AUTOMATED QUALITY INSPECTION ON TILE BORDER DETECTION USING VISION SYSTEM

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DECLARATION

I declare that this thesis entitled "AUTOMATED QUALITY INSPECTION ON TILE BORDER DETECTION USING VISION SYSTEM" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have checked this report entitled "AUTOMATED QUALITY INSPECTION ON TILE BORDER DETECTION USING VISION SYSTEM" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours.

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

Most of the ceramic tile industry still doing the quality control by manually. The accuracy of the manual inspection by human is lower due to the harsh industrial environment with noise, extreme temperature and humidity. A camera should replace the human eyes to recognise the defect tile effectively. Thus, a suitable method have to investigate for implementing this function. This project aim to design and develop an automated quality inspection in ceramic tile industry using vision system. The performance in term of detection accuracy for the system is analysed. An Imaging Source Series CMOS industrial camera is used to capture the tile border. The system is implemented in the MATLAB software. Image processing with Canny edge detection technique and morphological operation are used to segment and extract the tile border edge. The threshold level of image processing, focus and iris of camera and illumination of the light are adjusted to improve the performance of the system. The system developed is only to detect cracks occur on the edge of the tile border, middle crack such as pinhole is not included. The overall automation process involves image capturing, image processing, defect detection algorithms and decision making. The defect detection algorithms are developed to differentiate the defective tile. The automated quality inspection for the defect detection of tile border using vision system based on the background subtraction method and gradient variation of the tile border edge are presented in this research. The system using background subtraction method has achieved 50% accuracy in identify the status of tile since it consist of many limitation. By evaluate the gradient variation on the tile border edge, the accuracy of the defect detection has achieved 80% in identify the tile condition. The performance of the second method is relatively strong since the process of detection is considered in many aspects. In future, a consistent workspace such as in a production line can be achieved and reduce the error. The good and defect tiles will be classified and divided to different place by design a conveyer sorting system.

ABSTRAK

Kebanyakan industi jubin seramik masih menggunakan kawalan kualiti secara manual. Ketepatan pemeriksaan secara manual oleh manusia adalah rendah kerana persekitaran perindustrian yang dipenuhi dengan bunyi bising, suhu yang melampau dan kelembapan yang terlalu tinggi atau rendah. Kamera patut digunakan dengan mengantikan mata manusia untuk mengenali kecacatan di jubin dengan berkesan. Oleh itu, keadah yang sesuai harus dikaji demi melaksanakan fungsi ini. Objektif projek ini adalah untuk mereka cipta sistem pemeriksaan kualiti automatik dalam industri jubin seramik menggunakan penglihatan mesin. Prestasi sistem ini dianalisis berdasarkan ketepatan pengesanannya. Kamera industri Imaging Source CMOS digunakan dalam pengambilan gambar sisi jubin. Sistem ini dilaksanakan dalam perisian MATLAB. Pemprosesan gambar dengan mengunakan teknik "*Canny edge detection*" dan "*morphological operation*" untuk membahagi dan memperolehi hujung sisi jubin. Tahap ampang untuk pemprosesan gambar, tumpuan dan iris kamera serta pencahayaan lampu dilaraskan untuk menambahbaikkan prestasi sistem ini. Sistem ini dicipta hanya untuk mengesan retakan di hujung jubin, retakan di tengah jubin seperti lubang adalah tidak dapat dikesan. Keseluruhan proses automatik ini merangkumi pengambilan gambar, pemprosesan gambar, algoritma pengesanan kecacatan dan pengambilan keputusan. Algoritma pengesanan kecacatan ini direka cipta untuk memebezakan jubin yang mempunyai keccacatan. Pemeriksaan kualiti automatik untuk pengesanan kecacatan hujung jubin adalah berdasarkan kaedah "*background subtraction*" dan "*gradient variation*" dalam hujung jubin dibentangkan dalam kajian ini. Sistem yang menggunakan "*background subtraction*" telah mencapai ketepatan sebanyak 50% dalam memastikan keadaan jubin memandangkan ia mempunyai banyak pengehadan. Dengan menilaikan "*gradient variation*" di hujung jubin, ketepatan pengesanan kecacatan telah mencapai 80% dalam megenalpastikan keadaan jubin. Prestasi keadah kedua adalah lebih baik disebabkan oleh proses ini merangkumi banyak aspek dalam penilaian. Pada masa akan datang, ruang kerja yang tetap seperti dalam kawasan produksi dapat dicapai dan mengurangkan kesilapan sistem. Jubin dalam keadaan baik dan mempunyai kecacatan dapat dibezakan dan dibahagikan ke tempat belainan dengan menghasilkan satu sistem pengasingan dan penghantaran.

