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journal or publication title	Journal of Computational Information Systems
volume	6
number	14
page range	4657-4664
year	2010-12
URL	<a href="http://hdl.handle.net/10228/00006439">http://hdl.handle.net/10228/00006439</a>

## A numeric reading system for digital meter without I/O interface

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### Abstract

Recently, measuring instruments that automatically record measurement values by using the communication function of PC and RS232C have been widely used. However, there are a lot of measuring instruments that can not communicate with an external instrument at present. Also, the ones that have the communication function are very expensive. The system that reads the instruction value from the image is by taking a picture of the measuring instrument with a camera. However, because the specification of the target measuring instrument has been limited, versatility of this system is low. Therefore, this paper proposes a strong numerical recognition system that doesn't depend on the model of a digital measuring instrument. The experiments showed that the proposed method has the characteristics of fast speed, efficiency and strong anti-interference.

*Keywords:* Digital Meter; Image Processing; Projection Conversion; Correcting Image Distortion

### 1. Introduction

Recently, measuring instruments that automatically record measurement values by using the communication function of PC and RS232C have been widely used. However, there are a lot of measuring instruments that cannot communicate with external instruments at present. Also, the ones that have the communication function are very expensive.

As a method of solving this, the method of reading the instruction value from the picture image taken of the measuring instrument by a camera was devised [1]. In the research that reads the instruction value of an analog meter is done in such a method [2]. This presumes the parameters that are necessary for reading the instruction value by fitting the model made beforehand to the in meter image at the set camera time, and reads the instruction value. However, because this method corresponds only to the measuring instrument of the analog display, it is impossible to use it for measuring instruments with the digital displays widely used at present. As a method that is possible to use for measuring instruments with a digital display, a system that reads the instruction value at a high speed was researched by specializing in reading the instruction value of the measuring instrument in seven display segments [3]. This is a system that recognizes the position of seven-segments from the image that is taken by a camera, and distinguishes any lighting the segment according to the brightness at the position. The figure is distinguished by this pattern. However,

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the displays of measuring instruments have various kinds, like 14, 16 segments, and the dot matrix, etc. Therefore, this system is insufficient, because it supports only a seven-segment display. Although, the method of using a pattern match was also devised, there is a limit in the reading accuracy because there is a limit in the number of template images. Therefore, it is thought that the system is not able to read the figure sometimes when it has been distorted.

This paper proposes a strong numerical recognition system with a camera that can also be used for digital displays other than seven-segment displays, and can recognize distorted figures. To approach the figure in the image that is taken at the start of the system, this system corrects the template image. Thereafter, the instruction value is read by comparing the corrected image and the figure in the image.

## **2. Outline of System**

This system consists of "Initial Setting Part " and "Numerical Recognition Part". In "Initial Setting Part", a kind of the display of measuring instrument is selected in the image. To approach the selected image, the prepared template image is converted. In "Numerical Recognition Part", the converted template image is compared with selected image. Then the figure is judged and the correct measured value is obtained.

## **3. Initial Setting Part**

The flow of initial setting part is shown in Fig.1. In the following sections, this procedure is described.

### **3.1. Figure Extraction**

In this section, only figures are extracted from the acquired image. The range of the display and the brightness of the figures are specified from the image, which are fit to a gray scale as a preprocessing. A pixel near the brightness within the range is made a black, and other pixels are made white. The only figures extracted are by making binary images.

### **3.2. Extraction of Only One Figure**

In this section, only one figure is extracted from the image. First of all, by the expansion and the shrinkage processing, the noise is removed and the cut point is supplemented. Outline pursuit processing is performed on this image, and the outline of the first figure is extracted. At this time, the line width of this image adjusts to one pixel by line thinning processing. The pixel of this image located internally in the extracted outline is maintained, and other pixels are made white. As a result, one figure can be extracted. At this time, the circumscription rectangle of the extracted figure is drawn, and the four apexes of the rectangle are preserved as the apexes of the figure.

