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An Electronic Eye to Improve Efficiency of Cut Tile Measuring Function

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Abstract : *This paper presents an attempt to improve efficiency of cut tile measurement function by developing an 'electronic eye' device using image processing techniques. The automated system consists of a mechanical unit and an image processing unit. A conveyer belt used to move cut tiles one after the other. The camera unit situated above the conveyer belt is directly connected to a computer for image acquisition. Constant light condition was maintained by use of an external light system. The developed algorithm was capable of capturing images of the tiles moving on the conveyer belt automatically. Then image processing techniques were applied to calculate pixel length and pixel width of a cut tile. These pixel values were converted to length and width in mm scale and data saved in a text file. If the cut tile dimensions were not in the given range, the system sounds an alarm. The system presented in this paper is capable of measurement of tile dimension 0.4 mm of least measurement and measurement time is reduced from 20 s to 2.5 s compared to manual method. Furthermore, the number of employers can be reduced to one compared to work of three people involved in manual method.*
Keywords: *Cut Tile, Image Processing, Electronic Eye, Image Acquisition, Ceramic Industry*

I. Introduction

This work has been carried out based on a problem faced by one of the major tile manufacturers in Sri Lanka. The company manufactures tiles using local and foreign raw materials and export 40% of their production to the foreign market. They have production capacity of approximately 3.5 million square meters of tiles annually. A wide range of tiles are produced with different colors, textures, and sizes. Special and decorated tiles are manufactured by the 3rd firing section in the factory. The 3rd firing section produces different sizes of cut tiles for the export market. Both export market and local market consider the wall tile quality parameters critically. In this regard, tile dimensions (width, length and thickness etc.) are specifically evaluated to verify as if it match with the specifications given by the buyer. Sometimes, the entire pallet of tiles is rejected if the carrying tiles do not satisfy the required standard dimensions resulting significant financial loss. The 3rd firing section of the above mentioned factory currently measures and records length, and width of a tile manually. The process requires three employees to measure dimensions, record and sort tiles manually.

In the above setup, one person measures the dimensions using the machine available (Fig. 1.), while the other person records the measurements displayed in the digital display and the third person packs tiles in to cartoons. This manual checking of dimensions cost 20 seconds of average time per tile. Furthermore, machine currently in use has an error bar of ±0.1 mm. The standard dimensions of two kinds of tiles (P and Q) are stated in Table 1 with an error bar of ±0.1 mm. Thus, there is no mechanism to validate dimensions in the practical context. However, quality of measurements is significant in both export and local markets.

Therefore, the necessity to develop a mechanism to overcome the difficulties due to manual measuring technique is quite evident in order to reduce the amount of labor and time. The project presented here is focused on developing a system to measure dimensions of a tile with acceptable accuracy while reducing the time spent. The efficiency in dimension measurements will reduce the expenses due to rejection of tiles as only quality tiles are exported.

In literature, many researches have been carried out to find surface defects such as cracks, pinholes, spot, blob, corner damages, and glaze damages on ceramic tiles based on image processing techniques [1, 2, 3, 4, 5, 6]. In order to measure dimensions of ceramic tiles in high accuracy, high-tech machines such as TILE CONTROL TCE 5 has been introduced to the industry [7]. The machine optimized to measure tile dimension about 100×100 mm to 1800×3200 mm. The minimum measurement which can be taken using the machine is about 0.1 mm. The above mentioned machine incorporates 2 charge-coupled device (CCD) sensors and lasers. Even though the machine provides more accurate results on tile dimension, the limitation of tile size that the machine can measure (especially tile dimension less than the lower limitation) is a major issue which has been faced by the tile manufactures. Another problem that tile manufacturers face here is aligning tiles into machine's horizontal axis. Due to the difficulties that manage to feed tiles 100% horizontal to the machine axis, the machine gives an error without measuring dimension.