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LIST OF SYMBOLS AND ABBREVIATIONS

MATLAB	-	Matrix Laboratory
ROI	-	Regions of Interest
LED	-	Light-emitting Diode
HPC	-	Performance Cluster
CUDA	-	Compute Unified Device Architecture
PC	-	Personal Computer
USB	-	Universal Serial Bus
CMOS	-	Complementary Metal Oxide Semiconductor
RGB	-	Red, Green, Blue
GPU	-	Graphics Processing Unit
RAM	-	Random Access Memory
HDD	-	Hard Disk Drive
VRAM	-	Video Random Access Memory
OS	-	Operating System
m	-	Meter
IoT	-	Internet of Things

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CHAPTER 1

INTRODUCTION

1.1 Project Introduction

In this industry 4.0 era, automated system is indispensable to a modern manufacturing industry. The need of the mankind has demanded increase in productivity with the improved quality of the products. This has led to innovations, and these innovations have transformed the traditional manufacturing to advanced manufacturing. Quality control is a step in manufacturing to ensure customers receive a good product that meet their needs and free from defects. Consumers will face the risk if the quality of product is done in the wrong way [1]. There are several methods of quality checking. Each method has its own advantages and disadvantages. Contact type equipment consumes more time for quality check than non-contact type [2].

The conventional quality checking of a component is made by taking one sample out of a lot to ensure the quality of the particular lot. Such quality checking method may lead to rejection of the whole lot or even acceptance of defective parts. In order to ensure the quality of the product, each component has to undergo quality check, which raises the need of in-process inspection. In-process inspection ensures successful control over the quality of the component, reduces the quality check time, ensure inspection of each component and reliability as well as the efficiency of the system [3].

To fulfil the automated and in-process inspection, machine vision can be applicate. A machine vision system is a type of technology that enables a computing device to inspect, evaluate and identify still or moving images. The main problem in developing efficient machine vision is to translate the human visual perception into sequential and logical operations. In purpose to find some other ways for defect detecting the image processing methods are developed [4]. Edge detection is an image processing technique to find the boundaries of objects in images by detecting the discontinuities in brightness. In the ceramic tiles industry, the tile border can be found out using this method to identify the defect condition. Figure 1.1 shows the tile in the industry required a quality check of the tile border defect.

Figure 1.1: Quality Check of Tile Edge Defect [5]

There are many object analysis functions in MATLAB which are detect edges, circles and lines. MATLAB which developed by MathWorks is a multi-model numerical computing environment and possessed own programming language [6]. Image processing and computer vision is one of the product in MATLAB. Algorithm development is medium for image processing and computer vision due to each situation is unique and good solutions require many kinds of iterations on design [7]. It provided an Image Processing Toolbox contains many kinds of set of reference algorithms and workflow apps that can be applied for image processing, analysis, visualization, and algorithm development. It able to carry out image processing such as image segmentation, image enhancement and noise reduction. Many visualization functions and applications to explore images and produce histograms as well as manipulate regions of interest (ROIs) [8].

1.2 Motivation

Most production process is automated in ceramic tile industry, yet the final step which is quality inspection still monitored manually. Failures on ceramic tile always causing by human error. The manual inspection on detecting the defect is based on human decision. Inspectors may feel eyes fatigue and tired causing the fail in inspection [9]. The failures in product will make customer on risk and the vendor, installer and some implicated person have to take responsible on it.

Failure in quality inspection will cause the defect product shipped out to customers. Customer will complain and ask for recalled which will cause the company loss of money. Besides, customers not only ask for the product that failed

specifications or had to be recalled but the company's operations in general also will be question for the quality. The product may not be accepted if the company under excessive warning letter. The image and reputation of the company will be destroyed and cause loss in customers' trust and business in this competitive field. Associated the financial impact due by lost sales, lower production with increased production costs and material cost increased. Company will suffer tremendous loss for failing in quality control so that a proper solution should be implemented to solve the error in inspection of defect product [10].

