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Self-adaptive Location Method of Meter Reading Region

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Abstract

We propose a new self-adaptive reading region location method on the basis of 8-neighborhood connectivity segmentation algorithm. Through the combination of a modified Stroke Width Transform (SWT) algorithm, morphology and gray ratio technology, we achieve a higher recognition rate (as high as 98%) and a lower error rate (as low as 1.42%) compared with other methods under the same experiment condition, Our work can be useful to the information transformation of existing mechanical meters due to its high recognition efficiency and economy.

Keywords: *Self-adaptive; Location of reading region; Stroke Width Transform; Reintegration of connected domain*

I. INTRODUCTION

Though having many disadvantages, mechanical meters still account for a large percent in various application scenes at present. The greatest disadvantage of mechanical meters is the low efficiency and high cost in the meter reading which is done manually. To make up this disadvantage, technically renovating these mechanical meters is more approvable than thoroughly replacing them with the digital electronic alternatives considering the needed huge cost. On the other hand, machine vision technology is deemed to be competent to substitute human eye to distill the useful information from images of the scenes, for example, the face of mechanical meter, and thus provides as an appropriate tool to solve this problem. However, there still exist some limitations in this technology, for example, the complex background of meter cases and the different patterns of the reading region of these meters both adding some challenges for it to properly distinguish the right information from the target.

At present, the common location methods of the reading region include the projection method [1, 2], regional edge location method [3, 4], and connected domain segmentation method [5, 6], etc. Where, the projection method is to overlie the gray scales of pixel of the image in the horizontal and vertical directions and set a threshold to separate the reading region, but requiring that the reading region should have obvious difference with the other background region and should be defined by utilizing the prior knowledge that violate the concept of self-adaptive location to that extent. The regional edge location method utilizes the features of edge of the reading region to locate. For example, the reference [3] utilized the method to improve the corner point of curvature space to detect the vertex of edge to locate the reading region; and the reference [4] utilized the high contrast ratio between the key region color and background color for the separation. However, the regional edge location method performs not good if the edge of the reading region is not obvious or the color difference between the key region color and background color is not large enough. However, the connected domain segmentation method is different from the former two methods. It gathers similar features of the reading region to form an alternative region and filters out irrelevant region by the restriction of a series of filtering rules, charactering with stronger robustness and quicker calculation speed. Basing on this method, the reference [5] combined the regional growing algorithm and threshold segmentation to realize object localization; though easy to implement, it requires that the gray scale of the number region is even and the gray scales of the number region and the adjacent region have a great difference. Instead, the reference [6] located the objects from images through searching the extreme value of picture histograms of three RGB channels, but not available for case of the binary images.

Therefore, in this work, we propose a new method for the localization of the object region which bases on the connected domain segmentation method. We form the connected domains by the 8-neighborhood growing algorithm and reintegrate them through a projection method. Then, we roughly judge these reintegrated connected domains by utilizing an improved Stroke Width Transform (SWT) method, and finally specify the accurate location of the objects in the light of the features of morphology and gray scale ratio of these object domains.

We organize the structure of our material as following: the image preprocessing is first given in part 2; the construction of connected regions of the image is presented in part 3; the segmentation and recognition of the effective information of the image is then displayed in part 4; the experiment results and discussion of this method is posed in part 5 and a conclusion is given in part 6.

II. IMAGE PREPROCESSING OF METERS

A. GAUSSIAN BLUR AND GRAY SCALE PROCESSING

Firstly, to avoid the interference from other factors, the Gaussian Blur processing will be done for this to-be-processed meter image. Then, this image will be transformed to a binary image by the gray-scale transformation.

The Gaussian Blur processing[7] is mainly used to remove the image noise. As a kind of two-dimensional convolution blur operation, it possesses the similar effect of a low pass filter that removes some details in the image to remove the interference of detailed numbers but keeps the invariance of the whole image. Fig.1b shows the image after the operation of the Gaussian Blur.

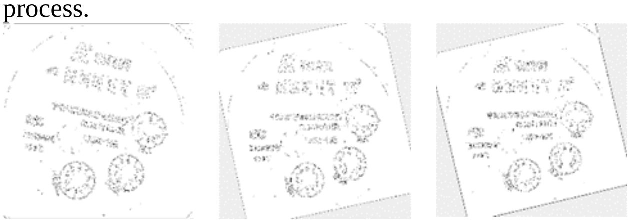
The gray-scale transformation is just to grayscale the object images. After this operation, the image after the operation of Gaussian Blur is displayed in Fig.1c.

