three-dimensional shape of an obstruction needs to be known as well as its exact location for a mobile robot to judge if it can manage to avoid collision with it. This is fairly a difficult subject with all the present TV image processing techniques. The employment of a range finder[9] may partially solve the difficulty, but, as explained earlier, we stick to the employment of a TV camera for the wider use of a TV image.

The present mobile robot is assumed to travel in a model environment which contains a cylindrical object as a destination and some conic obstructions as shown in Fig.4. The mobile robot travels to the destination among these obstructions. Although the shape is given, their locations remain to be known, which results in

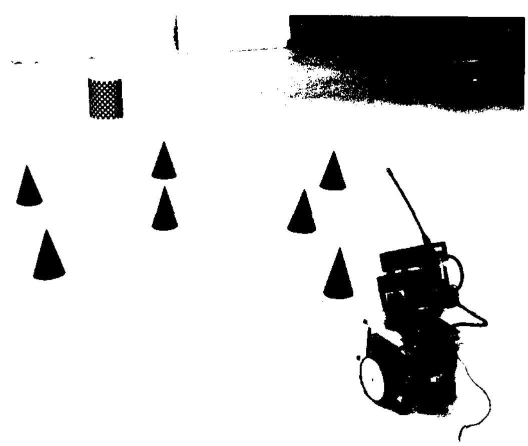

Fig.4. The model environment.

the heuristic search of the route to the destination. Our attention is focused on the route search of the mobile robot rather than recognizing the three-dimensional shape of the obstructions it encounters. Therefore the shape of the obstructions concerned is simplified, and this yields speeding up of the image processing.

3.2. The Avoidance Strategy

Whether an object obstructs the way of the mobile robot can be judged by the direction of its travel, the direction of the TV camera, and the location of the object in a taken image. Since an avoidance route is usually required to be shorter, the mobile robot passes a collision-free route which is nearer to the obstruction concerned. This is realized by monitoring the location of the object in the successive images taken by the TV camera.

Figure 5 shows the entire procedure of the obstructions avoidance. It begins by making every parameter concerned with the mobile robot initialized at the initial position, which is followed by the search for the destination given by a cylindrical object in the model environment with the horizontally held TV camera of the robot. Once it is found, the mobile robot starts travelling toward it, and, by letting the TV camera tilt downward by 30 degrees, it tries to find obstructions on the way. If it encounters an obstruction, the mobile robot tries to go around it by employing an avoidance strategy. This procedure is iterated until the mobile robot finally arrives at the destination.

An avoidance strategy is illustrated in Fig.6. Let us discuss the case where the mobile robot avoids collision with an obstruction and passes on its right. Suppose that, in Fig.6, object O is obstructing the way and the mobile robot is at the location indicated by P_1. It observes the front and left scene which contains obstruction O, and advances keeping obstruction O at a desirable location in the successive views so that it can avoid the possible collision with the obstruction (P_2). As it travels further, the bottom edge of the obstruction disappears from the front view. Then the mobile robot pans the TV camera furthermore to the left to catch the whole figure of obstruction O again (P_3), and advances till it comes just beside the obstruc-

