MVA '96 IAPR Workshop on Machine Vision Applications, November. 12-14, 1996, Tokyo, Japan

Analog and Digital Meter Recognition Using Computer Vision

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Abstract

The purpose of this paper is to build a computer vision system that endows an autonomous mobile robot the ability of automatic measuring of the anlog and digital meters installed in nuclear power plant(NPP). In the meter image captured by the camera, the meter area is sorted out using mainly the thresholding and the region labeling. The positions and the angles of the needles in analog meter images are detected using projection based method. In the case of digital meters, digits and points are extracted and finally recognized through the neural network classifier. The function name of the meter needs to be identified and the scale distributions are also required to be analyzed to make the meter recognition fully automatic.

1 Introduction

Robot vision systems have a variety of applications in the industrial fields. And one of the area demanding the robot vision application is Nuclear Power Plant(NPP)[1]. The automatic surveilance and inspection in NPP are performed by mobile robot equipped with multi-sensors. One of the sensors is vision sensor represented by CCD camera. There are works which can be done with vision sensors and we will deal with the analog and digital meter recognition specially. A fundamental report on the automatic surveilance system for NPP was submitted to the U.S. Nuclear Regulartory Commission. And related studies are on by Department of Energy[2]. Trivedi et al. have stuied on automatic inspection system for NPP. But they just proposed the simple procedure on the meter value recognition[3] [4]. This study is devided mainly into two parts, analog meter recognition and digital meter recognition. In the case of analog meters, needle is detected and the rotation angle is calculated. To get the real meter value from rotation angle we can use the look-up table. To select the appropriate look-up table, the identification of meters must precede. To do this, we extract the function name and recognize it using neural network classifier. Providing that the scale distribution of a analog meter can be found automatically, the real value can be obtained from needle angle without look-up table. We also did an experiment about this, but further study on this is in need. In the case of digital meters, digits are extracted and recognized. And the function name is recognized to identify the meter. The performance of this system is verified by computer simulation. The meters installed in NPP is not much deviation from general meter in shape, so this system can be used in other industrial fields with minor modifications.

2 Analog Meter Recognition

The automatic analog meter recognition system can be built in three methods by the degree of independency of recognition module to knowledge bases. The first method is to recognize only the deflection angle of needle and the angle is translated to true meter value by database containing information about position of meters, function names, units, and scale distributions. This method is the most database-dependent one. In the second method, we identify the meters by rocognizing the function name automatically. So the information about the meter position is no

longer in use. The third method is so called fully automatic and has no built-in database. In this method, the scale distribution is analyzed automatically, so we can translate deflection angle to true meter value without database. The process units for building the system are meter area extraction, deflection angle detection, function name recognition, and scale distribution analysis.

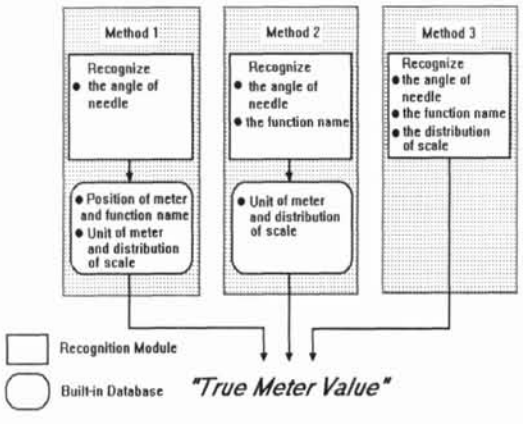

Figure 1: Strategies for the automatic analog meter recognition system

2.1 Meter area extraction

To extract the meter area from the image taken by camera installed in mobile robot, thresholding is performed as a first step. After binarizing the image, region labeling is applied to extract the image elements. Using spatial constraints such as area ratio and aspect ratio of region, we can extract the meter area.

2.2 Deflection angle detection

To detect needle in a meter area we use simple run length technique. We calculate the run length from the center to edge of meter image as sweeping circularly. And the position with maximum run length value is selected as needle position. Using run length instead of complex detection algorithm to find needle in a meter area has advantages such as high speed in performance and robustness to noises.

2.3 Function name recognition

In the automatic meter value recognition system, the identification of meter takes a significant part. We can identify meter by recognizing function name printed on it. For recognizing function name, each character composing function name should be segmented out successfully[5]. But some difficulties are expected in extracting characters. First, the meter image may have slant due to the leveling error of camera. Second, the gradient in illumination cause the shade drawn on the meter surface. These have characters touched toghether after binarization. To segment out each characters successfully, region labeling and thresholding technique are applied as well as simple projection algorithm. Each character segmented out is recognized through neural network classifier. We used mesh features extracted from 25 characters and a symbol('/') as input to classifier. The specification of neural network is shown in table 1.