1.3 Problem Statements

This research is to create an automated quality inspection system using vision system. This system is to check the border of ceramic tile whether it is good or defected by automated process instead of human monitored. Quality check by human causes a lot of time consumed and low efficiency. This also causes a high cost consumed in production since manually quality check cannot give feedback on the trend of defect and quality of the product cannot be improved efficiency.

In current research of tiles automated inspection system, the camera normally placed on the top for inspecting the surface of tiles. The inspection will only focus on the top side of tiles while the bottom side condition unable to detect. Camera intensity is the main element that need to concern in a vision system. If intensity is too high or low, an exposure and dark image will be formed respectively. The image with noise also influence the performance of the inspection system. With the aid of light source can improve the system performance but sometime the light which directly illuminate the tiles will provide unwanted reflection and influence the output image. The factors that will influence the performance of the system should be found out to reduce the error occur.

1.4 Objectives

This research has the following objectives:

1. To design and develop the automated quality inspection for the defect detection of tile border using vision system.
2. To obtain the characteristic of crack based on the tile border line.
3. To analyse the performance of the tiles border line detection in term of accuracy.

1.5 Scope

This research contain some scopes to narrow down the area of study. The defect detection algorithms developed is only tested on 10 pieces 30cmx30cm plain ceramic tile with different crack area on border. The distance between camera and tiles always fixed during the testing which is 2 m. The defect type to detect in the system is only focus on the crack defect of tile border. The system developed is only to detect cracks occur on the edge of the tile border, middle crack such as pinhole is not included. The tiles is always in static position for inspection. An Imaging Source CMOS industrial camera is used to capture the images. The focus and iris of the camera are adjusted manually to control the clarity and exposure of the image captured. MATLAB software is used for design the image processing, defect detection algorithms and data analysis of the image acquired. A laptop is used for executing the system program in the MATLAB.

CHAPTER 2

LITERATURE REVIEW

2.1 Background Theories

This section is basically explained about the background theories of the project. Vision inspection system and pixels are defined in the subsections. These theories are aided in developing the research.

2.1.1 Vision Inspection System

Vision inspection systems is an image-based automated inspection that provide convenience for a variety of industrial and manufacturing used. This kind of systems are now become commonly applied in automated inspection, quality control, sorting, robot guidance and so on.

The inspection systems required a camera or multiple cameras and even video and lighting. Vision systems are able to perform measuring, verifying parts are in the correct position and recognising the shape of parts at high speeds. Computer software can used for processing images captured when want to assess to capture data. Vision system is intelligent enough to do decision-making for controlling an operator in doing some output. These systems can provide a constant stream of information when embedded into the production line.

Any industries in which quality control is important suitable to apply these vision inspection systems. These system enable data collecting that help in efficiency improvement for manufacturing lines, sorting, packing and other tasks. Furthermore, the data obtained by the system can determine problems with the manufacturing line or other function to improve efficiency, stop bad processes and identify defective products.

The design of the vision inspection systems can be specialized to meet the needs of many industries due to these systems integrate various kinds of technologies. Therefore, a lot of companies have used this technology for quality control purposes and even security purposes. Industries using vision inspection systems involved in a

wider field such as automation, robotics, pharmaceuticals, packaging, automotive, food and beverage, semiconductors, medical imaging and much more.

Overall, the advantages of vision inspection systems consist of production improvements, uptime increased and cost reduction. Industries allow conducting completely inspection of parts for quality control purposes using vision systems. These system guarantee that all products will meet the customers' needs and specifications [11].

2.1.2 Pixels

The smallest element in an image is called pixel which is also known as pel. Each pixel represent a value. The value of the pixel is between 0 and 255 in an 8-bit gray scale image. The value of a pixel at any point correspond to the intensity of the light photons bombardment at that point. Each pixel contain a value proportional to the light intensity at that specific location. The value 0 means absence of light which denotes dark. It further means that whenever a value of pixel is 0 indicate that black colour would be formed at that point. For white colour is value 255.

There may be thousands of pixels that joined together and make up an image. The image is zoomed to the level that some pixels division able to see. Figure 2.1 have shown to explain this feature.

