Research on Autonomous Mobile Robot for Visually Handicapped Persons by Pattern Recognition

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Abstract: The research of the paper aims to move the robot automatically to the destination by image processing. On the road, some traffic signals are set for the experiment. For example, the letter "L" means to let robot move left, while "R" means to move right, "F" means moving forward, "P" is the command of parking, and so on. These letters will be recognized by the template matching method and the ART neural network. The robot can recognize the letter and decide the motion by itself based on these traffic signals.

Keywords: Autonomous mobile robot, Image processing, Pattern recognition, Template matching method, ART neural network.

I. INTRODUCTION

The visually handicapped humans can come and go freely in the place where they usually visit, but they cannot go to other place alone. Typically, the helpers are needed to help them. But such situations are big burden for both helpers and handicapped persons. In particular, it is said that mental burden of handicapped persons is larger. So the autonomous mobile robot is developed by improving from the electric wheelchair for the elderly people.

The object of the study is to automatically navigate the robot to the destination by the GPS and image processing. The robot previously gets the information of destination by GPS and automatically moves to the destination by comparing the information of the current place with that of the destination [1].

In this study, we propose the robot that recognizes a traffic sign by image processing and pattern recognition. For example, the robot turns right if there is a traffic sign called 'R'. It would lead to a big accident on this occasion if the robot does wrong recognition, thus the high recognition rate is important.

II. General Structure of the Mobile Robot

1. The specification of the electric wheelchair

The electric wheelchair that is developed by the SUZUKI Company is converted to the mobile robot (Fig.1) by installing the GPS receiver, the computer, and the network camera for image processing and other sensors for safety drive. By the Japanese traffic law, the electric wheelchair is treated as the wheelchair for the physically handicapped persons and is legally as walkers. Thus the navigators do not need to have the driver's license. Therefore, anyone can drive it. The specification of the electric wheelchair is as follows.

Fig.1. The developed electric wheelchair

Dimensions:	1170×660×1060[mm]
Weight:	79kg
Forward speed:	2 ~ 6km/h
Reverse speed:	2km/h
Drive system:	Direct drive system with rear-wheel drive
Braking system:	Electromagnetic brake that uses motor dynamic braking
Control system:	Microcomputer variable speed electronic control unit for accelerator lever

2. The specification of the network camera

Our previous research used a USB camera, but in this study, the network camera of AXIS 207W (Fig.2) is selected. The reason to select it is in the next section and the specification of the camera is as follows.

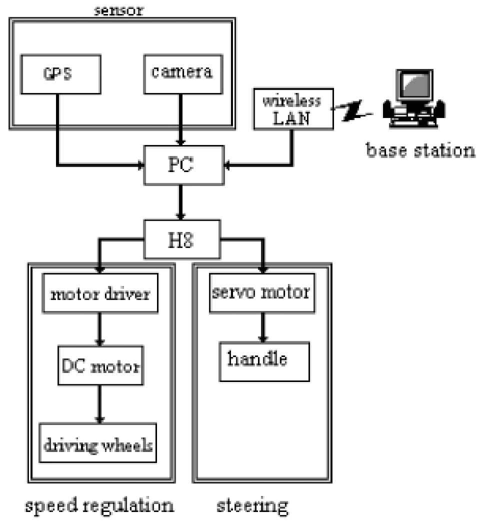
Fig.2. Network camera

- Delivers a high-resolution live image on a network
- MPEG-4 image compression technology to realize the specifications of the most suitable bandwidth
- Built-in motion detection function
- Accessible at the speed of the Maximum 54M bit/sec in wireless network environment (IEEE802.11g)
- WPA/WPA-2 security mechanism
- Built-in web server for remote monitoring
- Password is used for security of multi-level users

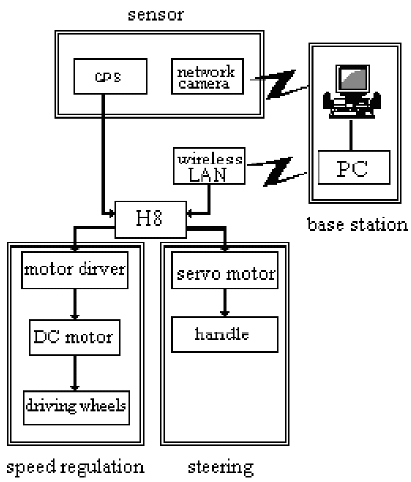
3. Structure of the system

Fig.3(a) proposed the block diagram of the system that developed before. Previously, the system has an embedded PC on the mobile robot. However, the consumption of the battery let the driving time shorter if loading a PC on the mobile robot, and the cost of PC on each electric wheelchair is also a problem.

Therefore the system in Fig.3(b) is suggested. The system uses the network camera. Using this camera can unload a PC from the mobile robot, and put it in the base station. It can solve the problems discussed above.