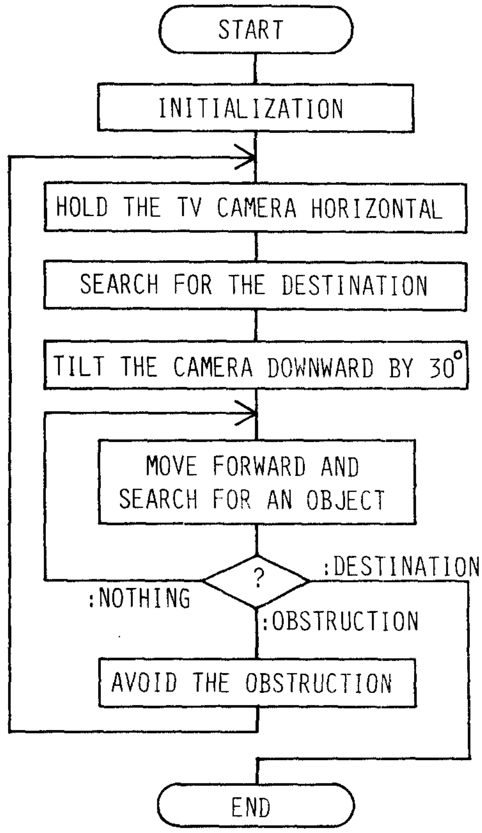

Fig.5. Flow chart of the obstructions avoidance process.

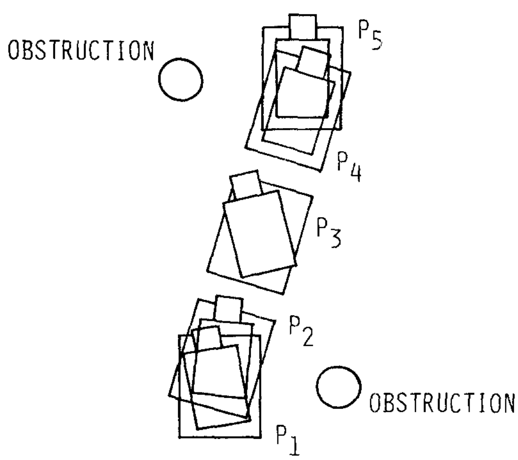

Fig.6. The strategy of avoiding obstructions.

tion. At this location, the direction of the TV camera is restored to its initial state, *i.e.*, it is turned to the same direction as the mobile robot and held horizontal (P_4). The mobile robot again starts searching for its destination drawing an arc gently to the left (P_5).

3.3. Experimental Results

The flow of the avoidance process given in Fig.5 was programmed by Lattice C (Version 3.0) and included in the entire mobile robot system. An experiment was performed with this program and satisfactory results were obtained. Figure 7 is an example of the successful performance of the travel the mobile robot does in the obstructive model environment. In the figure, a large circle denotes the destination of the mobile robot, while small circles denote obstructions. The actual route the mobile robot took in this experiment is given by a solid line between the initial and the final position. The route can be separated into three sections: the mobile robot searches its destination in section S_1; it judges if an object existent in a front view obstructs the way, while travelling in section S_2; and, once the object is understood as an obstruction, it tries to avoid collision with it, which results in the trajectory given in section S_3. The mobile robot stops travelling when it arrives at the final position which is about 30 cm distant from the destination.

4. DISCUSSION

In the research of a vision based mobile robot, fast processing of acquired images is particularly important because of the real-time nature of the problem. Since the present mobile robot system employs a 16-bit micro computer, simpler image processing algorithms are devised to speed up the decisions necessary for the mobile robot's travel. The present mobile robot realizes a reasonable travelling speed by this simplification, but somewhat ideal model environment is assumed. A powerful algorithm for avoiding obstructions in more complicated environment needs to be developed. It may, however, impose much on the image processing part of the system and may take time if a micro computer is employed for the processing. Hardware implementation of such an algorithm needs to be investigated to solve this problem.

