UNIVERSITI PUTRA MALAYSIA

COMPUTER VISION AUTOMATION SYSTEM FOR SORTING PARTIALLY OVERLAPPING TILES

NEAM TARIQ HUSSIN

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By

NEAM TARIQ HUSSIN

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COMPUTER VISION AUTOMATION SYSTEM FOR SORTING PARTIALLY OVERLAPPING TILES

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NEAM TARIQ HUSSIN

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Chairman : Associate Professor Sharifah Mumtazah bt Syed Ahmad Abdul Rahman, PhD
Faculty : Engineering

Traditionally, a method of manual sorting of tiles based on color is being performed by human operators via visual inspection. This method is slow and tedious. Another automatic method has been developed using assembly line machines, but it requires a significant amount of space to operate. New automatic tiles sorting method based on color using a robotic arm is proposed in this study which is more effective and does not require large physical space.

This method utilizes machine vision prior to sorting, however it also faces several challenges. One of these challenges is to differentiate between similar color tiles which are partially overlapped. Another is to distinguish between white tiles and the back of overturned white.

The aim of this thesis is to develop Color-based Automatic Tiles Sorting system (CbATS) to mitigate the mentioned challenges. The CbATS consists of three main components which are a color-detection algorithm for distinguishing tiles according to the color, image segmentation that ensures the separation between partially overlapped tiles, and texture features extraction method to determine overturned tiles. For the first component, three color-based models were implemented and compared. These models are Hue, Saturation and Value (HSV); Red, Green, and Blue (RGB); and Luma (brightness), Blue-difference, red-difference chroma components (YUV). The color models are employed to investigate the effectiveness of differentiating tiles based on color. The Watershed Distance Transform with H-minima (WDTH- minima) is utilized in the second component with different H-minima to produce sufficient separation results for partially overlapped tiles. A texture feature extraction algorithm based on (standard deviation of intensities and

entropy) were developed and compared in the third component to identify overturned tiles from white tiles.

The results show that color detection using HSV model produces 100% accuracy when a yellow light is used. Besides that, using WDTH-minima segmentation method with (H-minima<=1) produced 100% of accuracy for separation tiles. Furthermore, calculating standard deviation to determine the texture feature, obtains 100% of accuracy in distinguishing between "white tile" and overturned tiles. Combination of the methods HSV, WDTH-minima, and standard deviation significantly improved the accuracy of sorting that reached 100% for the overall proposed system.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

SISTEM AUTOMASI BERPANDANGAN KOMPUTER UNTUK MENYUSUN JUBIN SEPARA-BERTINDAN

Oleh

NEAM TARIQ HUSSIN

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Pengerusi : Profesor Madya Sharifah Mumtazah bt Syed Ahmad Abdul Rahman, PhD
Fakulti : Kejuruteraan

Dahulu, satu kaedah manual penyusunan jubin berdasarkan warna telah dilakukan oleh operator atau pengoperasi manusia melalui pemeriksaan visual. Kaedah ini perlahan dan merenyahkan. Satu lagi kaedah automatik telah dibangunkan menggunakan mesin pemasangan, tetapi ia memerlukan ruang yang signifikan untuk beroperasi. Satu kaedah penyusunan jubin automatik yang baru berasaskan warna menggunakan satu lengan robotik telah disarankan dalam kajian ini, yang mana ia lebih efektif dan tidak memerlukan ruang fizikal yang besar.

Kaedah ini menggunakan mesin visual sebelum penyusunan dilakukan, walau bagaimanapun ia juga berdepan dengan beberapa cabaran. Salah satu cabarannya ialah membezakan di antara warna jubin yang lebih kurang sama, yang separa bertindan. Satu lagi cabaran ialah jubin putih dan belakang yang terbalik, berwarna putih.