(a) The block diagram of the former system



(b) The block diagram of the proposed system

Fig.3. The block diagram of the systems

III. EXPERIMENT

1. Experiment description

The purpose of the study is to make the mobile robot recognize a traffic sign by image processing. It would become a big accident if the recognized result was wrong. Therefore, the high recognition rate is important. In this section, the experiment compares the template matching method to the ART neural network. Traffic signs are 'F' (move forward), 'R' (turn right), 'L' (turn left) and 'B' (move backward).

2. Image processing

In this study, the red traffic sign is extracted. Binary processing is done to extract the letter of a traffic sign from the original image (Fig.4(a)) that is taken from the camera. The binarization is processed by the threshold level of the R, G and B plane in the RGB color space.

First, the color of the object is decided, and then determines the maximum and minimum values of this color in the R, G and B planes. If the value of the pixel is within this range, it is set to 1 (white), otherwise is set to 0 (black). By this method only the traffic sign is set to 1 and all other colors in the image are set to 0 [2]. In Fig.4, (a) is the image taken by the camera. It is processed by two binarization processing.

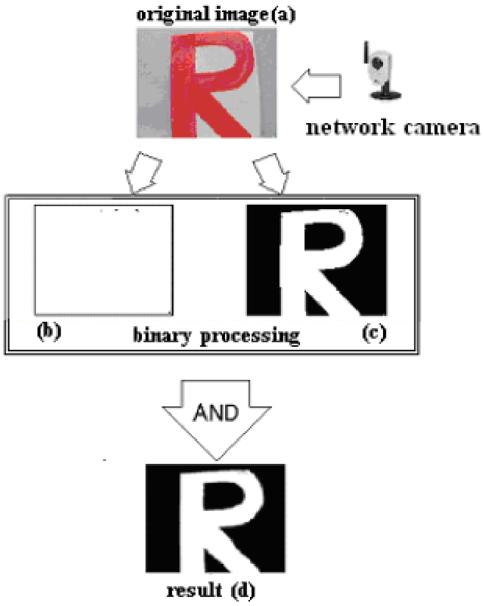


Fig.4. Binarization processing

The threshold of binarizing from Fig.4(a) to Fig.4(b) is R plane: 120 ~ 250, G plane: 0, B plane: 0. All the red color in the original image becomes white because the range of R plane is wide. The threshold of Fig.4(c) is R plane: 100 ~ 121, G plane: 50 ~ 100, B plane: 25 ~ 105. These thresholds are set to make the background black.

It is possible to extract the letter by doing the AND operation between Fig.4(b) and Fig.4(c), and the result is Fig.4(d).

3. Pattern recognition

The process of pattern recognition is shown in Fig.5. For recognizing the letter, extracting the feature vector (Fig.6(a)) is necessary. The value of feature vector is set to 0 (black) or 1 (white) from the processed binary image. By comparing (matching) the feature vector to

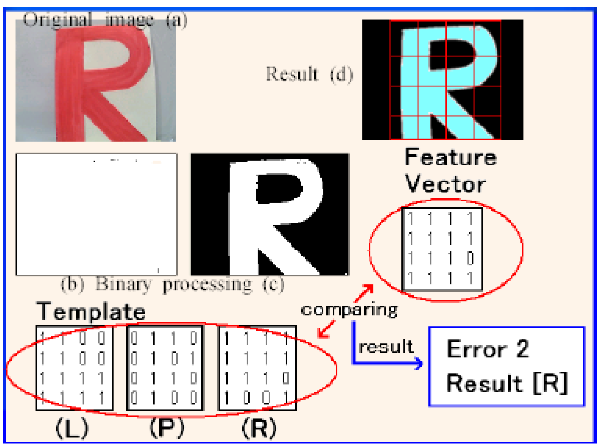
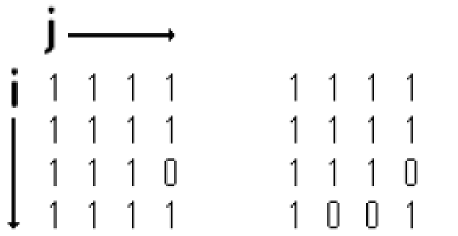


Fig.5. Program execution screen



(a) Feature vector (b) Template of 'R'

Fig.6. Comparisons

all the templates (shown in Fig.5), the result is recognized as the letter 'R', and the *error* between the extracted feature vector to the template of 'R' is 2. The meaning to determine *error* is explained below.

A: Template matching method

First, the experiment by the standard template matching method is done. Based on the test, all the templates are set (for example, the templates 'L', 'P' and 'R' in Fig.5).

In Fig.5, the differences between the feature vector (that is extracted from the image taken by the camera) and all the templates are calculated and the minimum value is *error* = 2, which is gotten from the template 'R'. Thus the letter 'R' is considered as the most suitable template to the feature vector. Eq.(1) gives the matching between the feature vector aij and the template bij.

$$\text{Error} = \sum |aij - bij| \qquad (1)$$

Based on Eq.(1), the difference between the feature vector and the template of 'R' is *error* = 2, the vectors of which are shown in Fig.6.

