Surface Defects Detection for Ceramic Tiles Using Image Processing and Morphological Techniques

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Abstract**—** Quality control in ceramic tile manufacturing is hard, labor intensive and it is performed in a harsh industrial environment with noise, extreme temperature and humidity. It can be divided into color analysis, dimension verification, and surface defect detection, which is the main purpose of our work. Defects detection is still based on the judgment of human operators while most of the other manufacturing activities are automated so, our work is a quality control enhancement by integrating a visual control stage using image processing and morphological operation techniques before the packing operation to improve the homogeneity of batches received by final users.

Keywords**—** Quality control, Defects detection, Visual control, Image processing, Morphological operation.

I. INTRODUCTION

THE ceramic tiles manufacturing process has now been completely automated with the exception of the final stage of production concerned with visual inspection. This paper is concerned with the problem of automatic inspection of ceramic tiles using computer vision. It must be noted that detection of defect in textured surfaces is an important area of automatic industrial inspection that has been largely overlooked by the recent wave of research in machine vision applications [1].

Humans are able to find such defects without prior knowledge of the defect-free pattern. Defects are viewed as in-homogeneities in regularity and orientation fields. Two distinct but conceptually related approaches are presented. The first one defines structural defects as regions of abruptly falling regularity, the second one as perturbations in the dominant orientation. Both methods are general in the senses that each of them is applicable to a variety of patterns and defects [3].

Human judgment is, as usual, influenced by expectations and prior knowledge. However, this problem is not specific to structural defects. In many detection tasks for example, edge detection, there is a gradual transition from presence to absence. On the other hand, in "obvious" cases most naïve observers agree that the defect is there, even when they cannot identify the structure. Such a monitoring task is of course tedious, subjective and expensive but it is based on a long experience and can utilize the huge appreciation and recognition abilities of the human brain.

Any machine vision system will never advantageously replace the visual inspection if it is not able to [2], [3]:

1. Analyze the color of the product with reliability.
2. Detect every type of manufacturing defects, with at least the same accuracy as the human eye.
3. Measure with high precision the dimensions of the tiles

The defect detection operation induces that the entire surface of every tile must be imaged and analyzed. The goal of the inspection is to give a statistical analysis of the production batches. So, all batches of tiles will be imaged individually without any sampling operation. The image acquisition achieved directly on line, in the real time. The image analysis algorithm must be fast enough to follow the production rate [4].

This paper aims to create a visual system that is capable of detecting the surface defects for the fired ceramic tiles. That ensure the products are free from defects for the classifying process. Classifying process must be effectively, objectively and repeatedly, with sufficient rapidness and low costs. It must have the ability to adapt autonomously to changes in materials. The techniques used range from Long crack, Crack, Blob, Pin-hole and Spot detectors algorithms for plain, and textures tiles. This therefore reduces the number of complaints tiles. The presented inspection procedures have been implemented and tested on a number of tiles using synthetic and real defects.

The results suggested that the performance is adequate to provide a basis for a viable commercial visual inspection system which we will see it in the next sections.

II. IMAGE ACQUISITION AND CAPTURING

We intended to create images that are more suitable the human visual perception object detection and target recognition. We used the principles of Image processing and Morphological operations on the ceramic tiles images. Therefore, we get new images that contain the surface defect only to make easier for the detecting process and classification operation via the judgment of the operator.

The ceramic tiles have been captured through the online camera held on the line production at the industry. The image captured will converted to another kinds of images (Binary, and Gray scale) to be suitable for the various defect detection algorithms used for the different types of defects.

A bag of tricks is used rather than standard algorithms and formal mathematical properties will be discussed like Edge detection, Morphology operations, Noise reduction, smoothing process, Histogram equalization, and intensity adjustment [5], [6].

The effects of unequal lighting and of the space sensitivity of the TV camera CCD are corrected analyzing a sample tile made of white Plexiglas whose image has been previously divided in 8x8 sectors. This number represents a compromise between spatial resolution distribution and computing time [13].