### **3.3. Map Graphics Transformation**

The error margin map is an image in which the brightness of pixels on the observation figure is 0, and a brightness decrease with increasing distance from the observation figure. Fig.2 shows an example of an error margin map.

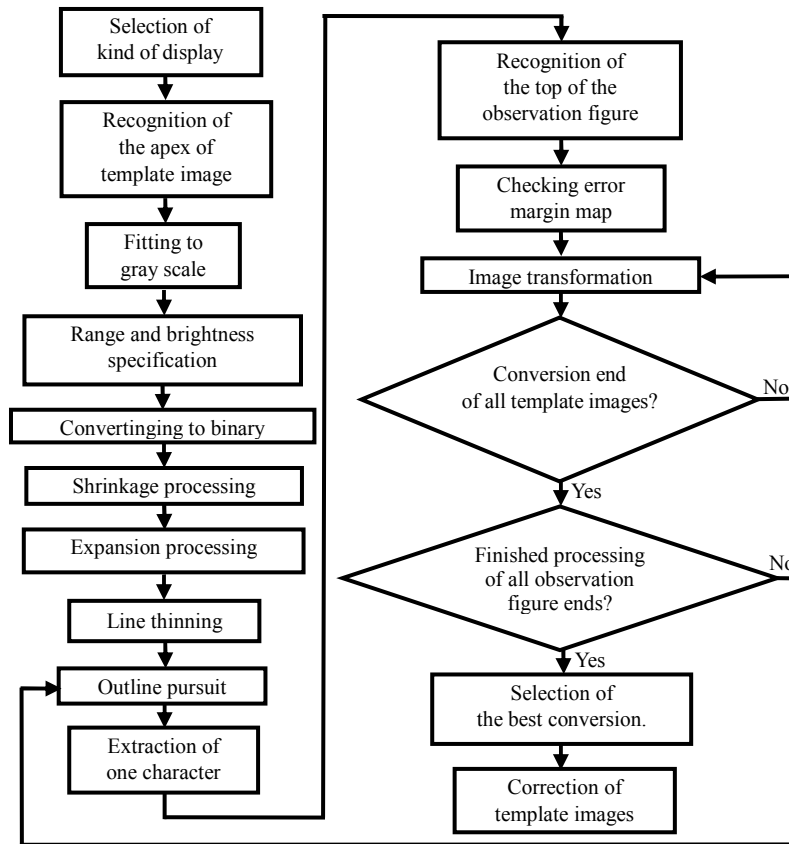


Fig.1 Flow of initial setting part

### 3.4. Graphics Transformation

There is a limit in the reading accuracy because there is a limit in the number of template images. However, this system corresponds to this by converting the template images. To convert the template images, it uses the conversion of projection, the Polytope method and the error margin map. The Polytope method is a kind of the minimization algorithm of the multidimensional function [4-6]. As the Polytope method does not require the derivative, the concept can be applied to a non-optimized search function. In this paper, the projection conversion can be described as follows:

$$X = \frac{a_1x + b_1y + c_1}{a_0x + b_0y + 1} \tag{1}$$

$$Y = \frac{a_2x + b_2y + c_2}{a_0x + b_0y + 1} \tag{2}$$

where,  $x$  and  $y$  are coordinate before the conversion.  $X$  and  $Y$  are coordinate after the conversion.

Thus, the eight constants ( $a_0, b_0, a_1, b_1, c_1, a_2, b_2, c_2$ ) used for the projection conversion are each assumed to be a search parameter, and an evaluation function  $E$  is made. Also, to minimize this evaluation function of  $E$ , the parameter searches by the Polytope method. In this paper, the evaluation function  $E$  is defined as follows:



Fig.2 Error margin map

$$E' = \sum Map(p_{xj}, p_{yj}) \quad (3)$$

$$E = \frac{E'}{dot\_num} \quad (4)$$

where,  $Map(p_{xj}, p_{yj})$  of the expression (3) shows the brightness of the pixels in coordinates  $(p_{xj}, p_{yj})$  of the error margin map.  $i$  is a pixel count of the observation figure. When the observation figure and the drawn figure are completely corresponding,  $E'$  becomes 0.  $dot\_num$  of the expression (4) shows the pixel count of the drawing figure. The method of the automatic compensation of the template image is shown below:

**Step1.** The vertexes of the first observation figure are assumed to be the initial values, and coordinates of four points that do the projection conversion are assumed to be the search parameters.

