DETECTION OF MISPLACED AND MISSING REGIONS IN IMAGE USING NEURAL NETWORK

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DETECTION OF MISPLACED AND MISSING REGIONS IN IMAGE USING NEURAL NETWORK

by

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LIST OF SYMBOLS

blockVectorC	Size of the column image
blockVectorR	Size of the row image
Bluechannel	Blue value of the pixel of the regions
Greenchannel	Green value of the pixel of the regions
I	Read image
I_resize	Resize image
I_tiles	Image pieces
numberOfColorBands	Three dimension image
Redchannel	Red value of the pixel of the regions
rgbBlock	One of the piece of the image
rgbImage	Array of pixel of the regions

LIST OF ABBREVIATIONS

B	Bias
PCB	Printed Circuit Board
RGB	Red Green Blue
SCG	Scaled Conjugate Gradient
W	Weight

Pengesanan Kawasan Salah Letak dan Hilang dalam Imej Menggunakan Rangkaian Neural

ABSTRAK

Teka-teki jigsaw adalah gambar bercetak yang dipotong menjadi pelbagai kepingan dalam bentuk yang berbeza-beza. Permainan ini memerlukan cantuman pelbagai kepingan berbentuk ganjil untuk menghasilkan gambar yang lengkap. Walau bagaimanapun, kepingan teka-teki jigsaw yang salah letak atau hilang sukar dikesan oleh mata manusia. Keadaan ini boleh dihubungkait dengan litar di atas papan reka, yang mempunyai keadaan yang sama iaitu mempunyai pelbagai jenis komponen di atas papan. Berdasarkan kepada kajian, kebanyakan algoritma tidak cukup pintar dan hanya mampu mengesan komponen yang hilang sahaja. Oleh itu, pembangunan algoritma yang dapat mengesan kedua-dua kepingan teka-teki jigsaw yang salah letak dan hilang amat diperlukan. Objektif utama projek ini adalah untuk membangunkan sistem pintar bagi menyelesaikan teka-teki jigsaw dengan menggunakan perisian Matlab. Sistem yang dibangunkan ini terdiri daripada fasa pemprosesan imej dan rangkaian neural. Dalam fasa pemprosesan imej, imej yang ditangkap dibahagikan kepada kawasan-kawasan dan nilai RGB (merah hijau biru) bagi setiap kawasan diperolehi. Rangkaian neural yang digunakan dalam kajian ini terdiri daripada rangkaian neural rambatan belakang. Ia dilatih dengan menggunakan algoritma latihan kecerunan konjugat berskala. Rangkaian neural menggunakan nilai RGB daripada fasa pemprosesan imej dan menganalisa setiap kawasan untuk memeriksa sama ada kepingan teka-teki jigsaw salah letak atau hilang. Dua eksperimen telah dijalankan; prestasi masa ketika sistem menganalisa kawasan dan keupayaan sistem dalam mengesan kepingan teka-teki jigsaw yang salah letak dan hilang. Daripada keputusan, didapati bahawa masa yang diperlukan untuk sistem menganalisis 20 kepingan imej adalah sekitar 89 saat. Sistem juga memberikan ketepatan hampir 100% dalam mengesan kepingan imej teka-teki jigsaw yang hilang atau tidak berada betul pada tempatnya.

Detection of Misplaced and Missing Regions in Image Using Neural Network

ABSTRACT

Jigsaw puzzle is a printed picture that is cut into various pieces of different shapes. The game requires assembly of many oddly shaped pieces into producing a complete picture. However, misplaced or missing jigsaw puzzle pieces are difficult to be detected by human eyes. This scenario can be bridged to circuit on the breadboard, which also has similar condition like having several components on the board. Based on research, most of the algorithms are not intelligent enough and only able to detect the missing component. Therefore, it is necessary to develop an algorithm that is able to detect both misplaced and missing jigsaw puzzles. The main objective of this project is to develop an intelligent system to solve the jigsaw puzzle using Matlab software. The developed system consists of the image processing and the neural network phases. In image processing phase, the captured image is split into regions and the RGB (Red Green Blue) value of the regions is obtained. The neural network used in this research is a back-propagation neural network and it is trained by using Scaled Conjugate Gradient training algorithm. The neural network uses the RGB value from the image processing phase and analyzes the regions to check whether there is misplaced or missing jigsaw puzzle. Two experiments have been conducted, which are time performance in order for the system to analyze the regions and the ability of the system in detecting the misplaced and missing jigsaw puzzle. From the result, it is found that the time needed for the system to analyze 20 pieces of the image is around 89 seconds. The system also gives almost 100% of accuracy in detecting the missing or misplaced regions of the jigsaw puzzles image.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Jigsaw puzzle is a printed picture that is cut into various pieces of different shapes. The game requires assembly of many oddly shaped pieces into producing a complete picture. To date, the jigsaw puzzle is available both on the cardboard and also via simulation on the computer. There are many types of pieces of jigsaw puzzle; From 12 pieces which normally used by the six years old kids, until 24000 of pieces which is used by secondary students and above. Figures 1.1 and Figure 1.2 show the type of pieces of jigsaw puzzle available in the market. Figure 1.1 shows a very simple picture of jigsaw puzzle but Figure 1.2 shows a more complicated picture of jigsaw puzzle.