Tujuan kajian ini ialah membangunkan satu sistem Penyusunan Jubin Automatik Berasaskan Warna (CbATS) untuk mengurangkan cabaran-cabaran yang terpaksa ditempuhi. CbATS terdiri dari tiga komponen utama iaitu algoritma pengesanan warna dalam membezakan jubin mengikut warna, pembahagian imej yang memastikan pemisahan di antara jubin separa bertindan, dan kaedah pengestrakan fitur tekstur untuk menentukan jubin yang terbalik. Untuk komponen pertama, tiga model berasaskan warna telah dilaksanakan dan dibandingkan. Model-model tersebut adalah Hue, Saturation and Value (HSV); Red, Green, and Blue (RGB); dan Luma (kecerahan), serta komponen-komponen kroma perbezaan biru dan merah (YUV). Model-model warna telah digunakan untuk mengkaji keberkesanan membezakan jubin berdasarkan warna. The Watershed Distance Transform with H-

minima (WDTH- minima) telah digunakan dalam komponen kedua dengan H-minima berbeza untuk menghasilkan keputusan pemisahan yang memadai untuk jubin-jubin yang separa bertindan. Satu algoritma pengestrakan fitur bertekstur berdasarkan (sisihan piawai intensiti dan entropi) telah dibangunkan dan dibandingkan dalam komponen ketiga untuk mengenalpasti jubin yang terbalik dari jubin-jubin putih.

Keputusan menunjukkan bahawa pengesanan warna menggunakan model HSV menghasilkan ketepatan 100% apabila satu cahaya kuning digunakan. Di samping itu, penggunaan metod segmentasi WDTH-minima dengan (H-minima<=1) menghasilkan ketepatan 100% untuk pemisahan jubin. Seterusnya, pengiraan sisihan piawai dalam menentukan fitur tekstur, memperolehi ketepatan 100% dalam membezakan di antara “jubin putih" dan jubin-jubin yang terbalik. Kombinasi kaedah-kaedah HSV, WDTH-minima, dan sisihan piawai memperbaiki ketepatan penyusunan secara signifikan sehingga ia mencapai 100% untuk keseluruhan sistem yang telah dicadangkan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Sharifah Mumtazah bt. Syed Ahmad Abdul Rahman, PhD
Associate Professor
Faculty of Engineering
Univerisiti Putra Malaysia
(Chairman)

Syamsiah binti Mashohor, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

_____

ZALILAH MOHD SHARIFF, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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This is to confirm that:

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Signature: _____
Name of Chairman of Supervisory Committee: Dr. Sharifah Mumtazah bt. Syed Ahmad Abdul Rahman

Signature: _____
Name of Member of Supervisory Committee: Dr. Syamsiah binti Mashohor

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LIST OF ABBREVIATIONS

2-D	Two-Dimensional
3-D	Three-Dimensional
ASM	Active Shape Model
BE-FRS	Bounded Erosion and Fast Radial Symmetry
CbATS	Colour-based Automatic Tiles Sorting System
GLCM	Gray Level Co-occurrence matrix
GUI	Graphical User Interface
HSV	Hue, Saturation and Value
HVS	Human Visual System
IP	Internet Protocol
LAN	Local Area Network
LBP	local Binary Pattern
LoG	Laplacian-of-Gaussian
PC	Personal Computer
RGB	Red, Green, Blue
ROI	Region of Interest
SIFT	Scale Invariant Feature Transform
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
UR5	Universal Robot 5
WDTH- minima	Watershed Distance Transform with H-minima
YUV	Luminance and Chromatic Components

CHAPTER 1

INTRODUCTION

This chapter presents a general introduction to traditional and modern methods of sorting tiles. In addition, the chapter describes the most important features that can be extracted from the image for automatic sorting tiles using machine vision approach. Moreover, the chapter describes the segmentation method that has been used for segment overlapping tiles. It also outlines the relevant problem statements with regards to partially overlapped or overturned tiles, the objectives of the study, as well as, the scope of the research**.**

1.1 Background

Sorting is a process by which two or more objects of similar, yet exhibit different features are arranged in an organized order. For instance, different fruits can be sorted into various categories according to their nature (Feng & Qixin, 2004). The same concept of object sorting can be applied in many fields today. Traditionally, the sorting of mosaic tiles has been a manual task performed by humans and need manual inspection. As a result of that, manual sorting is considered, tedious, low productivity and time-consuming process, especially when a large number of tiles have to be sorted. On the other hand, in modern sorting system the mechanical process and assembly line machine are used, which consequently, increases the productivity, improves the processing time but it requires huge space and it may not be practical for small to medium enterprises with space restriction. Thus, in this thesis, the sorting of tiles are done based on colors via a machine vision system with the robotic arm to perform pick and place sorting mechanism.