III. EDGE FINDING

An edge may be regarded as a boundary between two dissimilar regions in an image. These may be different surfaces of the object, or perhaps a boundary between light and shadow falling on a single surface. In principle, an edge is easy to find since differences in pixel values between regions are relatively easy to calculate by considering gradients. Many edge extraction techniques can be broken up into two distinct phases:

- Finding pixels in the image where edges are likely to occur by looking for discontinuities in gradients.
- Linking these edge points in some way to produce descriptions of edges in terms of lines curves *etc*.

Thresholding produces a segmentation that yields all the pixels that, in principle, belong to the object or objects of interest in an image. An alternative to this is to find those pixels that belong to the borders of the objects [9].

IV. Morphological Operations

Morphological operations are methods for processing binary images also for gray scale images based on shapes. These operations take the binary and gray scale images as input, and return it as output. The value of each pixel in the output image is based on the corresponding input pixel and its neighbors. By choosing the neighborhood shape appropriately, you can construct a morphological operation that is sensitive to specific shapes in the input image.

As binary images frequently result from segmentation processes on gray level images, the morphological processing of the binary result permits the improvement of the segmentation result. Defects are extracted from the background by thresholding the image and classified according to size and shape parameters. Existing machines commonly detect the following defaults [10], [11]:

1. Chips (edges and corners)
2. Cracks
3. Scratches
4. Glaze faults
5. Holes and pitting
6. Lumps

The sensitivity of the imaging system is linked to the local roughness contrast induced by the defect; it has nothing to do with the color contrast. Because they rely on two independent physical properties of the material, color defects and surface defect inspection are complementary. The tiles used in our experiments are of size 200 x 200mm and are either plain or textured. In the testable images, some defects may not be easily visible and we have randomly encircled some of them for saliency. In most defect images, a dilation operation is carried out to enhance the results. All detected faults correspond to true faults [12], [14].

V. Detection Algorithms for Fired Ceramic Tiles

We will see in this section a number of techniques developed for the detection of multifarious range of ceramic tile defects. Figure 1 shows the first part of the algorithm which takes the captured image for the defective tile then the output is an intensity adjustable histogram equalized image to be the input to the second part of the algorithm. The second part of the main algorithm include many of individual complementary algorithms differs due to the various kinds of defects.

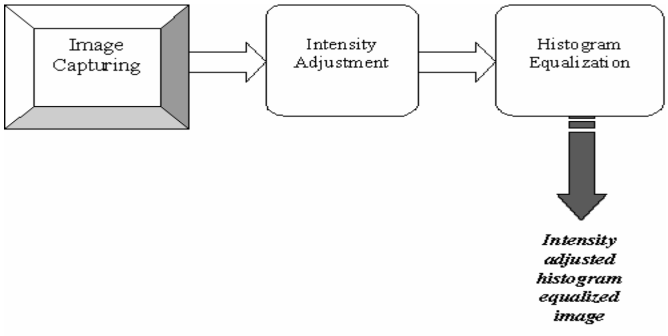


FIGURE 1
FIRST PART OF THE ALGORITHM

Now we will see the different complementary individual algorithms for the detection of variable defects. These algorithms take the intensity adjusted histogram equalized image as the input image. The input image in these algorithms passes through many stages to get the final image which include only the defect. These stages differ from algorithm to another due to the kinds of defects.

Figure 2 shows the Crack and Long Crack defect detection algorithm. The input image converted to a black/white image. An edge detection operation has been done to detect the defect pixels producing approximately areas to the defects so we follow it by a fill gaps operation to discriminate the defect pixels. Some morphology operations have been done to discriminate the defect pixels more accurately followed by Noise reduction and Smoothing object processing to give a clear image containing the defect only.