It is clearly shown that the Figure 1.1 jigsaw puzzle is very easy to complete, less time usage and less error as compared to Figure 1.2 jigsaw puzzle. Figure 1.2 jigsaw puzzle may need up to two to three months in order to complete the jigsaw puzzle. After the completion of the Figure 1.2 jigsaw puzzle, it is also difficult to figure out the error by using the human eyes. Besides that, the human eyes also ineffective in figuring out the similar pieces of the jigsaw puzzle.

Figure 1.1: 12 pieces of jigsaw puzzle (Karmin, 2016)

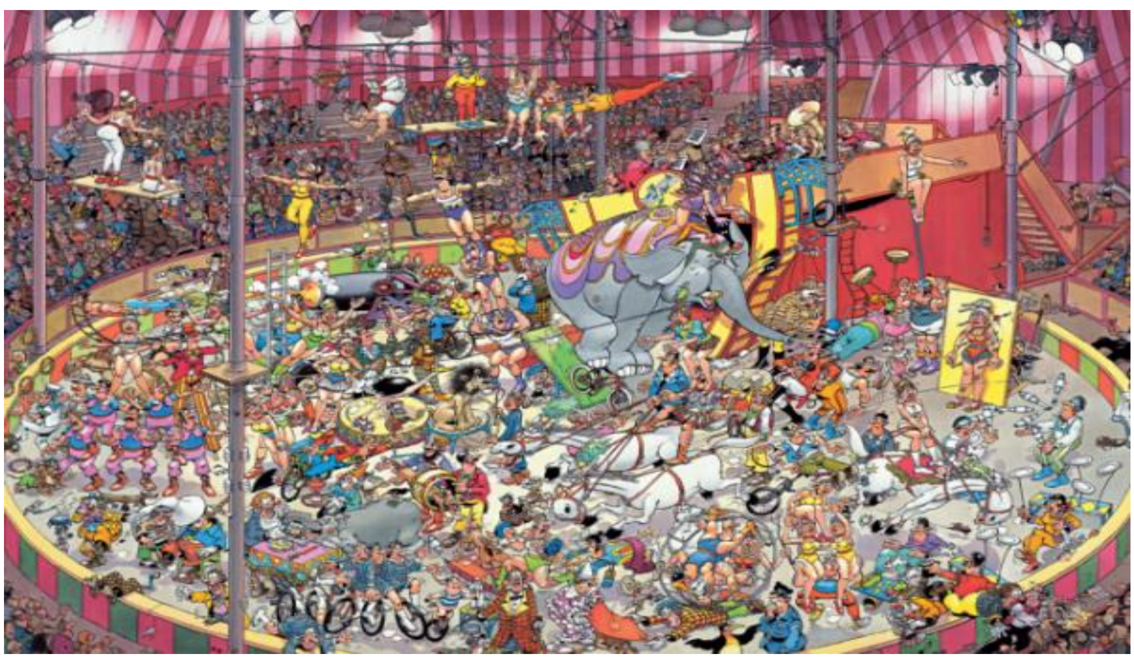

Figure 1.2: 5000 pieces of jigsaw puzzle (Jumbo, 2016)

On the other hand, breadboard is a white board that enables the user to assemble components to form an electric circuit (Davis, 2016). Components come in various type, shape and colours. They may have many combinations on the breadboard, for example as one shown in Figure 1.3. The right component selection, placement and connection on the board will determine whether the circuit is functioning correctly or not. Components on the breadboard have similar complexity to the jigsaw puzzle, in which, the possibility of misplaced and missing component may occur. Misplaced or missing of the components on the breadboard is also very difficult to be detected by using human eyes which is similar to the jigsaw puzzles issue.

The printed circuit board (PCB) also carries the same issue. For a complicated system, the circuit is also become more complex with various components involved. Figure 1.4 shows example of two layers printed circuit board. Based on study, there are a few problems that lead to PCB defect such as open and short circuit, misaligned, missing electrical component, defective electrical component, wrong component and excess solder (Houdek, 2014). Among all these factors, missing electrical component, misaligned and wrong component showed the 12%, 8% and 5%, respectively of the overall defects in the PCB circuit, which are relatively high among the defects (Houdek, 2014). Thus, problem of misplaced or missing components need to be addressed in order to improve the time and cost during manufacturing process.

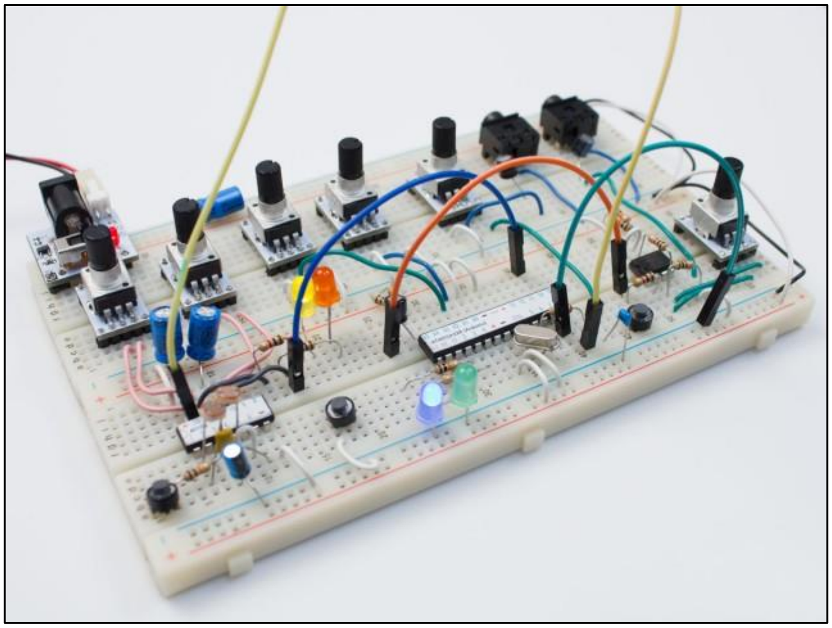

Figure 1.3: Circuit on the breadboard (Kirn, 2015)