(a) Original image of meter (b) Gaussian Blur image (c) Gray-scale processing image

Fig.1 Preprocessing Image of Meter (I)

B. EDGE EXTRACTION AND COMPENSATION PROCESSING

After the operation of Gaussian blurring and gray-scale, the edge details of image need also be processed. Here Sobel operator is chosen for the derivation since the meter board contains a large amount of image edges, such as, the frame of reading region and the pointer of meter and so on. Hough transform is adopted to check the slant angle of the edge of image, in terms of which the image will be calibrated [8]. And closed operation is used to make up for the edge absence in the edge extraction process.



(a) Edge extraction (b) Slant correction (c) Closed operation

Fig.2 Preprocessing Image of Meter (II)

III. CONSTRUCTION OF CONNECTED DOMAIN OF IMAGE

After the edge extraction, the information in the meter board should be classified and sorted. On the basis of the 8-neighborhood connectivity method, we improve the conventional connected-domain method to reintegrate the connected domains. The basic principle of the conventional 8-neighborhood connectivity method is shown in the Fig.3. Suppose that the black point in the Fig is the starting point with 8 neighborhoods circling around (8 grey points in the Fig). So if the gray scales in the grey points and are same with that in the black point, one connected domain is to be constructed. Then restarting from the grey point and repeating the same procedure until there is no any domain having neighbors that can be connected, one complete connected domain will be constructed.

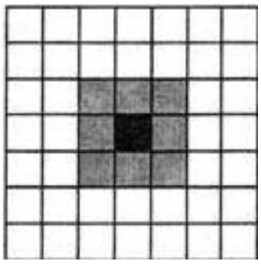


Fig.3 8-neighborhood Connectivity Method

Suppose that there are m*n pixels in the meter image. Let f (x, y) represent the pixel value of the x line and y column in the image array; f (0,0) represents the pixel value in the most top-left corner; and f (m-1, n-1) represents the pixel value in the most lower-right corner. All points in the image will be traversed and regrouped into different connected domains marked with R_1 to R_n through the 8-neighborhood connectivity method.

With respect to the reading region of meter, due to the gaps between the number and number, between number and frame, the complete reading region of meter image can't be obtained only by using the 8-neighborhood segmentation. Thus, the technology of reintegration, and resegmentation is needed for the complete separation of the reading region.

A. REINTEGRATION OF CONNECTED DOMAINS

First, read the coordinate values of pixels in the Rn of all connected domains, select the minimum value y_{min} and the maximal value y_{max} of pixels in the y-axis direction to constitute the array An [y_{min}, y_{min+1}, ……, y_{max}]. Synchronously, calculate the length of array $\Delta y_n = y_{max} - y_{min}$. Then, compare the array A_n of R_n in all connected domains and check

Condition 1: if the length of the intersection set of any two individual connected domains occupies more than 90% of the length of the shorter one of them.

Condition 2: if the array length Δy_n of the shorter one is larger than 50% of the longer one.

The two conditions are examined sequentially. If they are both satisfied, the corresponding two connected domains can be regarded as one connected domain that and will be combined together. As shown in Fig.4, the intersection set of array Δy_2 and Δy_3 occupies 100% of Δy_3, and the Δy_3 occupies more than 50% of Δy_2, so the above conditions are satisfied and the two domain can be successfully combined. However, for the two domains on the left edge of the meter frame, though the Condition 1 is satisfied, the Condition 2 is not, so they can't be combined together. Through the above comparing procedures, the connected domains sharing same feature, for example, orienting to the horizontal direction, will be combined together and reintegrated as a new domain. Note that certain range of error ratio is set to avoid the extra interference caused by the frame adhesion.

Fig.4 Combinations of Connected Domains

B. RESEGMENTATION OF CONNECTED DOMAINS

In order to avoid the error recognition that the unit information around the reading region and other marks are combined with the connected domain which is inside the reading region in the reintegration process, the connected domains after reintegration should be resegmented. The specific method is shown in Fig.5. Firstly, scan the connected regions from the central position and calculate the gap threshold *d* at the point whose pixel value is 0. Then continuously read the value of the n neighboring points dn (if n is less than 10, this process has no sense and the scan will be terminated); and then calculate the mean value d of them. The border of reading region appears when the dn of a pixel exceeds d more than 80%, then stop scanning and segment the connected domain. This resegmentation can filter the non-reading region contained in the connected domain such as the unit information: m^3 shown in the Fig.6.