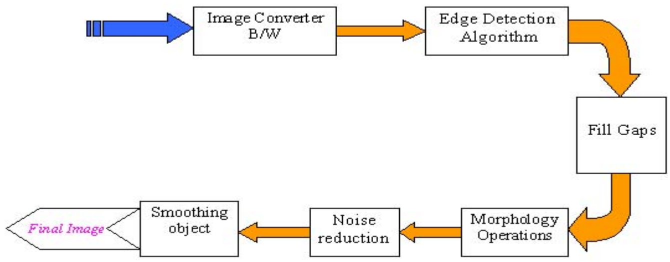


FIGURE 2
CRACK DEFECT, AND LONG CRACK DEFECT DETECTION ALGORITHM

The same operations have been applied to the other kinds of defects detection algorithms but without the same arrange and the number of processing cycles to the images. Figure 3 shows the Spot, Longitudinal Spot, and Depression Spot detection algorithm.

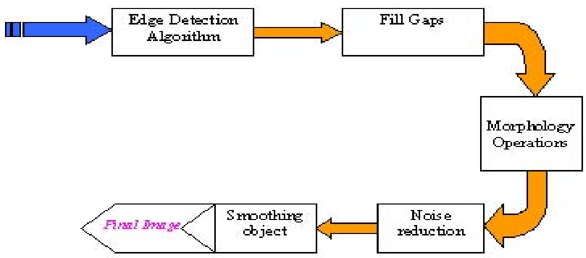
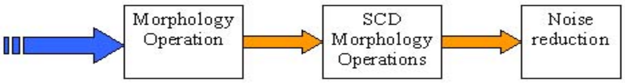


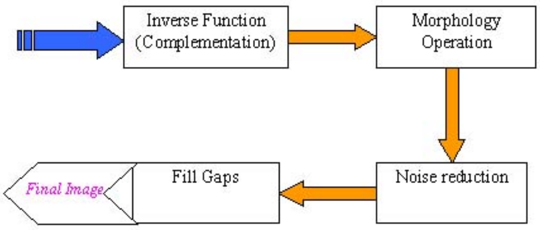
FIGURE 3
SPOT, LONGITUDINAL SPOT, AND DEPRESSION SPOT DETECTION ALGORITHM

It is easier to detect the Pin-hole defects. That by applying some morphological operations directly to the input image followed by SDC morphological operation (morphology operations specialized for grayscale images). Finally in this algorithm the image passes to Noise reduction processing to get a clear image for the defect. Figure 4 shows the Pin-hole defect detection algorithm.



PIN HOLE DEFECT DETECTION ALGORITHM

Because the blob defects always have no little pixels so it has a discriminated area needs only to display it. The input image complemented by an inverse operation to display more clearly the blob defect pixels followed by some morphological operations and nose reduction processing to get a final image for the blob defect pixels only. A fill gaps operation may be added to the final image to increase the clearance of the defects pixels than others. Figure 5 shows Blob defect detection algorithm.



BLOB DEFECT DETECTION ALGORITHM

VI. EXPERIMENTAL RESULTS

We had described in the previous section optimal Crack, Long-Crack, Pin-hole, Blob, and spot detection algorithms used independently also as post-processing stages to our other techniques. It is a very accurate approach but it is computationally demanding.

We apply these algorithms on a several number of tiles, which are plain tiles and textured tiles. In addition, we apply these algorithms on a dozen of tiles images. These tiles images have the same kind of defect whereas the operating conditions (speed of the line with all its irregularities, vibrations etc.) were similar to real conditions. That is for logistic reasons to see if the algorithm give the same result or not and see the differences. When applying the individual algorithms for defect detection we found the results as in the next figures.

Figure 6 and 7 show the defective tile image containing Crack defect and Isolated Crack defect tile image using Image processing and Morphology operations Crack defect detection algorithm.