**Step2.** The evaluation value  $E$  is calculated from the template image where the projection conversion is done based on the four points and the error margin map. Also, to minimize  $E$ , the four points are searched by the Polytope method.

**Step3.** When the evaluation function  $E$  is minimized, the value of the evaluation values of  $E$ ,  $a_0$ ,  $b_0$ ,  $a_1$ ,  $b_1$ ,  $c_1$ ,  $a_2$ ,  $b_2$ , and  $c_2$  are preserved.

**Step4.** Step2 and Step 3 are operated to all the template images. Each evaluation value of  $E$  is compared, and it is judged what the figure is.

**Step5.** Step1-4 are operated on all figures that are displayed in the measuring instrument.

**Step6.** At the time of processing ends in all figures, each digit has the projection conversion parameter that is preserved when the evaluation value is minimized. The template image is converted according to these parameters.

**Step7.** The result of the projection conversion is evaluated by the error margin map. Also, it judges the parameter of which digit is the best. As a result, the template image is converted based on the parameter of the digit to which the evaluation value is minimized. This is preserved as a new template image. Additionally, the apexes of each template image is searched and preserved.

Fig.4-6 shows the result of converting the template image by this method. Fig.5 is the image that extracted only the figure from the observation image like Fig.4. Fig.6(a) is the result of correcting the template image like Fig .6(b).

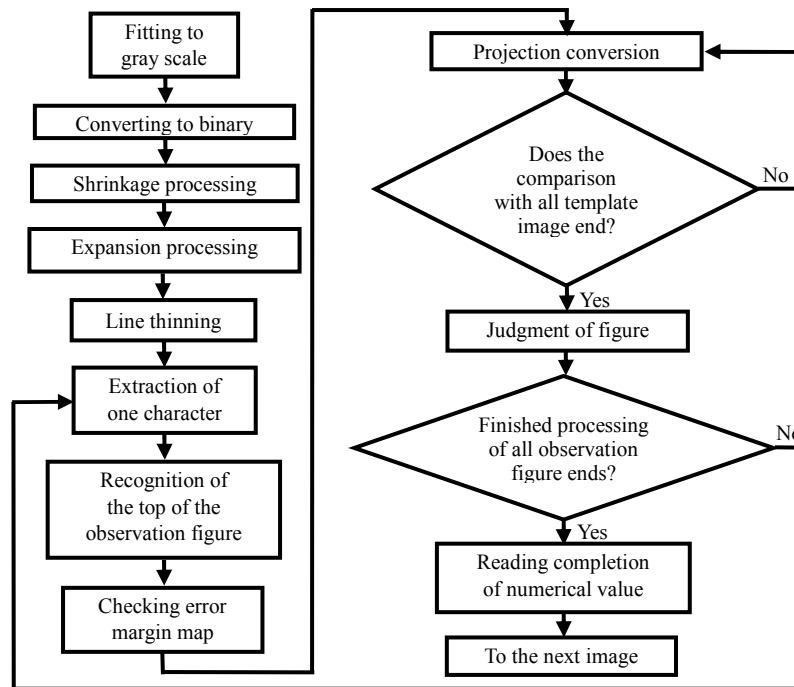


Fig.3 Flow of numerical recognition part

#### 4. Numerical recognition Part

The flow of numerical recognition part is shown in Fig.3. In the following sections, this procedure is described.

The numerical value of a measuring instrument is recognized by using the template image that was corrected in Chapter 3. The procedure is shown below:

**Step1.** Only the figures are extracted from the acquired image.

**Step2.** Four apexes of the observation figure are searched.

**Step3.** The error margin map is made from the figure extraction image.

**Step4.** The template image is projecting converted based on the coordinates of the apexes of each template image and the observation figure.