Figure 1.4: Circuit on PCB (Cohen, 2010)

1.2 Problem Statement

As mentioned in previous section, misplaced or missing components on the breadboard and misplaced or missing of jigsaw puzzle pieces are very difficult to be detected by using human eyes. Misplaced or missing of the components on the breadboard will cause the circuit to be incomplete circuit. Misplaced or missing jigsaw puzzle pieces will cause the jigsaw puzzle to be incomplete jigsaw puzzle as well.

The condition of placing each of the components correctly on the breadboard is also similar to the case of placing each of the pieces correctly to complete a jigsaw puzzle. The more the jigsaw pieces, it means that the greater complexity of matching the whole picture. Higher complexity of the jigsaw puzzle, it means that it is more difficult to detect the misplaced or missing jigsaw puzzle pieces by only using human eyes.

In Yao *et al*. (2002), the jigsaw puzzle can be solved by combining the shape and edge of the jigsaw puzzle piece and match it with the other pieces. The algorithm will capture the shape of the image and measure the edge of each piece of the puzzle and match them together (Yao *et al*, 2002). However, this approach cannot help in finding a misplaced or missing jigsaw puzzle pieces.

Therefore, in order to save time to find out the error and to detect the misplaced or missing component if occur, an intelligent system is required. In this study, a system which consists of the image processing and artificial neural network will be used to detect the misplaced and missing pieces of the jigsaw puzzle image.

1.3 Motivation

Nowadays, many of the applications are using the artificial intelligence systems to provide a service to the human's life. Artificial intelligence is a computer system that imitates the human intelligence in order to perform a task (Russell *et al*, 2009). There are many applications that are controlled by artificial intelligence system such as Google Search Engine, smart cars, computer games and so on (Albright, 2016). Artificial intelligence becomes a necessary computer system, in which, almost 100% of applications will be using artificial intelligence in year 2025 (Smith *et al*, 2014).

The idea of developing an artificial neural network algorithm that able to detect both misplaced and missing pieces of jigsaw puzzle image comes from an AlphaGo computer program which used artificial intelligence as the algorithm.

AlphaGo is a computer program developed by Google DeepMind by using two neural networks (Techopedia, 2016). In October 2015, this artificial intelligence technique had beaten the best European champion, Fan Hui with the winning of 5 – 0 match in the Go game, a board game originated from China more than 2500 years ago (Google Inc., 2016).

In March 2016, AlphaGo beat the Go game world champion, Lee Sedol as shown in Figure 1.5 with 4 – 1 matches. This is the very first artificial intelligence computer program that won against a professional human player. On this date, the world history has been written.

The reason behind of AlphaGo winning against the top world champion is through learning from the match and predict the movement of the opponent few steps more than the opponent. AlphaGo learned the game by using the simulation itself (Techopedia, 2016). This shows that the AlphaGo is able to behave and think like a human. This is the first step that the artificial intelligence system can think and learn like a human. This would be beneficial to human especially in solving complex issues in the future.

The idea of using the artificial intelligence algorithm to challenge the Go game inspired the use of similar technique to solve the jigsaw puzzle game. The ability to identify misplaced and missing pieces can be transformed to ability to identify misplaced and missing components on the PCB. In this study, an artificial intelligence algorithm is developed in detecting misplaced or missing regions in the jigsaw puzzle image.

Figure 1.5: South Korean player, Lee Sedol competing with AlphaGo (Techopedia, 2016)

1.4 Objectives

The objectives of this research are:

1. To develop a misplaced and missing detection system by using image processing and artificial neural network approach.
2. To detect the misplaced and missing regions in image and measure the accuracy.

1.5 Scope

A system which consists of image processing and neural network is developed using Matlab Version R2013a in solving the jigsaw puzzle and circuit on the breadboard. 20-piece and 60-piece picture jigsaw puzzles are used in this research. A fourth order low pass filter circuit is used as example for circuit on the breadboard. Firstly, a sample of jigsaw puzzle and the circuit on the breadboard are captured by using a Canon Digital IXUS 80 IS 8 Mega Pixel compact camera. The system is used for checking the sample image compared to the original image and finding out misplaced or missing pieces of jigsaw puzzle as well as the misplaced or missing component on the breadboard. Then the system will pinpoint the misplaced or missing region.

The neural network is trained by using 10 samples of the images and 10 samples of the background images. Each of the images is taken with the size of 1600 x 1200. One sample is taken for detecting the misplaced or missing region. The jigsaw puzzle and the circuit on the breadboard are fixed on one direction only during the testing. For the hardware, an ASUS laptop computer with first generation Intel i5 with 4 GB of RAM is used for simulation study.