Fig.1. Manual measurement machine

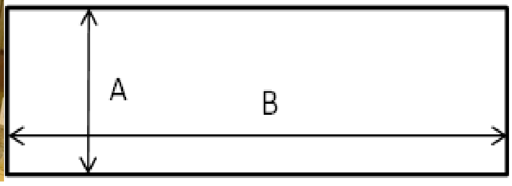


Fig. 2. Caliber Parameters of RX Tile

Table 1. Standard Dimension of Rx Tiles

Caliber	Caliber Range	
	Shorter Side (A)	*Longer Side (B)*
P	98.7 - 99.7 mm	401.4 - 402.4 mm
Q	98.7 - 99.7 mm	402.5- 403.5 mm

The proposed system can be divided into two sections as image processing and mechanical system. The mechanical system consists of a conveyer belt which carries cut tiles one after the other. The top view of the tile on the conveyer belt is captured by a camera at a predefined position of the moving tile on the belt. Finally, the images were processed and calculated the dimensions of the tile.

II. Methodology

In this work, authors focused on improving efficiency of cut tile measurement function by developing an electronic visual basic measurement device. Image processing techniques were used to develop the proposed system. The developed system has two major parts: Image processing part and mechanical construction part. Image processing part consists of several steps such as image acquisition at the appropriate position of the tile, image pre-processing and calculating the pixel width and length of the processed cut tile image.

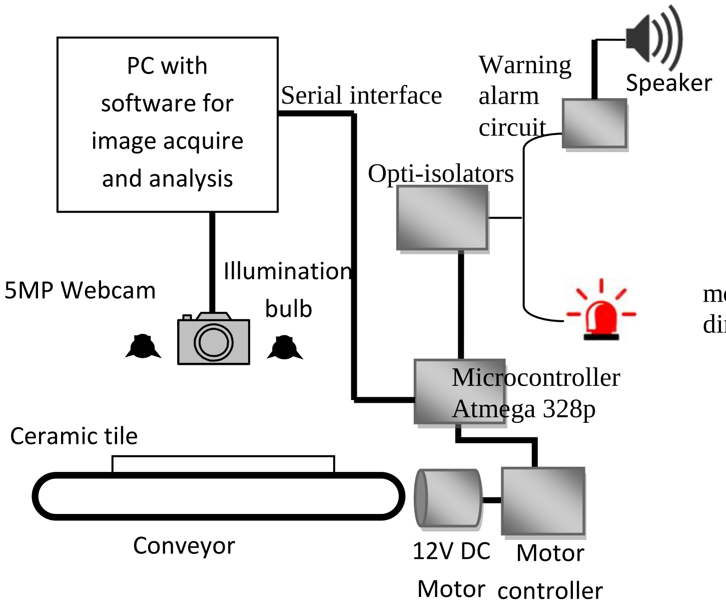


Fig. 3. System overview

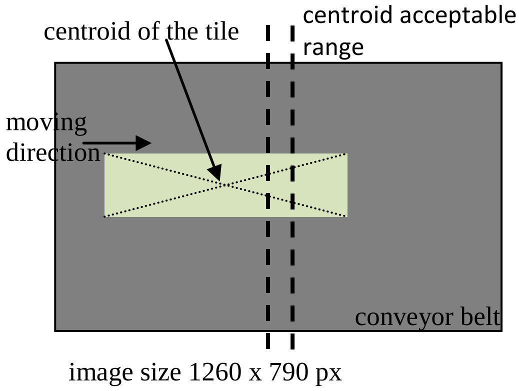


Fig.4. Appropriate position of capturing the image for further process

2.1 Cut Tile Image Acquisition

The top view of a moving tile on the conveyer belt is captured by a camera until the tile reach to a predefined acceptable range. To initialize the process, the acceptable ranges of tile dimensions and the appropriate position of the tile (threshold) must feed into the developed computer program as user inputs. Then the camera captures images of the moving tile. Each of the captured true color image (RGB color space) converts to a binary image (BW). The threshold value for image color conversion was taken as 0.9 which gives a better output. Here, a black color conveyer belt is intentionally used to get better contrast of the tile. Then the center position of the tile was evaluated after detecting edges of the BW image. The flow diagram of the process of image acquisition is shown in Fig. 5. Finally, a condition is given as a threshold point at which it is required to capture the final image. The whole tile must be in the captured image frame at this particular threshold point and it was pre-evaluated and fed to the system. If the center x-coordinate of the tile is below the threshold x-position then the tile is not at the appropriate location. Then the system was programmed to capture the next frame until the condition is satisfied [8]. Final captured image is further processed for calculating width and length of the RX tile.