1.2 Automatic tiles sorting mechanism

In ceramic tiles manufacturing, sorting of tiles is a very important step before tiling and is accomplished based on appearance such as color and texture (Phooripoom & Koomsap, 2015). Traditionally, manual sorting of mosaic tiles is based on visual inspection was performed by human operators, which is tedious, time-consuming, slow and non-consistent. It has become increasingly difficult to hire personnel who are adequately trained and willing to undertake the tedious task of sorting. However, a cost-effective and consistent sorting process can be achieved by using assembly line machines. It requires a significant amount of space. Figure (1.1) shows an example of a large sorting machine.

A new machine vision for automatic tiles sorting system based on color using a robotic arm is proposed in this study. The advantages of this system include robot mobility, increase productivity and accurate sorting mechanism. A UR5 robotic arm with six-degree of freedom is used to pick up tiles based on their color and place

them at their respective positions, using input from a machine vision system. However, the sorting process may not be straightforward due to the partially overlapped tiles in a practical environment. Thus there is a need to develop an effective machine vision which is able to differentiate partially overlapped tiles based on the distinguishing characteristic.

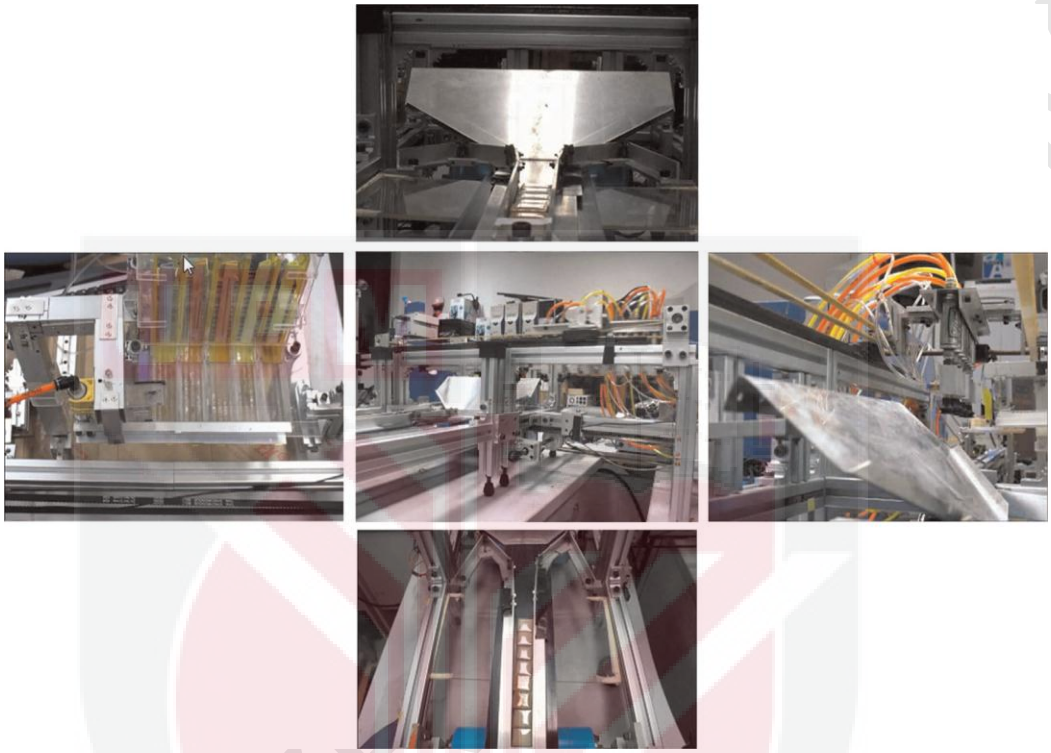

Figure 1.1 : Example of machines used with sorting mosaic tiles
(Phooripoom & Koomsap, 2015)

1.3 Tiles Color features

Different colors of mosaic tiles can be easily sorted manually by humans, but the grouping and sorting of these tiles according to their color are trivial when done manually and it is a difficult process when done digitally using computer-based simulation. Color feature extraction has been of great help in identifying objects. For that reason, color can be considered as one of the important criteria in which the sorting system needs to detect and localize partially overlapped tiles based on it. It is often useful to simplify a monochrome problem by improving the contrast. The process of color detection involves the extraction of useful information about the spectral properties of objects surfaces, and the discovering of the best match from a set of known descriptions, or class models to implement the recognition task. As a first step, the overlapped areas can be visibly differentiated by representing the tiles by their color. In image processing, there are several pre-existing color models for describing the specification of the colors such as Red, Green and Blue (RGB) model, luminance and chromatic components (YUV) model, and Hue, Saturation, and Value

model (HSV) , (Soleimanizadeh, Mohamad, Saba, & Rehman, 2015). This thesis makes use of different color models such as RGB color model, YUV color model, and HSV color model to investigate the most effective model among them for sorting tiles with high accuracy.

