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Research Article

Online Detection Approach for Rectangle Ceramic Tile Based on Sequenced Scenery Image

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Abstract: Image based ceramic tile detection is a way to labor liberation in the production process of ceramic tile. Shapes of ceramic tiles studied in this study are rectangle with different sizes. Many existed researches are based on a situation that only a piece of tile goes through special rail one time, resulting in one or less piece of tile hold in the image from CCD sensor. But in fact, multiple tiles with the same sizes run in a row simultaneously at most factories' rails, and a 'scenery' image is obtained from CCD sensor. And the image processing method based on close-up images is not satisfied in such cases. To detect different rectangle ceramic tiles online according to a sequence of scenery images, this study provide a vector corner method to decide the rectangle tiles with known size information, and a valley detection method via key-image-frames strategy to distinguish the first row in images. Finally, our Online Approach for Rectangle Tile Detection (OARTD) was embedded into a detection system and applied to a factory; testing results validated its good performance. Indeed, the use of such an automatic system, to control a tile plant for shape classifying has a good prospect.

Keywords: Online detection, rectangle ceramic tile, valley detection, vector corner

INTRODUCTION

In the ceramic tile productive process, most Chinese factories have been mechanized. But picking up different ceramic tiles is often conducted by labor, such as recognizing different colors, veins, sizes and so on. Because of the huge number of daily production, workers are hard to recognize the exact tiles all the time, and always make mistakes. Furthermore, the working environment with dense dust for long time is harmful to workers' health. One of the solutions is to hire more workers who just need to work a few times, but it increases the cost of the enterprise. For this reason, many scholars try to solve this problem by using computer visual technology. (Meysam *et al*., 2009) Although there are many articles about the tile detection (You *et al*., 2009, 2012), most of their researches are based on close-up images (Hocenski *et al*., 2009) in which only a piece of tile went through special rail one time, resulting in one or less piece of tile hold in the image from CCD sensor. But in fact, multiple same size tiles run in a row simultaneously at most factories' rail and a scenery image is obtained from CCD sensor. Obviously, there are more noises and uncertainties concerning the position (Farzaneh and Hossein, 2011) of each tile in the images. Therefore, the close-up image processing methods doesn't work. (Hocenski *et al*., 2007) In this situation, we focus on how to detect each rectangle (Zheng *et al*., 1999) of a ceramic tile in the scenery image. Furthermore, we also try to detect the tiles in first row constantly aiming to solve the online detection problem with a sequence of scenery images.

An online approach for rectangle tile detection (OARTD) is developed in this study. There are five significances considered in our method based on scenery images:

- The first is tile pixel judgment, and Ostu method is applied to get binary image.
- The second is margin detection, and Canny operators is adopted to identify all the probable margins
- The third is straight lines detection, and Hough Transform is used to detect all the probable straight lines
- The fourth is determining the rectangle of each piece of tile, here a vector corner method is proposed
- The last one is distinguishing the first row of the tiles' sequence, and a valley detection strategy is proposed to analysis the changing of the gray value in an area based on image sequences.

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Fig. 1: A scenery image

Fig. 2: Our online detection system

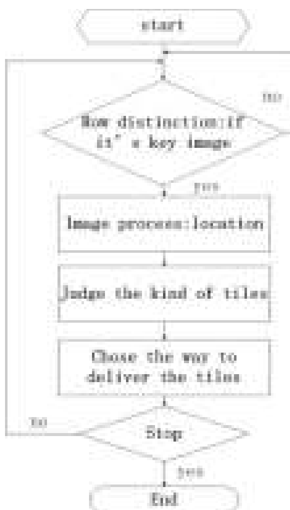

Fig. 3: Program flow diagram of OARTD

As for margin detection in one image, many operators like Roberts, Sobel, Laplace, Canny (1986) are often used. Canny (1986) perfected the basic marginal operator, and proposed the Canny operator Compared with other similar methods, canny operator balanced both two contradictory aspects of the location and noise suppression, resulting in a good effect of visual perception. Considering the advantages above, it's been widely adopted in many literatures and was utilized in our method.

Based on the image processed by canny operator, Hough Transform is introduced to detect straight lines which contain the margin information of tiles. Thus the following question is that which straight lines are belong to the margin of tiles, and which lines are belong to the same tile. There are some methods of rectangle detection based on Hough Transform (Li and Liu, 2007), but not suit for our noisy scenery images. Hereupon, the vector corner method based on known length information is proposed to determine the individual rectangle. By the way, a valley detection method is proposed to distinguish first rows of the sequence of scenery images, according to the gray scale changing degree of a small rectangle section in the front of images. The purpose of distinguishing first rows is to tell the IPC (Industrial personal computer) when to process the image and send control signal.