**Step5.** Evaluation value of  $E$  is calculated. Also, the evaluation values of each figure are compared, and the figure is judged.

**Step6.** Step4 and 5 are done on all figures, and the numerical values are judged as a whole.

Procedures Step1-4 are done the same processing as the initial setting part. However, the specification of the range in the digit portion and the specification of brightness need not be done again. In procedures Step5 and 6, high-speed processing can be achieved because it doesn't search by the Polytope method like the initial setting part.



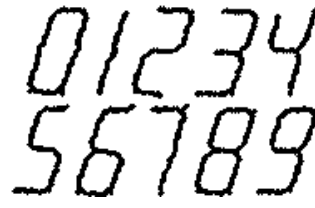
Fig.4 Observed image



Fig.5 Extraction image of figures



(a) Before



(b) After

Fig.6 Conversion of template image

## 5. Experiments

As an experiment, the probability that the instruction value of a measuring instrument was able to be read was measured. Also, a recognition experiment of distorted figures and digital meter made on a PC was done.

### 5.1. Digital Meter with Seven-segment Displays

The recognition rate in measuring instruments with seven-segment displays was measured. The experimental conditions are angles of three patterns as follows: (1) 0, 15 and 30[deg] on the  $x$ - $y$  coordinate plane, (2) 0, 15, 30, and 45 [deg] on the  $z$ - $x$  coordinate plane, 0, 7, and 15[deg] of inclinations of the camera as shown in Fig.7. It was judged that the numerical values were able to be recognized when all displayed figures were able to be recognized correctly. These experiments were repeated 10 times. As a result of the experiment, the recognition rate became 30% – 100% as shown in Table 1.

### 5.2. Recognition Rate of Distorted Figures and Digital Meter Made on a PC

The recognition rate of two kind of measuring instruments (The font of the figure is MS P Gothic) made on a PC like in Fig.9 was measured. Inclinations of the camera had three patterns (0, 7, and 15[deg]). The other experimental conditions are was the same as in section 5.1. As a result of the experiments, Examples of recognition results show Fig.8. The recognition rate became 100% in case of 0[deg], 95.2% in case of 7[deg], and 92.9% in case of 15[deg]. Examples of recognition results show Fig.8.

### 5.3. Consideration of the Outcome of an Experiment

However, the recognition rate was decreased when the camera was inclined, especially for a measuring instrument with a seven-segment display. Due to this reason, it is thought that it is because there was a difference between converted image and observation image. It is thought that this is ameliorable by widening the range of the search by the Polytope method, and by converting the template image into other