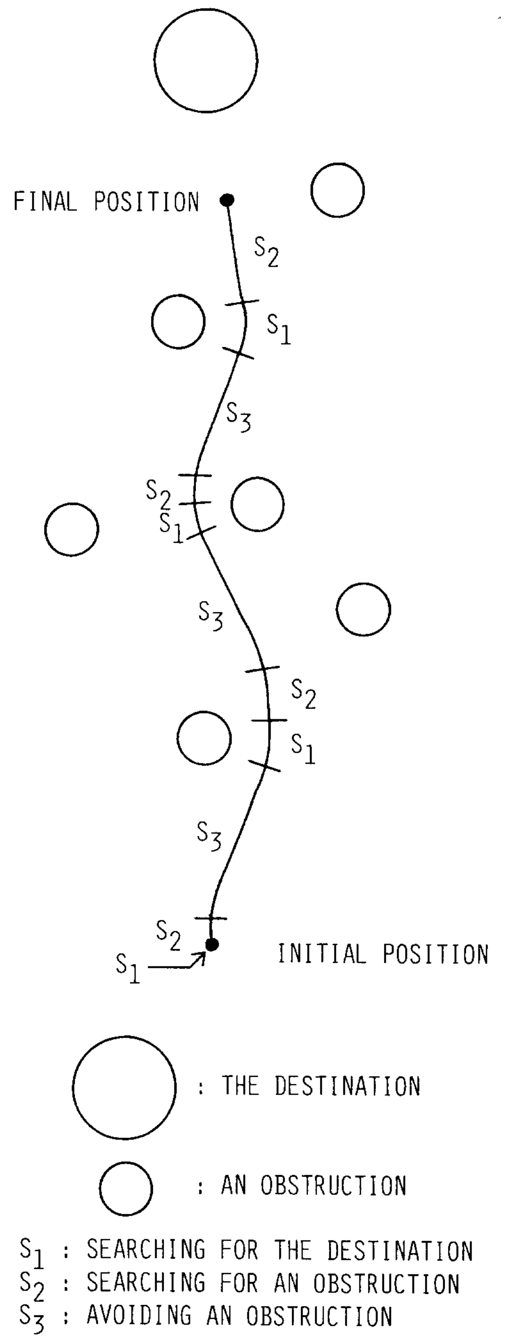

Fig.7. An experimental result.

The present mobile robot does not have any *a priori* knowledge on the situation of those objects in the model environment, and it searches for the right way to its destination in a heuristic manner. We aim at making the mobile robot draw a map of the environment during this search. The map is to indicate how much the mobile robot has understood its environment. It will then offer useful information for further travel of the mobile robot.

5. CONCLUSION

A vision based mobile robot was presented which was equipped solely with a TV camera as a sensor and the obstruction avoidance problem was discussed employing this mobile robot. The avoidance strategy was explained and an experimental result was shown. Though all the experimental results indicate that the present avoidance strategy works well, some improvements in the strategy need to be done for better performance of the present mobile robot.

REFERENCES

[1] T. Kanade : "Overview of research on autonomous mobile robots in the US ", *Journal of the Robotics Society of Japan*, **5**, 5, 44–51(1987).

[2] H. Mori, S. Kotani, H. Ishiguro, S. Yasutomi, and Y. Chino : "Self-contained mobile robot in campus road ", *Journal of the Robotics Society of Japan*, **5**, 5, 29–42(1987).

[3] T. Matsumoto, and S. Yuta : "Autonomous navigation system for mobile robots using the route map", *Journal of the Robotics Society of Japan*, **5**, 5, 19–28(1987).

[4] S. Ishikawa, H. Tamura, N. Harada, K. Ide, and K. Kato : "A self-moving vehicle with a visual sensor ", *Bulletin of the Kyushu Institute of Technology*, 53, 55–62(1986).

[5] S. Ishikawa, A. Ohishi, A. Kido, K. Ide, and K. Kato : "A self-moving vehicle with a visual sensor II ", *Bulletin of the Kyushu Institute of Technology*, 55, 69–76(1987).

[6] A. Kido, K. Gouhara, K. Ide, S. Ishikawa, and K. Kato : "On a vision dependent mobile robot ", Information Processing Society of Japan Technical Report, MC–47–5(1987).

[7] M. Kakikura : " Behavior planning for autonomous moving robots", *Journal of the Robotics Society of Japan*, **5**, 5, 66–70(1987).

[8] T. Lozano-Pérez and M. A. Wesley :"An algorithm for planning collision-free paths among polyhedral obstacles", *Commun. ACM*, **22**, 10, 560–570(1979).

[9] Y. Shirai : "Recognition of polyhedrons with a range finder ", *Pattern Recognition*, **4**, 243–250(1972).