1.4 Tiles texture features

The visual inspection of a tile's surface is one of the most important steps in the automatic sorting system. In industries, texture feature inspection is considered as the main feature of their product. For instance, tiles surfaces are inspected for smoothness and roughness quality, defect detection and color grading, (Karimi & Asemani, 2014); (Bianconi, González, Fernández, & Saetta, 2012); (Novak & Hocenski, 2005). Texture feature extraction can be used to distinguish between different patterns of tiles, by extracting the intensity dependencies between pixels, and their neighboring pixels, or by obtaining the intensity variance across pixels. Texture analysis based on the local spatial variation of intensity or color brightness serves an important role in many applications (Srinivasan & Shobha, 2008). It can be used to differentiate between tiles with similar colors and shapes but dissimilar in texture. These features can be extracted using several methods such as statistical, structural, model-based and transform information. In this study, a standard deviation for intensity values is extracted (Sergyan, 2008) as a histogram first-order statistical features, in order to differentiate "white" tiles from overturned tiles with a white surface.

1.5 Segmentation partially overlapping tiles

The sorting of an individual object from randomly scattered objects is one of the classical scenarios in robotic sorting, Figure (1.2) shows an example of overlapped mosaic tile. Effective image segmentation is the main requirement for the automatic sorting of objects via the use of robots. Traditional segmentation schemes are not capable of segmentation and labeling of overlapping tiles. The reason is that overlapped same color tiles need multiple labels for effective detection. The partially overlapped tiles with the same color must be segmented from each other accurately to be sorted. Numerous methods have been proposed to segmentation of partially overlapping objects such as Segmentation of Overlapping Elliptical Objects using K-Mean Clustering Method (S. Kaur & Mittal, 2017), SIFT-based Segmentation of Multiple Instances of Low-Textured Objects (Piccinini, Prati, & Cucchiara, 2013). Watershed distance transform algorithm is applied by using H-minima as a marker in this thesis. It is valuable for separating objects that are close or overlapped in the image and is less susceptible to overall intensity variations (Meyer & Beucher, 1990).

Figure 1.2 : Example of partially overlapped tiles

1.6 Problem statement

Most detection and object sorting systems consider the situation of well-alienated, and well-separated objects (Jia, Yang, & Saniie, 2017); (Tho & Thinh, 2015); (Tsarouchi, Matthaiakis, Michalos, Makris, & Chryssolouris, 2016). In this case, a simple guide proved to be sufficient to initiate the picking of the objects. However, there are several applications in which these approaches will be unsatisfactory, since imposing the objects to stay well-separated, and aligned on the working area, will waste space, and time of the process. Sorting partially overlapping tiles usually face several challenges.

Problem 1: Differentiate tiles based on color

Different color models have been used for labelling, and segmentation of specific color features of objects such as Red, Green and Blue (RGB) color model (Wu, Wang, Huang, & Xu, 2015) , luminance and chromatic components (YUV) color model ()Mohammed & Amer, 2017(), and Hue, Saturation, Value (HSV) color model, (Hamuda et al., 2017; (Hamuda, Mc Ginley, Glavin, & Jones, 2017). However, these color models can detect the color of objects, but detection process may fail, as some of these color models affected by the light conditions, the separation of light and chromatic information could be unclear. As a result of that, there is a need to analyze and investigate the most efficient color model amongst other models in which it can adapt to different environmental illumination conditions with high accuracy of differentiating tiles based on color.

Problem 2: Partially overlapped tiles

To reduce space requirement, tiles are partially overlapped. The separation of the same color tiles that have been partially overlapped considered is a challenge as in image processing, if there is more than one object of the same color being partially

overlapped, then they will be considered as one object geometrically (Molnar, Kato, & Jermyn, 2015); (Shu, Fu, Qiu, Kaye, & Ilyas, 2013b); (L. Xu, Lu, & Zhang, 2014) and they will be grouped as one object with the same boundary. As a result of that, there is a need to develop an effective algorithm to differentiate partially overlapped tiles. In this thesis, a suitable region-based segmentation method is applied, which is Watershed Distance Transform with H-minima as a marker (Jung & Kim, 2010), to separate tiles with the same color.