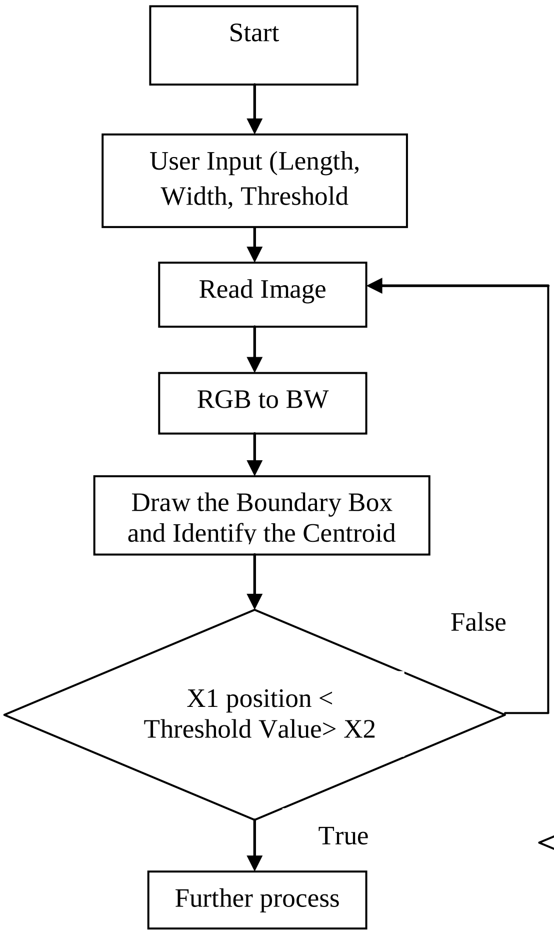


Fig.5. Flow Chart of image acquisition of a cut tile

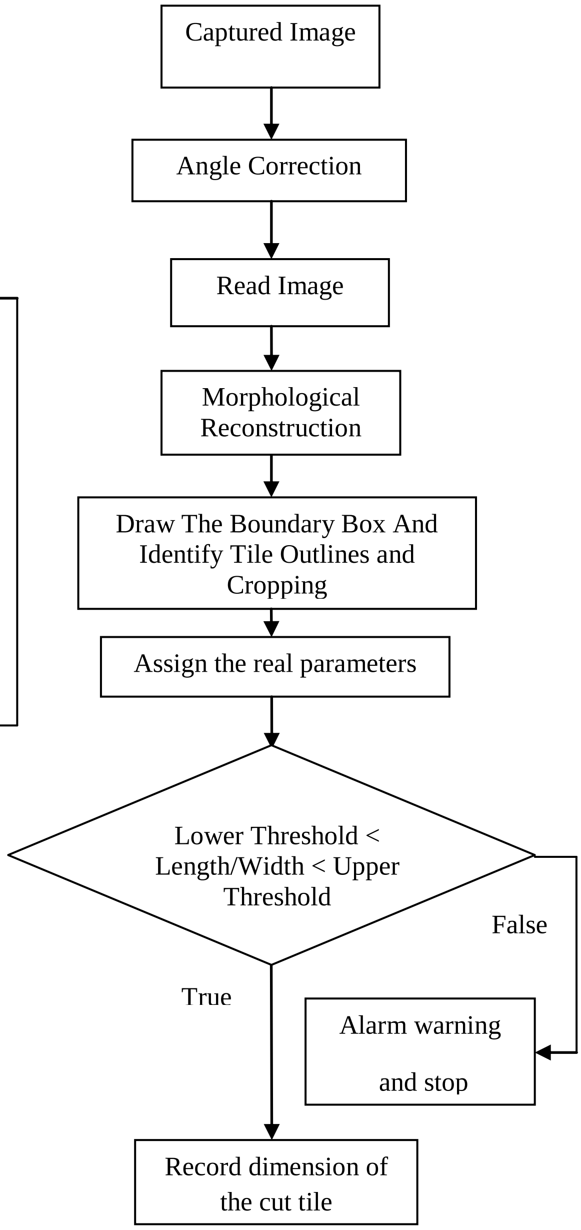


Fig.6. Flow chart of calculating dimension of a single cut tile

2.2 Image Pre-Processing and Cut Tile Dimension Calculating

At the end of the image acquisition step explained in above, the properly captured image of whole cut tile further processed for evaluate the dimension. The flow chart of the process of evaluating the dimension of a cut tile is shown in Fig. 6. In order to evaluate more accurate dimensions it is essential that the tile is oriented parallel to the x axes. But in practical situation, the tile may orient in different ways. Therefore, in the first step of processing, correction for perfect orient of tile parallel to x axes is required. Here, we used Radon