To test our method in factory, an online detection system is built. Although testing environment is harsh, such as dark light, dense dust, few broken tiles, it shows a good result (Fig. 1).

INSTRUMENTS STRUCTURE

Our online detection system mainly consists of two parts. One is made up of a CCD senor and an Industrial Computer (IPC) which is used to collect image information and to process data. The latter comprises the relative hardware including the PLC controller and the communication microcontroller board. Our online detection system placed in the factory site is shown in Fig. 2. In this study, we don't talk about the more details about hardware, but focus on the developed algorithm OARTD. Its program flow diagram shows in Fig. 3.

Detection algorithm: In this section, an Online Approach for Rectangle Tile Detection (OARTD) is illustrated in detail. It roughly contains two parts, including: the location processing which is to determine the exact position of tiles based on single image; and the first row distinguishing in image sequence.

Location in single Image: At first, Canny and Hough Transforming are taken to process the single image. Canny and Hough Transforming are well-known methods which here omit to illustrate for the limitation of paper length. Thus all the straight line will be found with appropriate Canny and Hough thresholds. Then corner feature which is the line intersection becomes legible. As we all know, rectangle has four corners and two couples of margin. Now both the margin and corner information are known. If the exact corners and margins of tiles are known, the exact position of each rectangle tile would be gotten. Hence a vector corner method is proposed.

To realize the above idea, all Hough straight lines are collected as a set $L = \{(ps_i, pe_i), i = 1, 2, 3, \ldots, n\}$, where ps and pe represent the start and the end points of a straight line segment, respectively. How to pick up the corner of rectangle is the question we will discuss next.

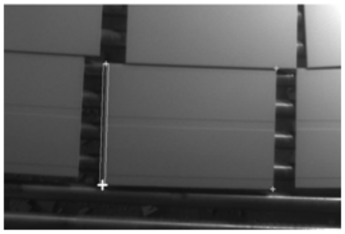

Fig. 4: The margin prediction

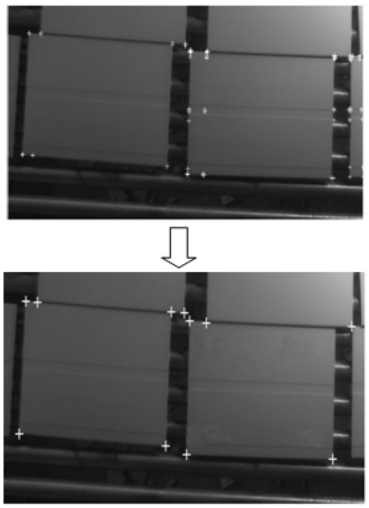

Fig. 5: The location result

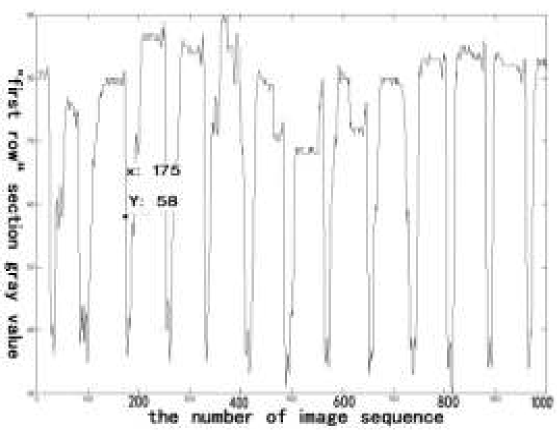

Fig. 6: Gray value changing vs; the sequence number in the valley detection

At first, Otsu method is used to get a binary image and determine which pixel is the tile point. Then assuming straight line segments l_1 and l_2 intersect at the point c, and p_{m1} and p_{m2} are the middle point of l_1 and l_2, respectively. So l_1 and l_2 can be written by the vectors $\overrightarrow{cp}_{m1}$ and $\overrightarrow{cp}_{m2}$. Normalizing the vectors to get $\vec{\alpha}_1$ and $\vec{\alpha}_2$. Thus each elements of set I can be represent as I = $\{(c_i,\ \vec{\alpha}_{1i}, \vec{\alpha}_{2i}), i\ 1, 2, \ldots, C_n^2\}$. Corners of tiles can be determined, if they are subject to the following conditions.

$$\left|COS < \overrightarrow{\alpha_{1i}}, \overrightarrow{\alpha_{2i}} >\right| > \delta, \delta > 0 \tag{1}$$

where δ is the threshold to judge the right angle:

$$\left\|\overrightarrow{p_{m1i}\, p_{m2i}}\right\| > T_1 \tag{2}$$

where, T_1 is a threshold to assure that the corner is the tile corner:

$$\left\|\Delta_{c_i p_{m1i} p_{m2i}}\right\| > T_2 \tag{3}$$

where, T_2 is a threshold and Δ denotes a section of triangle. It's to assure that the corner is in single tile.

||*|| Denotes the tile pixel number of * section.