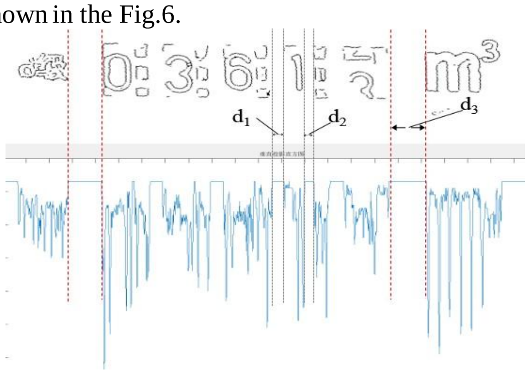


Fig.5 Resegmentation of Connected Domains

IV. RECOGNITION OF METER READING REGION

After completing the reintegration and resegmentation of connected domains, the respective connected domains in the meter image are formed, including the reading regions we need and also the irrelevant connected domains such as the pointer meter area, the company information area, the number area and other special images. The useful information in these connected domains is to be distilled with a modified Stroke Width Transform (SWT) method.

A. MODIFIED STROKE WIDTH TRANSFORM RECOGNITION

The Stroke Width Transform (SWT) is available for detecting the character in natural scenes proposed by Boris Epshtein, et al. [9]. Its principle is to utilize the feature that the character and the number are basically same in the stroke width so that the possible character and number regions can be identified through the stroke width information of the pixel. However, this method is difficult to match the repeated point pairs well because it first searches for the edge point pairs and assigns the width which gets rid of overlapped edge point pairs in accordance with the value of width assignment. So, we improve this SWT method so that the result of the recognition is more accurate. The calculation process is shown as follows.

1.SEARCH AND ASSIGNMENT OF EDGE POINT PAIRS.

Each edge pixel p has a direction gradient threshold dp. If p is located at the edge of the stroke, dp is perpendicular to the direction of stroke. Seek the other one corresponding edge pixel q along the gradient of ray (n >= 0), such that dp and dq are roughly in the opposite direction (dp = dq ± π/6). We set an angle limit ±π/6 to tackle the problem of stroke bending. If the point p exceeds the range of ± π / 6, it will be abandoned; if the point q meeting the requirements is found to constitute edge point pairs, each pixel points in the [p, q] route will be endued to the stroke width value w = ‖ p - q ‖ (Euclidean distance) [10].

However, as shown in Fig.6, one r direction of [p, q] has multiple intersection points. In this case, the judgment condition should be added: compare the width values w_1 and w_2 of the edge point pairs formed by point p with the q_1 point and the q_2 point, select the smaller width value w_1 and its corresponding edge point $p\text{-}q_1$ so as to filter the interference of other strokes.

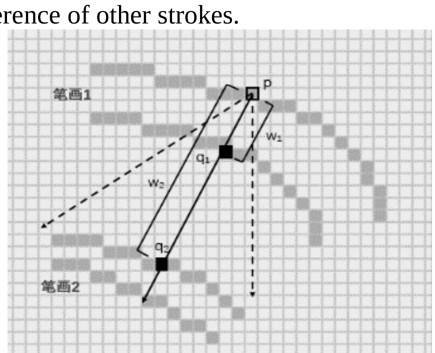


Fig.6 Construction of Edge Point Pairs

2. Selection of Repeated Items of Edge Point Pairs

Since the stroke edge forms a closed loop, it means that a certain point in the rear of one stroke recognizes as the q constitutes an edge point pair with a corresponding p points before, but later as a p which will pair with another different q point that make the situation more complex especially in the bending region of the stroke. As shown in Fig.7, p_1 point and p_2 point correspond to the same q' point. According to the original SWT algorithm, the edge point pair p_2-q' will be abandoned due to the larger value of its width value comparing with that of the edge point pair p_1-q'. However, the edge point pair p2-q' in the same bending position is more in accordant with the edge-width logic rather than the edge pair p1-q'. So, to improve the above mentioned problem, we instead compare the angle difference between dp and dq of the two edge point pairs and choose the one with smaller angle difference. As shown in Fig.7, the angle difference of dp and dp_2 is very smaller than that between the dp and dp_1, accordingly p2-q' will be chosen as the right edge point pair and w_2 as the width value.