transformation [9] for angle correction. The Fig.7 shows the originally captured image at the end of the image acquisition process and angle corrected image through the Radon transformation.

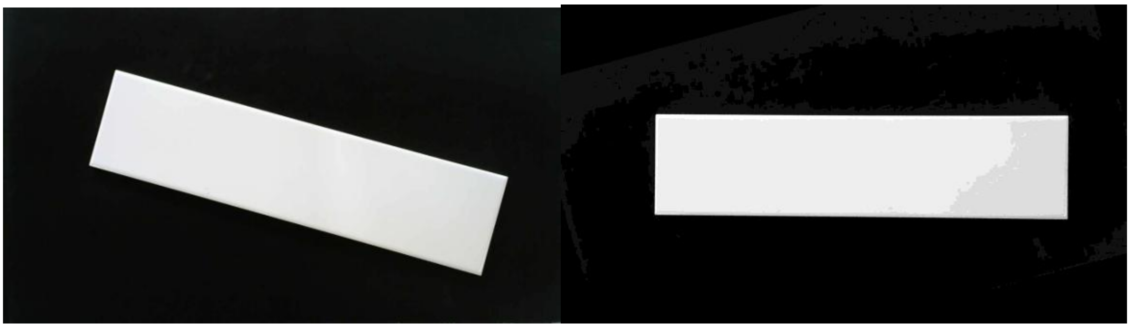
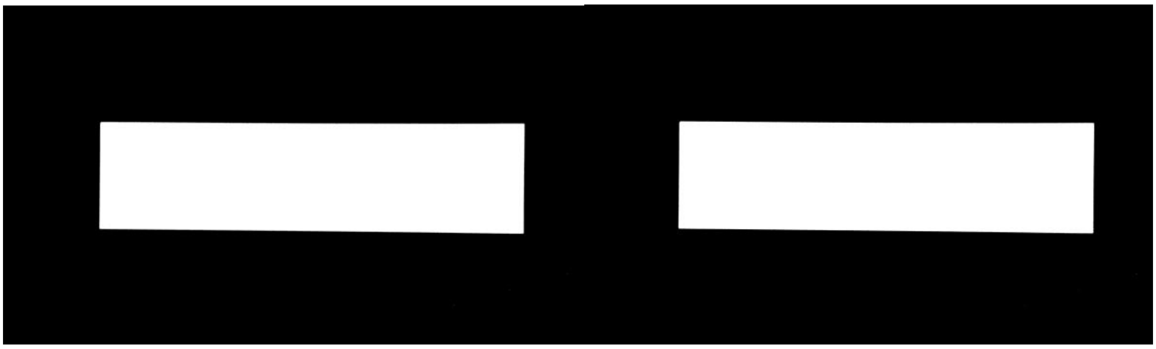


Fig.7. Angle correction (a) original (b) after applying Radon transformation

The Radon transformation outputs an angle in degrees (± angle) where it is required to rotate the captured image counterclockwise (+ angle) or clockwise (- angle) around its center point in order to orient the tile parallel to the x- axis incorporating 'bilinear' interpolation method. This process makes change to the size of originally captured image. Therefore, in order to keep the size of the image same as the size of the input image, the 'crop' method was applied.