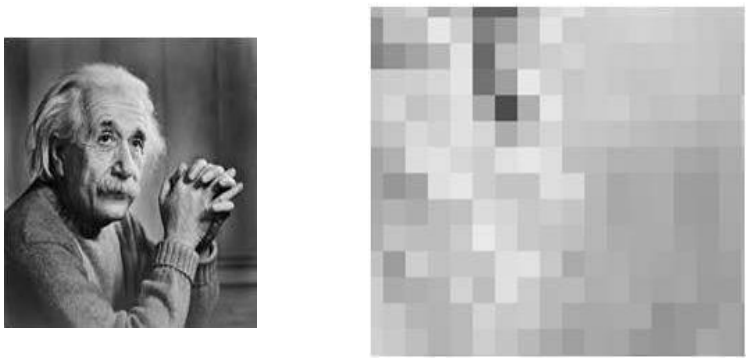

Figure 2.1: Pixels Division in Zoomed Image [12]

Next, an image is defined as a two-dimensional matrix. In this case, the number of pixels would correspond to the number of rows multiply with number of columns. It can be said that the number of (x,y) coordinate pairs make up the total number of pixels. The mathematically represented as below:

$$Total\ number\ of\ pixels = number\ of\ rows \times number\ of\ columns \quad (2.1)$$

A binary image is a digital image that has only two possible values for each pixel which are 1 and 0. Typically, the two colors used for a binary image are black and white. Value 0 represent black while value 1 represent white [12].

2.2 Review of Previous Related Works

This section is discussed about the review of previous related works done by other researchers. Methods for defect detection, edge detection algorithms, type of defects, the processors used and light sources applied in vision system are reviewed and compared for finding the advantages and limitations of various aspect before implementing the own project.

2.2.1 Methods for Defect Detection

Ceramic tile defect can be detected by many methods. The more traditional method is detected by human eyes. A research is conducted by F. Ozkan [9] using an eye-tracker to assess workers when detect the surface defect of ceramic tile. The workers will mark a straight line on a surface of tile when they realise the defect occur. The marked tile will be sorted automatic by sensor detected. The research found that an expert worker have shown a systematic pattern when inspect the ceramic tile on conveyer. A good inspectors are evaluated by accuracy and speed are relatively high and make many brief eye fixations during the time they have to inspect. For a novice worker, the accuracy and speed will relatively low. Human eyes can detect some obvious defects but not all recognizable by human eyes. Human resources also expensive to use and sometime they are not accurate enough for visual controlling [13].

Time of Flight Diffraction (TOFD) technique using ultrasonic sensor is one of a non-destructive testing in the quality control of ceramic tile. It used to do the mapping of edges position. Ultrasound is transmitted and reflected in a normal direction if the tile is perfect. Diffracted wave will emitted with a wide angular range when a crack is detected. This method saving production cost but may affected by temperature, dust, vibration, humidity, roughness and movement of tile [14]. A laser speckle photometry also applied in ceramic industries for detection of micro-cracks on the surface of

ceramic. A speckle pattern will varies based on the thermal and mechanical excitation of object. Heat will be distributed on the surrounding of defect area. Camera is positioning above the object act as a detector of the pattern change to recognise the defect such as crack [15].

There are many research of defect detection on ceramic tile with automated visual inspection system based on image processing method. The detection speed and accuracy rate are high which extremely improves the accuracy, stability and efficiency of product detection [3]. Image processing can be done within production line process. The cameras scan the tile quickly without stalling it and fixing position [13]. Image processing required less time to do defect detection and many algorithms have available to classify different type of defect [16]. In the research of Y. C. Samarawickrama by using Matlab image processing technique to detect the surface defect of tile, the accuracy have reached 96.36% from 110 sample and the rate of perform image processing and result delivering are just consumed 2 seconds [17]. The comparison of the methods for defect detection is shown in Table 2.1.

Table 2.1: Comparison of Methods for Defect Detection

Researcher	Methods used	Advantage	Limitation
F. Ozkan and B. Ulutas [9]	Human	•Decision making •Easy to train	•Eyes fatigue and tired causing the fail in inspection.
E. Golkar et al. [13]			
H. M. Elbehiery et al. [14]	Ultrasonic sensor	•Destructive Testing •Not affect future usefulness	•Diffracted wave depended. •Do not have image reference.
B. Bendjus et al. [15]	Laser speckle photometry	•Speckle image show defect •More details	•Reflective index, angle between camera and laser needed to do future adjustment.
R. Kiran et al. [3]	Image processing	•High detection speed and accuracy rate •Improves the accuracy and the stability of detection	•Intensity change will affect the performance.
E. Golkar et al. [13]			
A. N. Shire [16]			
Y. C. Samarawickrama and C. D. Wickramasinghe [17]			