Finally, close corners should be combined to improve the accuracy.

After getting the corner of tiles, the next step is how to recognize each tile. Assuming the known tile length and width are w_b and h_b, the position of tile would be predicted by using the tile corner set:

$$IC = \{x_i = (c_i, \overrightarrow{\alpha_{1i}}, \overrightarrow{\alpha_{2i}}), x_i \text{ is tile corner}\} \tag{4}$$

and get the forecasted rectangle set:

$$R = \{(c_i, c_{1i}, c_{2i}, c_{3i}), i = 1, \ldots\} \tag{5}$$

Furthermore a threshold T_3 to determine whether predict margins are real margins. The detail can depict as that if the tile pixel number is larger than T_3 in the small rectangle which surround the forecasted margin shows in Fig. 4, the margin is real. The above method called vector corner method. The application result shows in Fig. 5. Through the above method, it's possible to assure each rectangle tile.

First row distinction: Our task is to recognize the first row in the image sequence. Valley detection method is proposed here to pick up the key-image-frames in which different tiles cross the "first row" section. Each key-image-frame shows us different row in the front.

The "first row" section is an assumed rectangle section in the front of the images shows in Fig. 1. By observing the gray change in this section which is called Valley Detection, it's possible to judge whether the next row comes. The gray change can be depicted as one row comes in, then the section is brighter; when it goes out, then the section is darker; thereupon coming of the next row makes this section bright again. We can obviously observing the gray change in Fig. 6.

In Fig. 6, the horizontal axis represents the sequence number of image frame; the vertical axis

Table 1: The test results in factor

	Total size	450*300 mm	300*300 mm
Total row number (row)	750	531	219
Exact row distinction (row)	750	531	219
Exact row distinction percents	100%	100%	100%
Exact location (row)	748	531	217
Exact location percents	99.73%	100%	99.087%

denotes gray values of the image sequences. Thereby the key-image-frames can be located as the middle points between the valley and wave crest. The time of the key-image-frame implies the coming of the first row. As long as the time of the first row is known, the IPC will be informed to process the image. The image processing results will indicate the normal/abnormal state of current first row tiles, and the computer will send control signal based on such results to decide different tiles go to different lanes. So far, the online detection problem is settled.

EXPERIMENT AND ANALYSIS

Our online system is tested in the factory and with two kinds of different size tiles under consideration, one is 450*300 mm and the other is 300*300 mm. In the location processing, according to the tiles in the first row, if the exact position (shape) of a tile is gotten via OARTD, it’s obvious that the kind of this tile is determined. Although back lighting is added to brighter the tiles, the condition is some kind of harsh with dense dust and occasional shadow. The rail speed is about 0.2 row/s. The change of illumination is very small and can be ignored. This test lasted about 1 hour. Then the results showed in Table 1. From the results, we can see that there is a perfect identifying rate in row distinction procedures, and a high accuracy in detecting different size tiles. Only two rows of smaller tiles are error detected, because of the disorder of tiles in these rows.

From Table 1, testing results show the high accuracy of our location processing method. However, 0.1% error detection would still make a big lose because of the output of hundreds of thousands tiles a day. So it's still necessary to hire few workers to supervise the classification stage. In short, this online detection system would share most labor resource.

In the future, smart vision instruments with improvement of the technology and software, will conquer the influence of the bad mill condition, and then such automatic detecting system will get a more higher absolute accuracy.

CONCLUSION

In this study, we try to solve a practical image identifying problem and construct an online detection system which is to distinguish different size rectangle tiles. Comparing with many existed researches based on close-up images, the difficulty in our task is that there are many tiles in one scenery image obtained from CCD sensor. Besides using the popular methods for image processing such as Otsu method, Canny and Hough Transform operators, we also propose vector corner and valley detection methods to solve the rectangle detection and row distinction problems, which are necessary to inform the computer when to process the image. Based on the image processing results, the computer will send control signals to guide the normal or abnormal tiles in the first row to different lanes. Finally we construct a real system to test our approach in the factory. In practice, our online detection system exhibits a good performance and largely reduces manpower cost. But just recognizing different size is not enough, the following work is to distinguish different veins.

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