1.6 Thesis Outline

This thesis is about the study on detection of misplaced or missing jigsaw puzzle pieces by using artificial intelligence approach. In this thesis, Chapter 1 covers the research background, problem statement and motivation in conducting the research project. The objective and scope of study are also stated in this chapter. The theory, basic principle and a review of previous related work of the method of solving jigsaw puzzle and detecting missing components on PCB board are covered in Chapter 2 of the thesis. Next, the methods and techniques used in this research are discussed in Chapter 3. The result and the conclusion are covered in Chapter 4 and Chapter 5 of this thesis, respectively.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Theory and basic principle of solving jigsaw puzzle are discussed in detail in this chapter. It covers the artificial neural network, type of neural network and type of training algorithm. Previous works related to the research study are also discussed in this chapter.

2.2 Artificial Neural Network

Artificial Neural Network is a computational model based on the biological neural networks structure and functions which mean that it functions like a human neural network system in the brain. Artificial Neural Network is able to learn or change like human mind based on the information that flows through the network and it will affect the structure of the Artificial Neural Network (Hassoun, 2003; Templeton, 2015; Techopedia, 2017).

Artificial Neural Network is a nonlinear statistical data modelling tools which used for modelling the complex relationship between inputs and outputs and it also contains a minimum of three layers that are interconnected which are inputs layer, hidden layer and output layer as shown in Figure 2.1. However, the accuracy of the Artificial Neural Network can be improved by increasing the number of hidden layers which are used for processing the inputs (Castrounis, 2016).

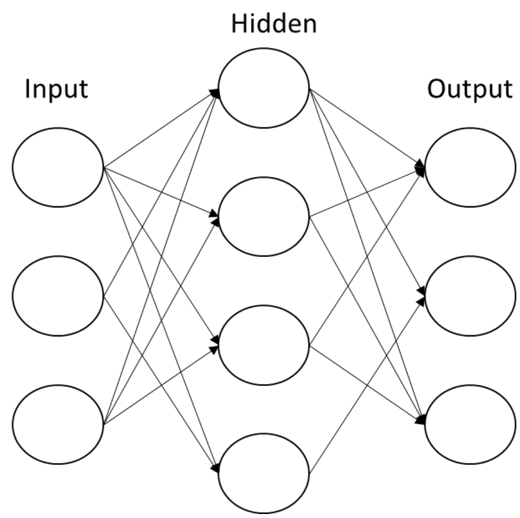

Figure 2.1: Artificial Neural Network

2.2.1 Type of Artificial Neural Network

According to Hinton *et al.* (2017), there are a few types of neural network; those are feed-forward neural network, recurrent networks and symmetrically connected networks. Feed-forward neural networks are the most commonly used neural network type. It only consists of one layer of input, one layer of output and one layer of hidden layer as shown in the Figure 2.2. It is commonly used in the classification and prediction (Clabaugh *et al*., 2000).

Recurrent network is a type of neural network that directed cycles in their connection graph as shown in the Figure 2.3. It is very complicated and very difficult to train but they are more biologically realistic. It can be used in the prediction as well. Symmetrically connected networks is similar to recurrent networks.

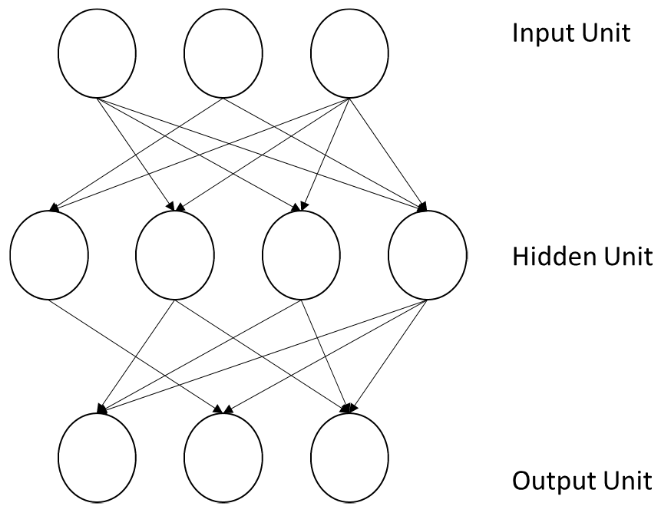

Figure 2.2: Feed forward neural network (Hinton *et al.*, 2017)

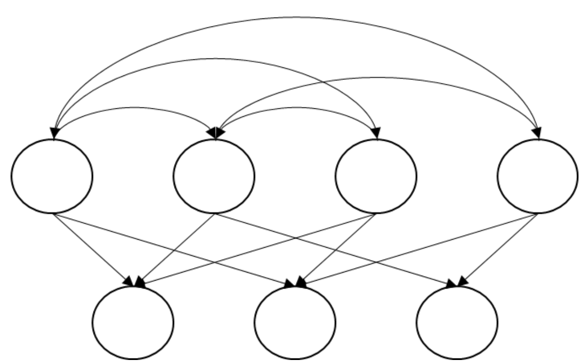

Figure 2.3: Recurrent networks (Hinton *et al*., 2017)

2.2.2 Back-Propagation Network

Back-propagation network is a multilayered, feed-forward neural network (Lu, 2000). According to Clabaugh, *et al.* (2000), feed-forward neural network have some characteristics which are:

i. Each neuron are arranged in layers with the first layer is the input layer and followed by hidden layer and lastly output layer. Hidden layer has no interaction with the input and output.
ii. Each neuron is connected to the next layer neurons.
iii. There is no connection between the neurons at the same layer.