FIGURE 6
THE ORIGINAL IMAGE FOR THE CRACK DEFECT

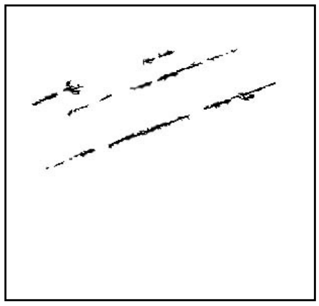


FIGURE 7
ISOLATED CRACK DEFECT TILE IMAGE USING CRACK DEFECT DETECTION ALGORITHM

Figures 8 and 9 show the defective tile image containing Long crack defect and Isolated Long crack defect tile image using Image processing and Morphology operations Long crack defect detection algorithm.

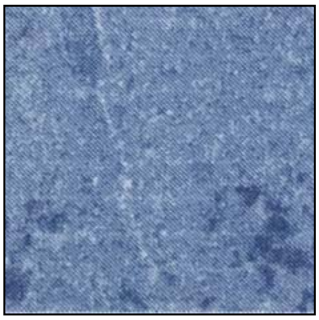


FIGURE 8
THE ORIGINAL IMAGE FOR THE LONG-CRACK DEFECT

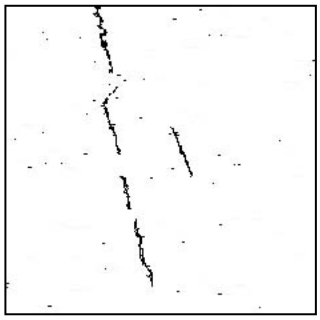


FIGURE 9
ISOLATED LONG-CRACK DEFECT TILE IMAGE LONG-CRACK DEFECT DETECTION ALGORITHM

Figure 10 and 11 show the defective tile image containing Blob defect and Isolated Blob defect tile image using Image processing and Morphology operations Blob defect detection algorithm.

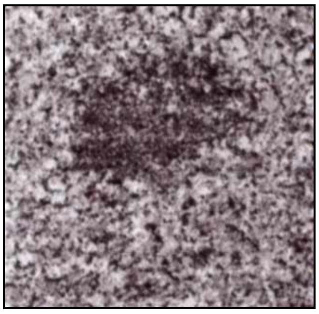


FIGURE 10
THE ORIGINAL IMAGE FOR THE BLOB DEFECT

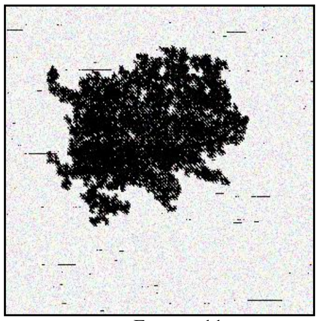


FIGURE 11
ISOLATED BLOB DEFECT TILE IMAGE USING BLOB DEFECT DETECTION ALGORITHM

Figure 12 and 13 show the defective tile image containing Pin-hole defect and Isolated Pin-hole defect tile image using Image processing and Morphology operations Pin-hole defect detection algorithm.

FIGURE 12
THE ORIGINAL IMAGE FOR THE PIN-HOLE DEFECT

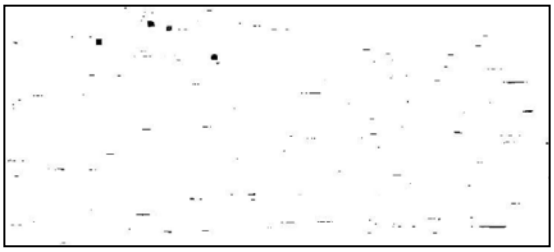


FIGURE 13
ISOLATED PIN-HOLE DEFECT TILE IMAGE USING PIN-HOLE DEFECT DETECTION ALGORITHM

We analyze dozens of tiles including various types of defects. We choose one tile image from each dozen of defective tile images to drag it in this paper. Other typical conditions of ceramic factories (dust, high temperatures, etc) were taken into account during design by applying the first part of Image Processing and Morphology operation detection algorithm which gives an accurate and clear image to be processed in all complementary individual algorithms.

