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RECTANGULARITY DEFECT DETECTION FOR CERAMIC TILE USING MORPHOLOGICAL TECHNIQUES

Rosny Gonydjaja[1], Bertalya[1], and Tubagus Maulana Kusuma[2]
[1]Faculty of Computer Science and Information Technology, Gunadarma University, Indonesia
[2]Graduate Program in Technology and Engineering, Gunadarma University, Indonesia
E-Mail: rosni-gj@staff.gunadarma.ac.id

ABSTRACT

In ceramic tile factory, the production process has now performed automatically by industrial automation system, except the examination process for ceramic quality classification which is still conducted manually. Classification process is performed using the human visual assessment to find and to classify defect, where human judgment is dependent entirely on experience and knowledge. Therefore, this process requires an automatic mechanism which can provide an assessment of the ceramic quality accurately and consistently. This mechanism is based on a dimensional defect detection process, in particular rectangularity defect with shape feature extraction, using morphological techniques.

Keywords: ceramic tiles, dimensional defects, shape feature, morphology techniques, rectangularity defect.

1. INTRODUCTION

Computer technology has been growing and expanding its use in helping to resolve the problems on various aspects of human life. In the fields of medicine, image processing techniques has been widely used to extract features from various images in the process for classifying and indexing color of leukocyte [1]. In the field of manufacturing, the combination of computer technology and image processing techniques is used in quality control for inspection of textile fabric defect [2], inspection of aluminium casting [3], classification of surface defects on wood boards [4], and grading of ceramic by inspection of ceramic surface [5].

Currently, the production process at ceramic tiles factory have been done automatically by machine through industrial automation system, except the examination process for ceramic quality classification which is still performed manually by the intervention of human operator. This process has many drawbacks, such as time efficiency, accuracy and endurance, which is very expensive, since it requires workers to work in shifts. The other drawback is subjectivity since it is fully influenced by the experience and knowledge of the workers. These disadvantages can lead to errors in the phase of ceramic quality identification.

The decision of quality categories is based-on the severity of the defect found in every ceramic. Defect free or slight defect ceramic will be categorized as first quality ceramic (KW A). Ceramic with more defects will be categorized as second quality ceramic (KW B) and so on.

Standardization on the determination of ceramics quality has been established by the International Standard Organization (ISO) in the SNI ISO 10545-2:2010 document [6]. Defects in the standard measurement is divided into two, namely quality measurement of ceramic surface, such as cracks, crazing, unevenness, pinhole, devitrification glazes, specks or spots, blisters, and welts, and the measurement of dimensions, such as length and width, straightness of side, rectangularity, and surface flatness.

This research identifies and measures dimensionality defects, particularly rectangular defect, using shape feature extraction with morphological techniques that facilitates ceramic quality classification process.

2. Existing Defect Detection Methods

In many proposed techniques, most of them are to extract texture feature for detecting defect on ceramic, as in [7], [8], and [9]. In this section, defect detection on ceramic tile using extracted shape feature is proposed.

H. Elbehiery *et al*. [10] proposed techniques for detecting surface defects on ceramic tiles. Their algorithm is divided into two stages. In the first stage, the algorithm for obtaining clear image tiles using histogram equalization was used. In the second stage, the algorithm for detecting different types of surface defects, such as crack, spot, pinhole, and blob using shape feature extraction with morphological operations was performed.

G.M.A. Rahaman *et al*. [11] study for the preparation of the analyzed image noise removal, which was done using median filter and sobel edge detection. In this study, the proposed algorithm is intended to separate tiles into defect or no defect category. Separation had done by comparing the number of defect pixels on the analyzed image with the reference image. Morphological operations were then applied to the defective tile image during the defect classification process.

Z. Hozenki *et al*. [12] proposed a ceramic edge defect detection analysis based on contour description. To prepare the image for analysis, thresholding method was used by the histogram of the foreground image with the background image. For edge detection, canny kernel was used. Afterwards, contour search was performed by tracing five angles (0, 45, -45, 90, -90 degree). The results were clear visible contour based on the shape and geometric structure.

In [13], E. Golkar *et al.* proposed an image retrieval system from the top and sides of the tile, so it could detect not only surface defect but also dimensional

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defect. For this purpose, canny edge detection was used. Further, segmentation process for extracting the edge tiles using hough transformation was performed, as well as deep-first algorithm and straight line detection with morphological operations. Classification process was done after calculating the ratio of defects.

3. Morphological Techniques

Morphological technique consists of a set of operations that change the image according to the rules of set theory. Morphological technique originally developed for binary image and then extended to gray level image. Originally, morphology was developed in the 60's by a French mathematician, Jean Serra and Georges Matheron. The basic idea in binary morphology is to examine an image with ease, determination of initial form called structured elements, describing conclusions how match or remove shape in the image [14].