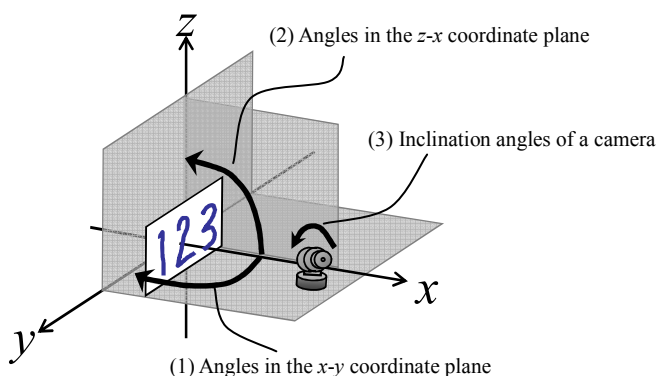


Fig.7 Experimental conditions for digital meter with seven-segment displays

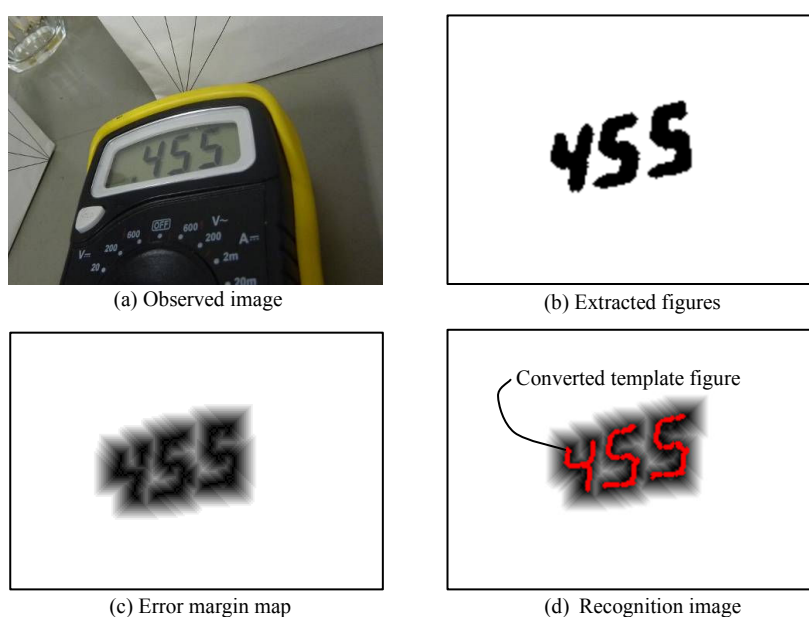


Fig.8 Examples of recognition results

images. It is thought that the recognition rate lowered in measuring instruments with seven-segment displays because figures other than the observation figure approached the observation figure. For instance, 3, 6, and 9 of the template images overlap the observation image when the observation image is eight. It is thought that this can be solved by the method of evaluating the part where the line doesn't exist in the template image though there is a line in the observation figure.

## 6. Conclusions

This paper proposed a numerical recognition system that reads the instruction value of a measuring instrument by taking a picture of the measuring instrument with a camera, extracting the figure from the image, correcting the template image to approach the figure of the observation image, and comparing the corrected template image with the observation figure. This time, the recognition rate became 30% – 100% as a result of experimenting with two kinds of measuring instruments in various inclination patterns of the camera. As a result, a numerical recognition system that did not depend on the model of the measuring



Table 1 Recognition rate of the experimental result using digital meter with seven-segment displays (%)

		z-x [deg]			
		0	15	30	45
x-y [deg]	0	100	100	100	90
	15	100	100	100	90
	30	100	80	80	80

		z-x [deg]			
		0	15	30	45
x-y [deg]	0	100	80	90	80
	15	100	80	80	60
	30	90	60	70	60

		z-x [deg]			
		0	15	30	45
x-y [deg]	0	70	60	30	40
	15	70	20	40	30
	30	50	50	50	40

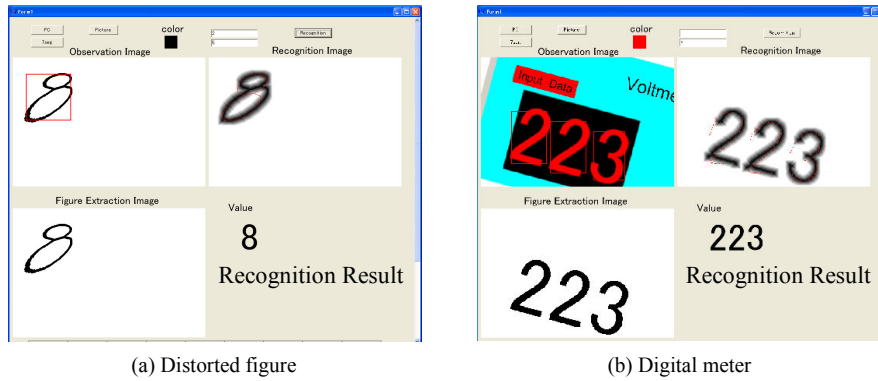


Fig.9 Examples of recognition results using distorted figures and digital meter made on a PC

instrument and corresponded to the distortion of the figure able to be constructed when the inclination of the camera is small.

Future tasks to improve the recognition rate include improvement of the algorithm, recognizing decimal points and simplification of the initial setting.

### Acknowledgement

This research was partly supported by Grant-in-Aid for Scientific Research(C), 19500478.

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