Problem 3: Some tiles may be overturned

In an unsorted tiles environment, identify the white tiles and the overturned tiles which has a white surface can be confused with tiles. Color, in this case, will not be enough to distinguish "white" tiles from overturned tiles, as they hold same color and shape. Therefore, there is a necessity to differentiate white tile from the overturned tile as they have the same color. Texture analysis plays an important role in determining a specific pattern of tiles. Add to that, texture surface tiles inspection can be used as a vital clue to identify and differentiate between white tiles and overturned white tiles. Different texture analysis has been proposed by researcher, (YongHua & Jin-Cong, 2015) for wood surface defect detection, (Ghazvini, Monadjemi, Movahhedinia, & Jamshidi, 2009a); (Bertalya, Prihandoko, Oktavina, & Febrianto, 2013), to inspect tiles surface for grading and determining tiles defect. In this thesis, an effective histogram-based texture feature extraction method is proposed and applied (Sergyan, 2008), in which a standard deviation of intensities for each tile surface has been calculated to discriminate the white tiles from overturned white tiles in order to complete the sorting process with optimum results.

1.7 Research aim and objectives

This research aims to design and develop an effective machine vision color based tiles sorting system via the use of a robotic arm. The main aim can be further divided into the following objectives

i. To investigate the effectiveness of differentiating tiles based on their color under different color schemes.
ii. To design an effective algorithm to segment partially overlapped tiles of the same color.
iii. To investigate the effectiveness of using texture features to differentiate the white tiles from the overturned tiles with a white surface.
iv. To design and develop a robotic arm instructions translation to extract the color and information of individual tile for robotic arm sorting operation.

1.8 Scope of the study

1. In this study, for the machine vision, a single top position camera is used as an input device for capturing images of partially overlapped mosaic tiles
2. A light source from an incandescent lamp is used, which is installed near the inspection area so that, important tiles characteristics can be easily extracted.
3. The tiles size used in this study is limited to 25mm x 25mm with three color, red, black and white with 100 tiles are scattered over a working surface.
4. Three working surfaces for the inspection area of tiles were used which are orange, blue and green.
5. A slider system is used as a platform to place the square tiles accordingly.
6. A 6-degree of freedom Universal Robotic arm (UR5) is used for picking and placing the tiles, with the height of the robot set uniformly for all tiles
7. Efficiency i.e of the robotic arm will be measured but will not be used as the main performance indicator as it is affected by the mechanical constraints of the robotic arm.
8. Evaluations are carried out with regards to effectiveness hence accuracy in performing the relevant task.

1.9 Thesis contribution

Briefly outlined in this section are the contributions in this thesis:

i. This thesis investigated the effectiveness of differentiating tiles based on their color using different color schemes.
ii. An algorithm to separate the partially overlapped tiles is proposed
iii. An algorithm to differentiate white tiles and overturned tiles with white surfaces is proposed.
iv. The implementation of the proposed tiles sorting algorithms via the use of the UR5 robot.

1.10 Thesis Layout

The thesis comprises of 5 main chapters, whereby chapter 1 gives a background on the sorting of objects, tiles sorting, color and texture features extraction for sorting tiles. The chapter also points out the problem statement, objectives and the scope of the thesis. Chapter 2, gives a review of previous studies about object sorting, feature extraction, and image segmentation. Chapter 3 explains the proposed framework on the detection of positions and colors of overlapped mosaics tiles. The methodologies utilized are also explained in details. Chapter 4 presents the analysis of the experimental results obtained. Finally, chapter 5 provides a conclusion and recommendation for future studies.

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BIODATA OF STUDENT

Neam Tariq Hussin Almalah received her Bachelor of Science degree in Electrical and Electronics Engineering from the Mosul University in Iraq, State, Mosul in 2007. After graduation from a Bachelor degree. She was appointed as Assistant engineering in the 2007 University of Mosul. In the same year of her youth service, she worked as assistant engineering at labs of image processing, digital signal processing, Graphic, signal, and system. Later in 2016, she was admitted to the Department of Communication and Computer Systems Engineering, Universiti Putra Malaysia, where she is currently a postgraduate student. His research interests include Image processing and Robotics.

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