The output of the above step may consist noises and shadows. Morphological reconstruction techniques were applied to reduce noises and shadows [10]. Since the tile has a shiny surface, adjust image function is used to remove the reflected shadows on the tile surface. It is a technique used for mapping image intensity values to a new range. Contrast of the image was increased after remapping the data values to fill the entire intensity range (0 - 175) [11]. This suitable intensity range was determined by investigation of intensity variation of 20 sample images. Then, to enhance the image quality (removing noises), holes were filled in the intensity adjusted image [12]. Following Fig.8 shows the difference before and after the morphological reconstruction was applied to the angle corrected image.



(a). Intensity adjusted image (b). Noise 'holes' removed image

Fig.8. Enhancing the quality of region of interest

Then region properties were evaluated of the noise free binary image. Following matlab command was used for evaluating the region properties: regionprops(tile_bw, 'Area', 'BoundingBox') . According to the output of the command the region of interest was cropped considering the pixel area as well. The number of rows and number of columns of the cropped image were used to calculate the width and length of the cut tile in millimeters. The conversion index was obtained for known manually measured dimensions of cut tiles. Dimensions of ten cult tiles were manually measured (length and width in mm) and recorded. Then dimensions (length and width in pixels) of the same tiles were obtained using the developed method. Accordingly, the average value for the length conversion index (0.4302 mm/pixel) and width conversion index (0.4259 mm/pixel) were obtained.

Length (mm) = (0.4302) *number of columns (pixels) (1)
Width (mm) = (0.4259) *number of rows (pixels) (2)

2.3 Mechanical construction

The developed electronic eye system is shown in Fig. 9. It consists of 5 megapixel webcam, black conveyer belt, conveyer roller mechanism, illumination bulbs, and a personal computer. Matlab software was used to develop the proposed image processing based electronic eye system.

Fig.9. Developed electronic eye cut tile measuring function

The black conveyor belt is used to differentiate tile from the background. Machine dimension is as follows: height 900 mm, length 750 mm and width 600 mm.

III. RESULTS AND DISCUSSION

The developed system was tested for manually measured tiles and the results are in good agreement. Table 01 shows the results of the dimension measurement function obtained from this work.

Table 2. Dimension measuring function using an Electronic Eye system

	Manual Measurements		Electronic Eye Measurements		
Tile No.	**Length (mm)**	**Width (mm)**	**Length (mm)**	**Width (mm)**	**Decision**
Tile 1	402.3	99.5	402.3672	99.5637	Accepted
Tile 2	402.1	99.6	402.3672	99.9414	Accepted
Tile 3	402.0	99.5	402.087	99.4364	Accepted
Tile 4	402.2	99.1	402.237	99.1032	Accepted
Tile 5	402.3	99.2	402.237	99.2347	Accepted
Tile 6	402.6	99.7	402.611	99.7074	Accepted
Tile 7	402.9	99.4	402.985	99.412	Accepted
Tile 8	402.8	99.7	402.8915	99.7007	Accepted
Tile 9	403.0	99.8	403.0416	99.8172	Rejected
Tile 10	402.9	99.8	402.985	99.8172	Rejected

The acceptable dimension ranges of the tested tiles were length: 401.5 mm – 403.5 mm and width: 98.7 mm to 98.7 mm. Outputs of the tested tiles obtained from the electronic eye system are in good agreement with the manual measurements. The measurement time required in the process was 20 seconds (per one tile) in manual method and it is improved to 2.5 seconds (per one tile) with this proposed electronic eye system. The developed code was tested in Intel(R) Core(TM) i5-6200U CPU @ 2.30GHz, x64-besed processor and 4GB of RAM.

As stated above, existing procedure requires manual measurement and recording. Additionally, it is significant to note that the developed mechanism measures any size of cut tiles according to the user given inputs. Earlier labor requirement is 3 employees in the measurement process which can be reduced to one employee with this electronic eye system. Furthermore, the employment requirement can be reduced to zero if the electronic eye machine can be directly connected to the production conveyer line and fully automated. Number of tiles that can be measured per one day (24 hours) increased from 4400 to 14400. The electronic eye system is developed to give a warning alarm if the detected tile dimensions are not in the customer required range.

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