Each weight is associated with the neurons in each layer of the network (Leverington, 2009). Feed-forward neural network is commonly used as classification. It can vary number of neurons in input layer, output layer and hidden layer as well as the number of layers.

Back-propagation neural network is used to minimize the squared error of the output value as compared to the desired value during the training of the network. The main purpose of training the back-propagation is to modify the weight of each layer of the network so that the network is able to generalize the relationship between the input and the output (Leverington, 2009). Therefore, in order to perform classification with the minimum amount of mean squared error for the neural network, it is suitable to use the back-propagation neural network.

2.2.3 Type of Training Algorithm

There are a few types of training algorithm that are commonly used (Quesada, 2017; Haykin, 1998). Gradient descent which is the simplest training algorithm is the most commonly used training algorithm. It is a first order method. It can help to save memory due to it only saves the gradient vector. It also can be used in a large neural network which contains a lot of parameters. Newton's method is a second order of training algorithm which makes use of the Hessian matrix. It can be used to find better training directions by using second derivatives of the loss function. However, due to usage of the Hessian matrix, it becomes a very complex training algorithm.

Conjugate gradient is also one of the training methods. It has a better training speed as compared to the gradient descent. It also has a more effective training method as compared to the gradient descent. There are a few types of conjugate gradient; those are scaled conjugate gradient, Powell conjugate gradient and Fletcher-Powell conjugate gradient (MathWorks, 2017). According to MathWorks (2017), for pattern categorization, scaled conjugate gradient is the most suitable training algorithm due to its speed and its ability to handle a lot of data at a time.

Quasi-Newton training algorithm is one of the Newton's training algorithm application. It is computationally expensive due to it requiring many operations to evaluate the Hessian matrix and compute its inverse. It is faster than gradient descent and conjugate gradient but required a lot of memory due to the Hessian matrix.

2.2.3.1 Scaled Conjugate Gradient Training Method

Scaled Conjugate Gradient (SCG) is one of the class of Conjugate Gradient methods which is an optimization technique in numerical analysis. Although SCG is using second order information from the neural network, it requires a very low memory usage. Its performance is comparable to the current existing techniques (Moller, 1990).

In comparison to the conjugate gradient back-propagation and Broyden-Fletcher-Goldfarb-Shanno memory less quasi-Newton algorithm, SCG's speed is much faster than those techniques. SCG algorithm also has a lower mean absolute percentage error as compared to the Lavenberg-Marquardt algorithm and Bayesian Regularization back-propagation algorithms (Baghirli, 2015).

Therefore, the SCG algorithm is suitable in handling massive data especially in handling high resolution of images due to its high speed in handling those data and has low mean absolute percentage error.

2.3 Methods for Solving Jigsaw Puzzle

Various methods have been developed in solving the jigsaw puzzle. Yao and Shao (2003) said that every canonical jigsaw puzzle has four corner points. Each of the corner points can be fitted into three patterns which are a straight lined edge, a concaved and curved edge, and a convexed and curved edge. Those patterns can help to classify the jigsaw puzzle into corner piece, edge piece and interior piece. After the classification, a pattern matching algorithm was used to match the boundary shape to identify the candidates for neighboring pieces. Then, image merging was performed between the current pieces and all the candidates as shown in Figure 2.4 where R_i^{MN} represents clockwise corner piece from start point *M* to end point *N* of number of i^{th} pieces and E_i^{MN} represents clockwise edge piece from start point *M* to end point *N* of number of i^{th} pieces.

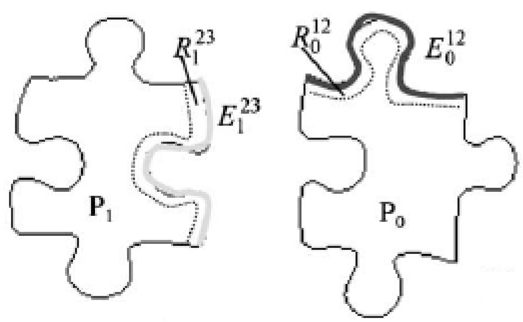

Figure 2.4: Matching with Other Jigsaw Pieces (Yao and Shao, 2003)

Mahdi (2005) also proposed a similar algorithm to Yao and Shao solution in solving the jigsaw puzzle. The author used the computer vision to capture every single piece of the jigsaw puzzle and applied morphological operations to reduce the noise. After that, the corner points of every piece of the jigsaw puzzle were detected and the inner pixel of the image was removed in order to leave the border of jigsaw puzzle as shown in Figure 2.5. This was to allow the algorithm to not to confuse with the image of the jigsaw pieces. Finally all the pieces will be matched by comparing with the border of the jigsaw puzzle pieces.