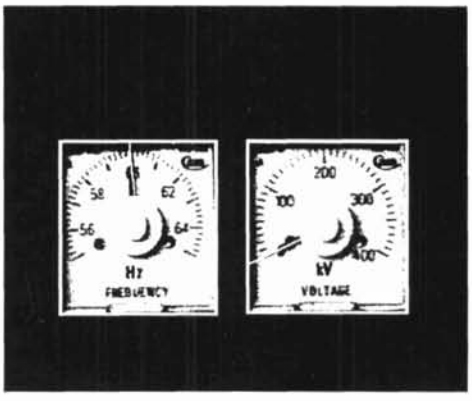

Figure 2: Analog meter extraction and needle detection

Table 1. Architecture and parameters of neural network

Structure of neural network	Multilayer perceptron trained by back-propagation algorithm
No. of input nodes	80(8*10)
No. of hidden nodes	30
No. of output nodes	25
No. of training pattern	950 (25 Characters * 38 Sets)
Learning rate	0.1
Momentum	0.7
Max. error rate	0.01

Character stream composed of each character recognized by neural network is compared with the function names in database. And the function name with highest matching score is selected as final result.

2.4 Scale distribution analysis

There can be two ways obtaining true meter value from needle deflection angle. One method is to use scale distribution table by way of identification of meter through function name recognition. The other method is to analyze the scale distribution automatically and then make it possible to get true meter value without lookup table. The procedure of analyzing scale distribution is as follows.

1. Segmenting out meter area
2. Extracting scales through region labeling
3. Sorting out large scale
4. Extracting digits near the large scale
5. Recognizing the digits and scale angle.
6. Analyzing the scale distribution through interpolation and outerpolation.
7. Converting the needle deflection angle to true meter value.

One thing noticeable is that at least two large scales and correponding scale values must be extracted successfully to analyze the entire scale distribution.There are some difficulties in segmenting out digits corresponding to scale value because of the touchness between digits. We applied variable window method to segment touched digits. In this method, a resonable size of window is set at the left side of digits. And each time as the window expands to right, digit segment extracted by window is put as input of neural network and the reliability factor(RF) is produced as output. In this process, digits are segmented by windows with highest RF values. Here, RF is defined by

$$RF = O_{\max} - O_{\text{second}}$$

where $O_{\max}$ is the highest output value of neural network and O_{second} is the second highest value.

3 Digital Meter Recognition

Digital meter value recognition can be performed by two processes such as numeric code recognition and function name recognition.

3.1 Numeric code recognition

Digital meter installed in NPP has up to four numeric codes and each of them is displayed by LED matrix(4*7). After extracting the meter area using region labeling, numetric codes and point should be segmented out. As a first step, we extract point by region labeling and measuring the distance between LED cells. And then extract each numeric code through projection and sliding window method. The reason why we use sliding window to segment numeric code vertically is that there exist gaps between LED cells, so it is hard to segment codes with simple projection method. The width of sliding window must be wider than the vertical gap between LED cells and narrower than the distance between the codes. Each numeric code segmented is recognized through neural network. True meter value can be calculated because we can know the position of point at the segmentation level. The final result of digital meter value recognition is shown in figure 3.

Figure 3: Recognition result of LED display

3.2 Function name recognition

The process of function name recognition is similar to that of analog meter. How to extract each character successfully

is also a key to the function name recognition. In this case, there are characters touched together by a nearby long line-shaped image element. We can know that the characters are not touched in gray level image, so if proper threshold can be chosen each character will be segmented out without touch. We use thresholding and region labeling iteratively getting threshold decreased until all characters are segmented out successfully. Each character extracted is recognized through neural network. And the final function name is determined through string matching.

4 Experiments

The images of meters are taken from the Advanced Compact Nuclear Simulator in Korea Atomic Energy Research Institute. There are 10 kinds of analog meters and 20 kinds of digital meters. We performed experiments with about 50 images including those containing several meters. Table 2 shows the result of experiment.

Table 2. Recognition accuracy

Type of meter	Experiment	No. of data image	No. of success
Analog	Detection of needle	20	20
Analog	Recognition of function name	10	9
Digital	Recognition of numeric code	30	30
Digital	Recognition of function name	20	19

5 Conclusion

In this paper, we described about the automatic recognition of analog and digital meters installed in nuclear power plants. We applied simple and elementary techniques such as binarization, region labeling, and projection to extract needles in analog meters and numeric codes in digital meters. By using these simple methods can we get high speed in performance and robustness to noises. We identified meters by recognizing their function name through neural network. Some techniques such as variable window method and iterative binarization-and-region labeling method are used in extracting function name and scale value. More experiments with the meter images reflecting various illumination conditions are required. And more studies are required on the preprocessing including local thresholding and automatic scale distribution analysis.

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