B: ART neural network

ART, also called as the vector classifier, is a kind of unsupervised, competitive neural networks. It can recognize the patterns by self-organization in response to the input vector. When given an input vector, the ART network tries to classify it into one of the stored categories depending on which stored pattern it most resembles. If the input vector does not match any stored pattern within a system parameter called *vigilance*, a new category is created.

For the traditional BP network, if a new pattern is added, all the weights should be trained again. But for ART, there is no stored pattern is destroyed if it does not match the current input pattern. A new output node will be created to match this new pattern [3].

Fig.7 gives the general structure of the ART network. It has two layers: F1 (N nodes) - the comparison layer, F2 (M nodes) – the recognition layer. N represents the size of the input vector. M is the number of patterns that ART has stored.

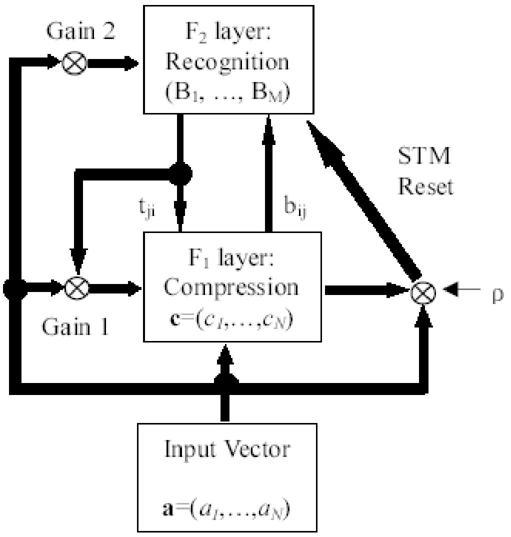


Fig.7. ART structure

F1 and F2 layers are interacted by bottom-up b_{ij} and top-down t_{ji} weights. Gain1, Gain2 and "STM Reset" are functions for training and classification.

Based on the principle [4], the ART classification algorithm is given in Fig.8. It consists of five steps: initialization, recognition, comparison, search and training.

The initial parameters for ART are the number of F1 nodes N = 5×5 = 25, and F2 nodes M = 3, which represents the letters of L, P, and R. After training, when one of above three letters appears, ART can recognize it without error. If a new letter 'F' is found, it can be added by the ART network to show that a new category is created, then the number of output nodes is changed to M = 4, the new one is pointed to the letter 'F'.

IV. CONCLUSION

In this paper, two kinds of recognition methods are tested. The traditional template matching method is compared to the ART network. In the experiment, when the camera catches the letter, it can be recognized after image processing, and then the robot can move automatically based on its command.

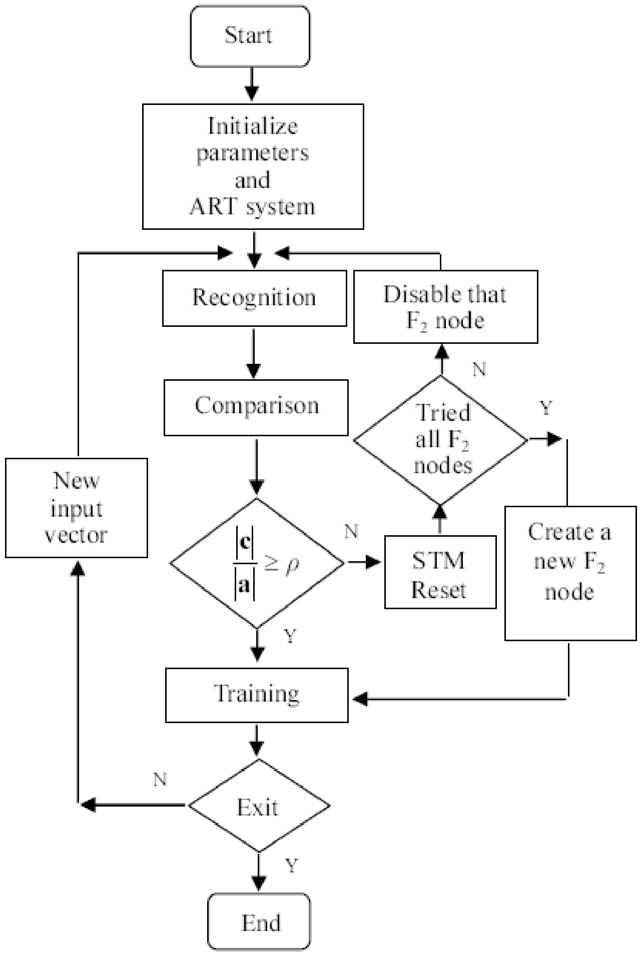


Fig.8. ART algorithm

For the ART network, when a new control function (for example, *move forward*) wants to be added to the categories, a new letter *F* that can represent it will be used. ART can automatically recognize it and add it as a new pattern in such a fashion that the existing patterns are not forgotten or modified. That is to say, the connection weights in the ART network for other characters will not be retrained.

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