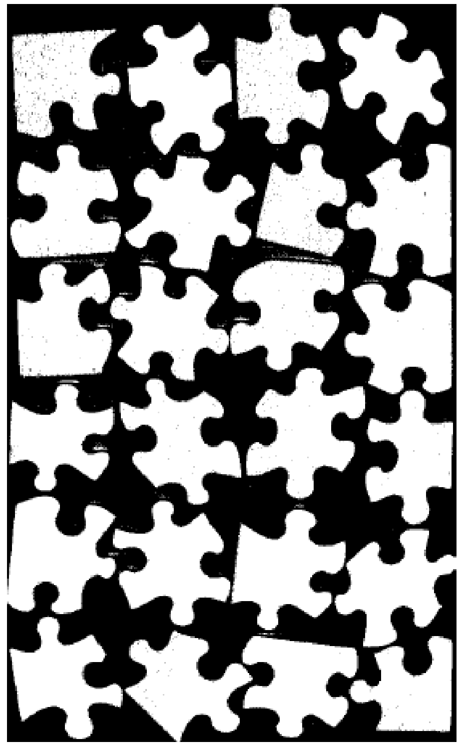

Figure 2.5: Captured image of the puzzle by removing the inner pixels (Mahdi, 2005)

Sholomon *et al*. (2013) proposed a genetic algorithm in order to solve a very large jigsaw puzzle. A genetic algorithm contains a population of chromosomes and each of them represents a possible solution to the problems. The algorithm was used to generate 1000 random chromosomes and evaluate all chromosomes fitness function. After that, two parents' chromosomes were chosen and crossover those to generate a child chromosome which was a complete solved jigsaw puzzles as shown in the Figure 2.6.

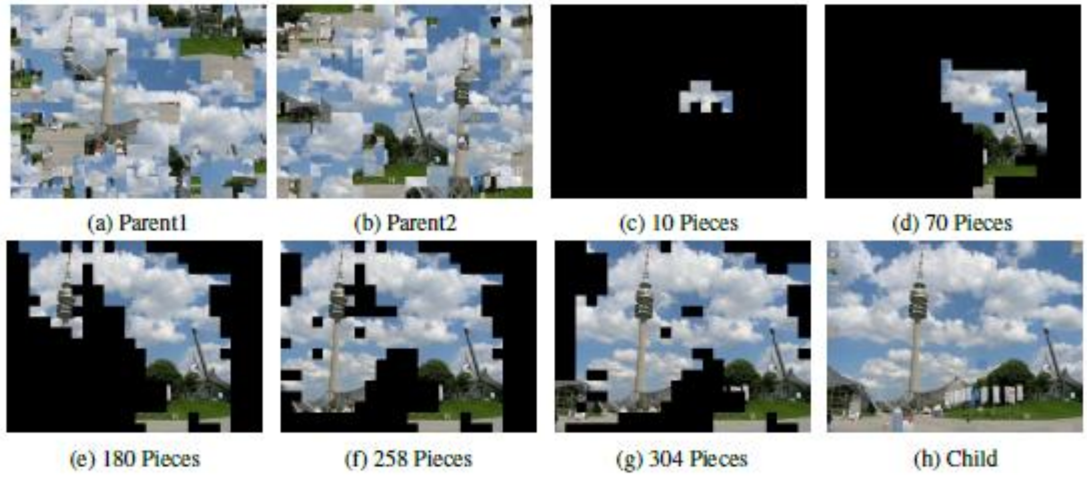

Figure 2.6: Crossover of two parents' chromosomes and generate a child chromosomes (Sholomon *et al*., 2013)

Gindre *et al.* (2010) combined both neural network and genetic algorithms and developed an Intelligent Robotic System. This system consisted of two previously discussed algorithms: Genetic Algorithm and Matching Jigsaw Border Algorithm to solve the jigsaw puzzle with the limited amount of time. This algorithm can be used to solve canonical jigsaw puzzles. The study proposed that the jigsaw puzzles is represented as a multi-graph where each node stands for a piece of the puzzle and each edge establishes a border to border adjacency between two pieces while the genetic algorithm is redesigned to fulfill to the graph approach as shown in Figure 2.7.

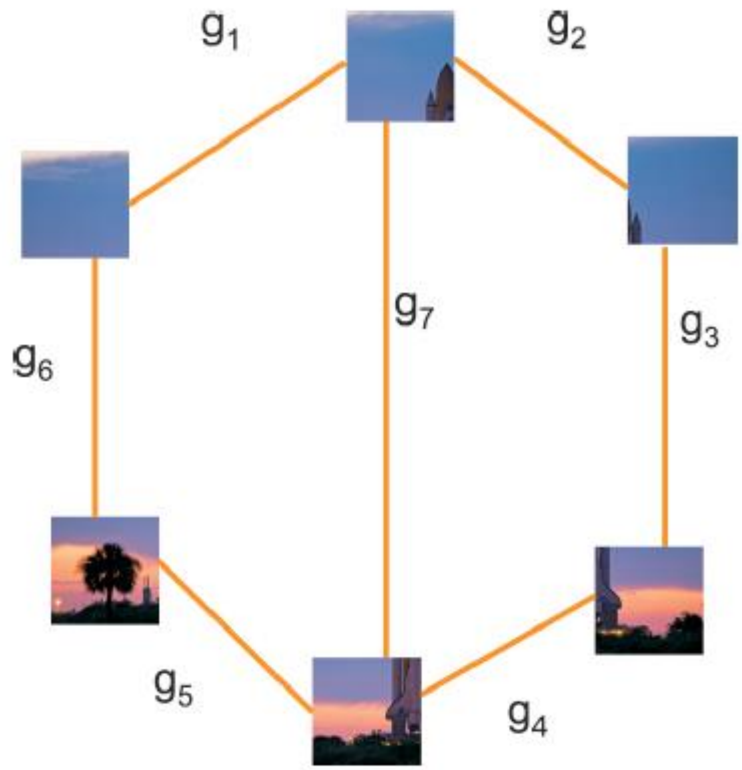

Figure 2.7: Jigsaw puzzle pieces represented as a graph (Gindre *et al*., 2010)

2.4 Methods for Detecting the Missing Component

In detecting the missing component on the printed circuit board, there are a few methods that also being developed. One of them was using vision based inspection system which was implemented by Mogharrebi *et al*. (2016) as shown in Figure 2.8. This system was used to detect the missing footprint on the printed circuit board. Fuzzy logic was used during the classification. The image was first converted into RGB format by using image processing tools. After that, the footprints were classified by using two fuzzy techniques which were Sugeno fuzzy and Mamdani fuzzy as to improve the quality of the classifications as shown in the Figure 2.9. Then, the system was able to detect the missing footprints based on the outcome of classification of the fuzzy logic techniques.