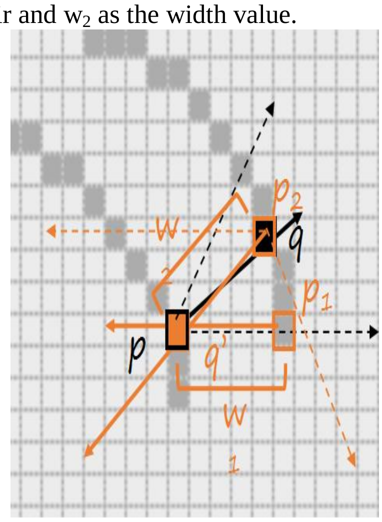


Fig.7 Selection of Repeated Items of Edge Point Pairs

3. Recognition of Character and Number Regions

Our modified SWT method can better calculate the mean value of stroke widths in every connected region, whereby, the overlength regions, such as the meter frame, can be filtered. Then, by filtering out the peak value of the stroke width in the existing regions, we can filter the irregular width of image of other interference and thus identify the number and character regions in the meter image. As shown in Fig.8, the regions filtered by the modified SWT method only holds the character and number which are with similar stroke width.

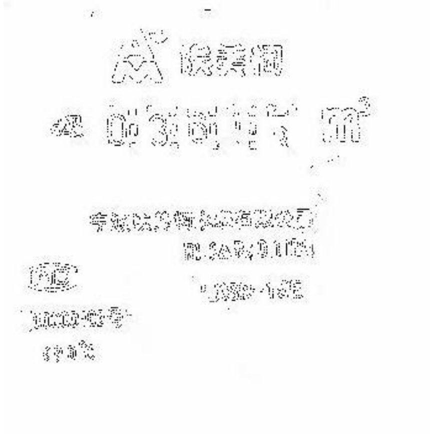


Fig.8 Image after SWT Filtering

B. Recognition of Number Region

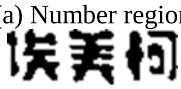
Suppose that f(x, y) represents the pixel value of the x line and the y column in the image array in the existing number and character connected domains, first, find the pixel set of f(x, y)=1 in the current connected domains, cut out the region determined by the coordinates of the pixels whose values are minimum or maximal t, namely, (x_{min}, y_{min}), (x_{max}, y_{min}), (x_{min}, y_{max}) and (x_{max}, y_{max}).

Next, set the threshold of length-width ratio as (3:1 - 5:1) to filter out the irrelevant regions, such as the small letter region and edge region, as shown in Fig.9. And the region incongruent to the morphology condition in the frame is also filtered out.

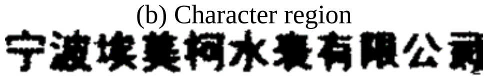
Fig.9 Morphology Recognition

Finally, according to the prior knowledge, that is the character stroke represented by Chinese characters is more than the stroke of number and the density of black pixels of Chinese characters in the unit area is much greater than that of the black pixels of numbers, we can restore the alternative regions to the grayscale black-and-white processing image and detect the gray-scale value pixel by pixel in the region, and calculate the ratio of the pixels of gray-scale value of 255 in the total pixels. In our experiments, we set the region whose gray-scale ratio is less than 1/3 as the number region.

(a) Number region



(b) Character region



(c) Character region

Fig.10 Recognition of Character and Number Regions

The final experiment results are as shown in Fig.10 (a).

V. RESULT AND DISCUSSION OF EXPERIMENT

A. System Implementation Process

The image of the mechanical meters, including the water meter, conventional electricity meter, etc., are captured with a cellphone camera whose resolution is 1600*1200. These acquired images are processed under the MATLAB R2015b circumstance. The flow of process is displayed in Fig.11 which largely can be divided into the stages of preprocessing, construction of connected domains and recognition of meter reading region.