Dilation and erosion are two basic operating morphology techniques. Dilation adds pixels on object boundaries in an image, while erosion removes the pixels on the object boundary. Number of pixels are added or removed from the object in the image depends on the size and shape of the formation of the elements that are used to process the image. Dilation and erosion are often used in combination for image processing operations. A morphological technique is commonly used in image processing for reducing noise, increasing image quality and feature detection [15]. Moreover, it can be used for image pre-processing, edge detection, segmentation and object recognition [16].

Four basic operations in morphological techniques are: erosion, dilation, opening and closing.

1) Erosion

Erosion of the input image A with B forming elements defined as:

$$A \ominus B = \{ x : B + x \subset A\} \quad (1)$$

The sequence to perform the erosion of A by B is to translate B with x contained in A. The set of all point x corresponding to such a condition is written as $A \ominus B$. Erosion of an image can also be found at the intersection of all the translation of the input image with the reflection element formation:

$$A \ominus B = \cap\{A + b : b \in B\} \quad (2)$$

2) Dilation

A dilation of the input image with the formation of B elements is defined as:

$$A \oplus B = \cup\{B + a : a \in A\} \quad (3)$$

The sequence to perform dilation of A by B is to translate B to all the points contained in A. The union of all of this translation is written as $A \oplus B$.

3) Opening

Opening of the input image A to B forming elements defined as:

$$A \circ B = (A \ominus B) \oplus B \quad (4)$$

Definition is equivalent to opening:

$$A \circ B = \cup\{B + x : B + x \subset A\} \quad (5)$$

The order for the opening of A by B is first to translate B to all the points x contained in A. The union of all translations is written as $A \circ B$.

4) Closing

Closing of the input image A to B forming elements defined as:

$$A \cdot B = (A \oplus B) \ominus B \quad (6)$$

4. MATERIALS AND METHODS

A. Proposed Approach For Rectangularity Defect Detection And Classification

The rectangularity defect detection flowchart is illustrated in Figure-1.

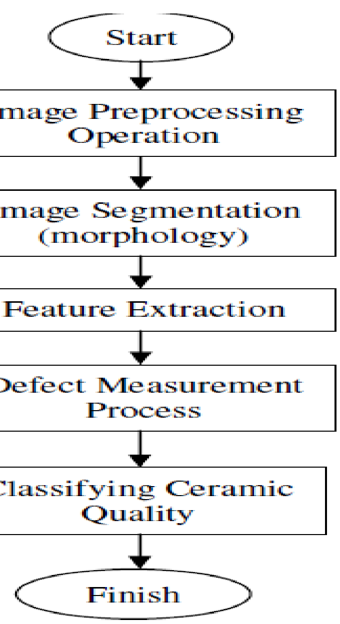

Figure-1. Flowchart of Proposed Method.

The proposed rectangularity defect detection method on ceramic tiles is divided into five stages:
Step 1: Image Preprocessing Operations
Step 2: Image Segmentation (Morphology)
Step 3: Feature Extraction
Step 4: Defect Measurement
Step 5: Ceramic Quality Classification

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B. Image Preprocessing Operations

In this step, image enhancement, noise reduction and image conversion to binary image was performed.

1) Image Enhancement

At this stage, ceramic RGB image was converted into grayscale image and was followed by contrast stretching operation to increase the dynamic range image intensity level.

2) Noise Reduction

The grayscale image was then filtered to reduce noise in the image. The filter used in this operation was the median filter. This filter provides the ability to reduce noise with less blur than linear smoothing filter for the same image size. This filter is formulated as follows:

$$f(x,y) = median_{(s,t) \in S_{xy}}\{g(s,t)\} \quad (7)$$

Median filter takes certain areas of the mask image in accordance with a predetermined size (usually measuring 3 × 3), then visits each pixel value in the area, and the central value of the area is replaced by the median value.

3) Conversion Image to Binary Image

Image conversion operation to binary image was performed to identify the presence of objects by separating objects from the background. Pixel object declared with a value of 1 while the other pixels to 0. Once the object was separated from the background, then object geometry and morphological properties was calculated from the binary image.

C. Image Segmentation (Morphology)

To separate tile object from the background, segmentation process was performed using morphological technique. Morphology is a technique in processing image that based on the image formation of segments or region in image. Since it is focused on the shape of object, this operation was applied to the binary image. Morphological techniques used in this operation include opening, filling, clear border, and closing.

The command to open an image and to remove small object is:

```
M1 = bwareaopen(A,10000);
```

Operation imfill was used to fill the holes in the ceramic image. The command to apply this operation is:

```
M2 = imfill(A, ‘holes’);
```

Operation imclearborder was used to remove objects that touch the border of an image. The command of this operation is:

```
M3 = imclearborder(A, 1);
```

The command for applying closing operation is:

```
SE = strel(‘square’,3);
M4 = imclose(A, SE);
```

SE is strel matrix. Strel is a function to construct structuring elements with a variety of shapes and sizes.