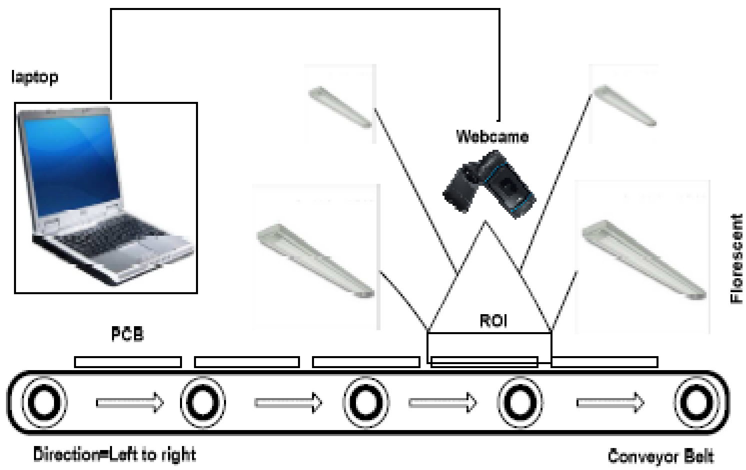

Figure 2.8: Vision based inspection system (Mogharrebi *et al*., 2016)

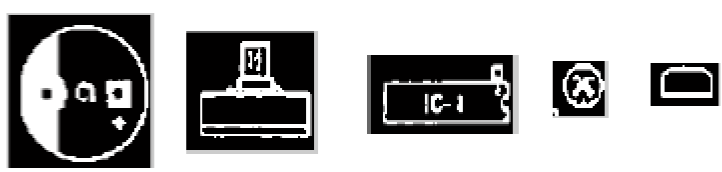

Figure 2.9: Classification of the footprints (Mogharrebi *et al*., 2016)

There are some reported works that used background subtraction to find the missing component on the printed circuit board. For example, Bhardwaj (2016) used image subtraction for finding the missing component in the printed circuit board. The image was converted into grayscale format so that the system would not get confused by the color of the image during image subtraction. After that, the image of correct printed circuit board was subtracted with the incorrect image as shown in the Figure 2.10. Then, region of interest algorithm was used to locate the missing component as shown in Figure 2.11.

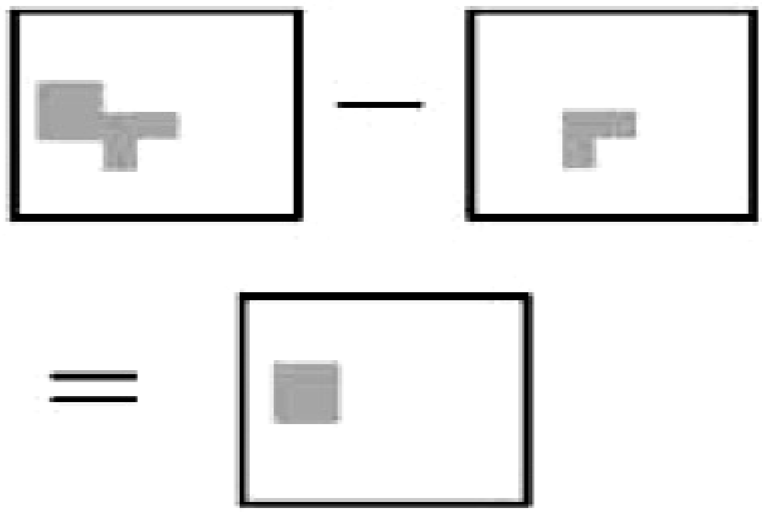

Figure 2.10: Image subtraction (Bhardwaj, 2016)

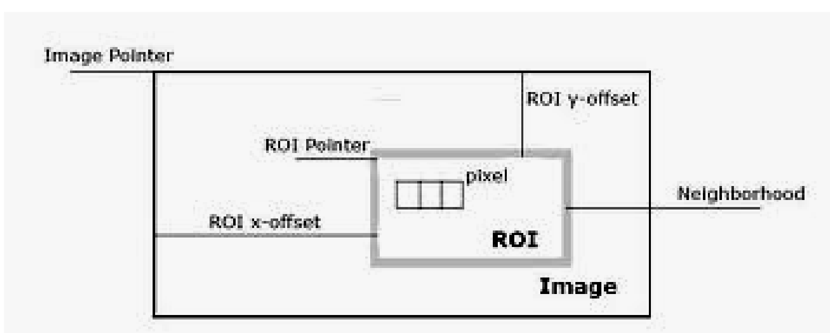

Figure 2.11: Locate missing component using region of interest algorithm (Bhardwaj, 2016)

Sundaraj (2009) used similar techniques to find missing or misaligned components using background subtraction. The system was taught to learn the background from a correct printed circuit board image by capturing the RGB value from a randomly sampled printed circuit board and tabulated in a histogram as shown in Figure 2.12. After the system had learned the background, then the system was able to do background subtraction without converting the image to grayscale as shown in Figure 2.13.