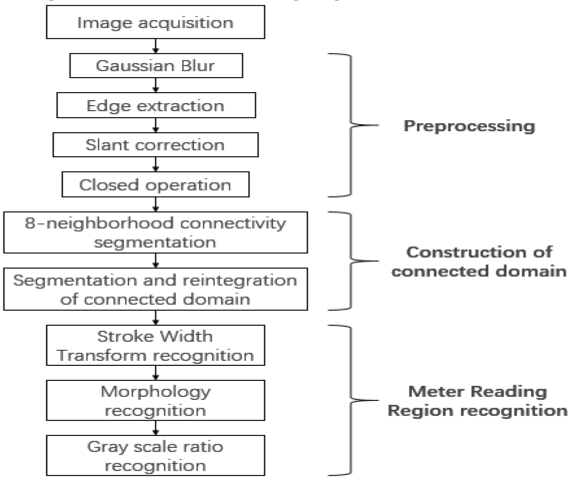


Fig.11 Algorithm Flow Chart

B. Analysis of Experiment Result

To verify the recognition rate of this method, we tested it by using various types of meters, including water meter, electricity meter, gas meter, etc. The total number of samples is 67. We compared our method with other methods, for instance, the projection method stated [1], regional edge location method [3] and the traditional connected domain method [5]. The results are stated in in the Table 1.

	Identifying Quantity	Recognition Rate	Indentifying Error Quantity	Error Rate
This Method	66	98.5%	1	1.49%
Projection method	61	91.0%	6	8.96%
Regional Edge Location Method	62	92.5%	5	7.46%
Traditional Connected Domain Method	64	95.5%	3	4.48%

Table.1 Test Results of Various Methods

From Table.1, we can see that the recognition rate of our method is higher than that of other three methods. And the aspect of error recognition is also lower compared with other methods. We find that the error occurs in projection method is mainly due to the difficulty to locate when the pixel distribution of the meter images is too irregular; the error present in regional edge location method is mainly from the disconnect of the frames of reading region; and the errors appear in traditional connected domain method comes from misreading the error regions of meter reading region. We also find that our method is deficient in processing the region with large area of stain. In other words, if without considering the condition that a large area of stain is present; our method has better performances compared with other methods.

VI. CONCLUSION

In this work, on the basis of the 8-neighborhood connected domain segmentation method, we identified the effective information from the informative region of target images by a method that combines a modified SWT algorithm, the morphology and gray ratio technology. We utilized it for the recognition of the effective information in the images of mechanical meter boards and achieved a higher recognition rate (as high as 98%) and a lower error rate (as low as 1.42%) compared with other methods. Our method for image segmentation and recognition can apply in the information transformation of existing mechanical meters due to its high recognition efficiency and economy.

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REFERENCE

[1] He Xun. Research on Recognition Methods of Water Meter Number Reading [D]. Nanjing University of Science and Technology, 2007

[2] Gao Ju and Ye Hua. An effective two-times recognition algorithm of meter digital image [J]. Journal of Southeast University (Natural Science Edition), 2013,43 (S1): 153-157.

[3] Yuan Weiqi and Jiang Haiyan. Recognition Algorithm for Display Value of LCD Meter Based on the ACSS Corner Localization [J]. Computer Application System, 2015,24 (7): 111-116.

[4] Y. Zhong, K. Karu and A. K. Jain. Locating text in complex color images[C]. In ICDAR, 1995.

[5] Tang Yijun, Shen Xiaoyang, et al. Recognition System for Character of Numeral Instrument Dynamic Displayed Based on BP Neural Network [J]. Optical Instruments, 2005, 27 (6): 62-66.

[6] Zhang Dongping, Zhu Jinbiao and Liu Jilin. Automatic text location in color images [J]. Journal of Zhejiang University, 2005,39(2):229-233.

[7] Zhou Kailong. Application and Research of Image Recognition Based on Deep Learning [J]. Beijing University of Technology, 2016

[8] LIN Jianping and Liao Yipeng. Automatic Recognition of Digital Meter Readings Based on Open CV and LSSVM [J]. 2017,36 (2): 37-40.

[9] Epshtein B, Ofek E, Wexler Y. Detecting text in natural scenes with stroke width transform[C]. Proceedings of 2010 IEEE Conference on the Computer Vision and Pattern recognition (CVPR), 2010:2963– 2970.

[10] Zhu Bin and Xue Luqiang, et al. Research on an Modified Digital Image Location Method [J]. Computer Technology and Development, 2007 [8]