D. Feature Extraction

Following the morphology, extraction of shape feature and spatial information of the object was performed to obtain clear edge position of the ceramic tile side, as well as the specific coordinate points for the defect measurement process. With resize operation of 2500 pixels x 2500 pixels, feature extraction process produced the coordinate values as shown in Figure-6.

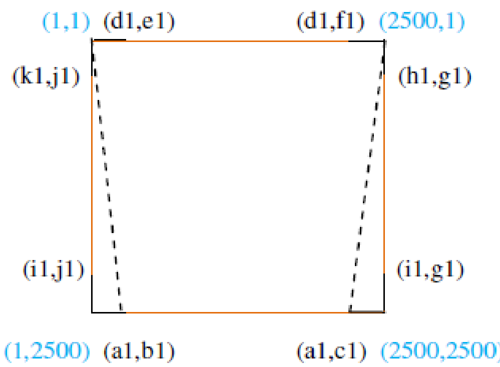

Figure-6. Feature Extraction of Edge Tiles.

E. Defect Measurement Process

Measurement process of defect on ceramic start with counting value defect from each edge corner. Defect values was obtained as follows:

Value defect on upper left, P1 = e1-1.
Value defect on upper left side, P2 = k1-1.
Value defect on lower left, P3 = b1-1.
Value defect on lower left side, P4 = 2500-l1.
Value defect on upper right, P5 = 2500- f1.
Value defect on upper right side, P6 = h1-1.
Value defect on lower right, P7 = 2500-c1.
Value defect on lower right side, P8 = 2500-i1.

Subsequently, minimum value of the two values defect at each corner was acquired as follows,

Upper left corner, PX = min (P1, P2).
Lower left corner, PY = min (P3, P4).
Upper right corner, PZ = min (P5, P6).
Lower right corner, PW = min (P7, P8).

The maximum value of all values defect from each corner produced final rectangular defect.

F. Ceramic Quality Classification

Rectangularity defect measurement values were then compared to the ceramic tile standards defined by the company to determine the quality of the test tiles.

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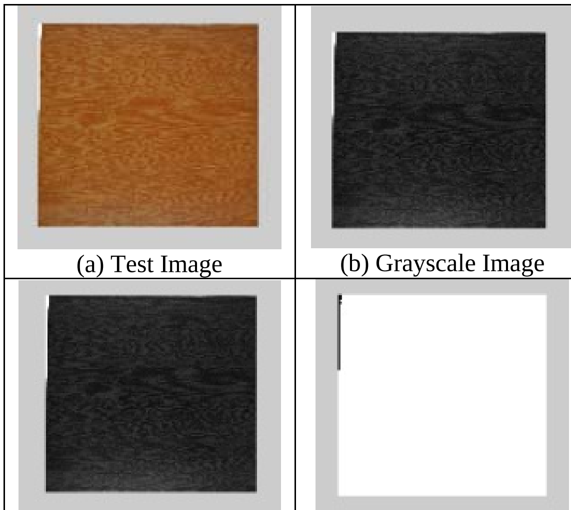
5. Experimental Results

A. Defect Detection

The test data used in this research was the ceramic image of size 30 cm x 30 cm. The digital ceramic image includes in the experiment was from various quality, such as KW A (quality A), KW B (quality B) and Reject. Image capturing was taken against 100 ceramics in an upright position on the surface of the ceramic. Ceramic motif includes white, ebony, pine, walnut, and rokie. Following is the sample images as a result of image processing, which conformed to the proposed defect detection process.



(a) Test Image (b) Grayscale Image

(c) Image after filtering (d) Binary Image

Figure-7. Proposed Preprocessing Steps Applied on Test Image.

(e) Image after Morphology

Figure-8. Proposed Steps Segmentation Applied on Test Image.

B. Defect Classification

In this experiment, 100 digital images of ceramic with type KW A, KW B and reject were used. The quantity of ceramic image of KW A=40, KW B=30 and reject=30. The number of correct identification of KW A=27 of 40 (68%), KW B=12 of 30 (40%), and reject=28 of 30 (93%). Table-1 shows the results for all trial data.

Table-1. Test Results.

Quality	Number	Correct Identification	Percentage
KW A	40	27	68%
KW B	30	12	40%
Reject	30	28	93%
Total	100		

6. CONCLUSIONS

The results obtained from the experiment have shown that correct classification achieved on average of 67%. The detection of KW B was more difficult than the detection of KW A and Reject category because small defect was harder to detect. This result proves that this method can be used to detect rectangularity defects in the process of ceramic classification. This research will be continued by improving the image retrieval process as well as to include the capability of real-time processing of ceramic tiles from the acquisition to the decision. Furthermore, light intensity and arrangement must be improved in order to increase the sensitivity of the vision system.

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