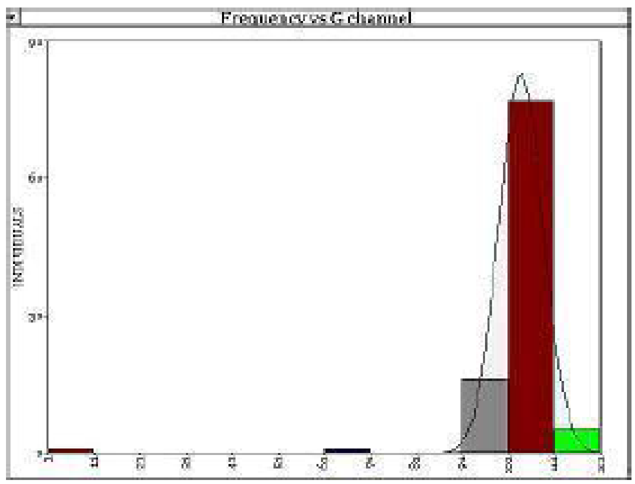

Figure 2.12: RGB value of the sampled image (Sundaraj, 2009)

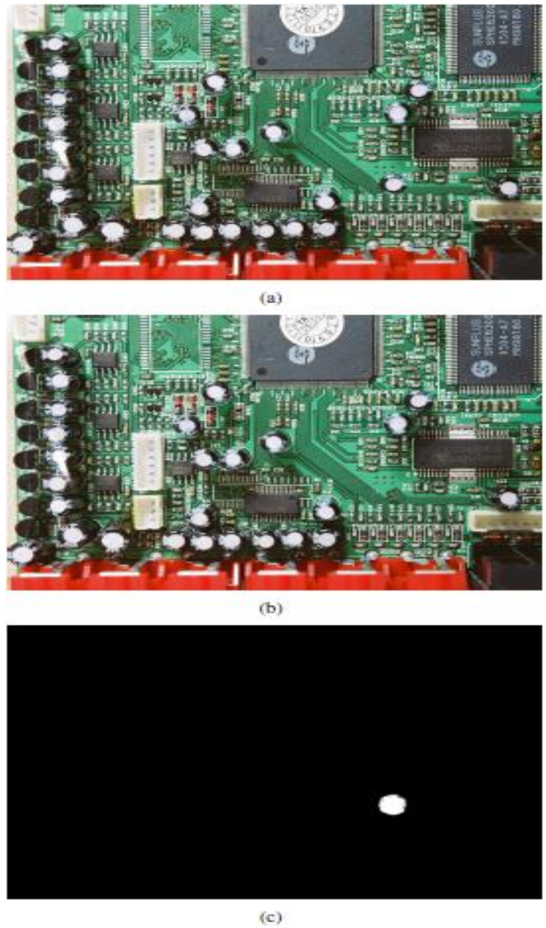

Figure 2.13: Background subtraction (Sundaraj, 2009)

Singh and Bharti (2012) also used background subtraction to detect the missing component on the PCB board in the Automatic Visual Inspection System. The grayscale image with noise removal was used as shown in the Figure 2.14. This algorithm was not only able to detect the missing component but also able to detect the missing trace line on the PCB board as shown in the Figure 2.15. The defect localization algorithm was also used to notify the user the location of the missing component and missing trace.

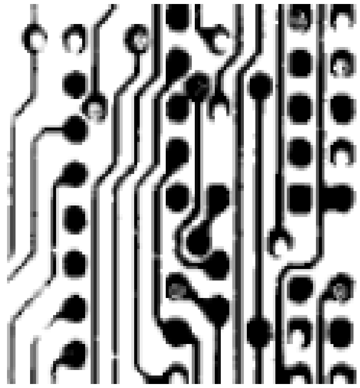

Figure 2.14: Grayscale image (Singh and Bharti, 2012)

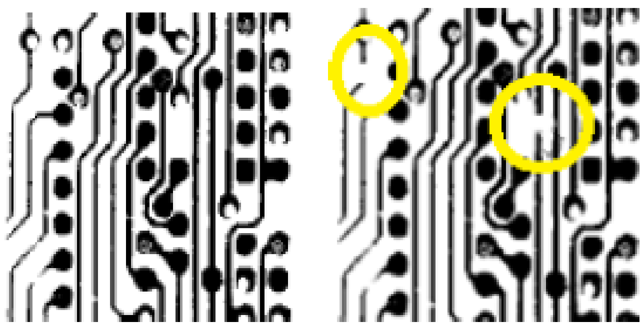

Figure 2.15: Trace line missing on the PCB board (Singh and Bharti, 2012)

Lin and Su (2006) used a slightly different kind of inspection system method. Neural network was used as the algorithm by letting the system learn the image index to detect the missing, reverse or skew component on the PCB board as shown in the Figure 2.16. The image index consisted of white pixel count index, histogram index, correlation coefficient, regional index and high contrast index. The system was trained based on 18 reference images with 468 additional training samples by slightly adjusting the position of the components.