We success in designing individual algorithms that can detect almost all kinds of defects in the fired ceramic tiles. When we tried to apply all individual algorithms as a unique algorithm or an overall algorithm regardless the sequence of these algorithms on the previous defective tile images, we get good results but not as when we had applied individual algorithms. These results are not accurate and clear like the previous results. In addition some defect pixels disappeared therefore it is not described the defect accurately which affect in classification or sorting process that depend on the area of defect.

Figures 14, 15, 16, and 17 show isolated Crack defect, Long-Crack defect, Blob defect, and Pin-hole defect tile images using the overall detection algorithm.

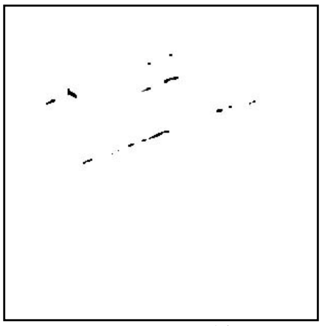


FIGURE 14
ISOLATED CRACK DEFECT TILE IMA GE USINGOVERALL DETECTION ALGORITHM

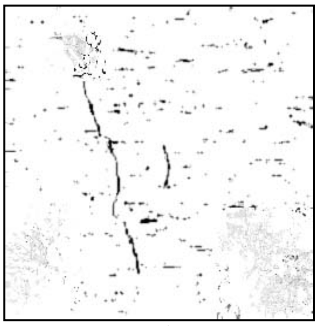


FIGURE 15
ISOLATED LONG-CRACK DEFECT TILE IMAGE USING OVERALL DETECTION ALGORITHM

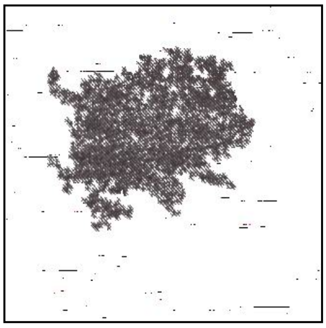


FIGURE 16
ISOLATED BLOB DEFECT TILE IMAGE USINGOVERALL DETECTION ALGORITHM

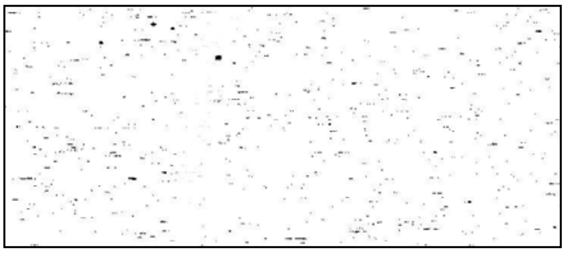


FIGURE 17
ISOLATED PIN-HOLE DEFECT TILE IMAGE USING OVERALL DETECTION ALGORITHM

The result of the project is a prototype analyzer technique with some major simplifications compared to the solutions currently available on the market using an algorithm for detecting the defects in fired ceramic tile. The acquisition system allows the system to be installed without having to make mechanical or electrical modifications to the sorting line. These results in lower costs and means that the system can be moved when required.

VII. CONCLUSION

This paper concerned with the problem of detection of the surface defects included on the fired ceramic tiles using the image processing and Morphology operations. By using this technique we can develop the sorting system in the ceramic tiles industries from depending on the human which detects the defects manually upon his experience and skills which varies from one to one to the automated system depending on the computer vision. That affect mainly in the classification or sorting operation which also done by human in the industry. People can work effectively for short periods and many different operators are involved in checking the same batch of tiles. Continuity over time is not guaranteed and may result in overall poor quality, which may cause customers to complain or even to reject the batch. Miss-sorting is kept at an extremely low level. We success in isolating different kinds of defect in ceramic tiles images. Automated sorting systems would bring numerous benefits to the entire sector with major economic advantages, also guarantee product quality, increase plant efficiency and reduce fixed and periodic investments. The continuous measurement of surface defects gives line production operators to optimize temperature profile, speed and other operating parameters.

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