SIMULATION OF IDENTIFYING SHORTEST PATH WALKWAY IN LIBRARY BY USING ANT COLONY OPTIMIZATION

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SIMULATION OF IDENTIFYING SHORTEST PATH WALKWAY IN LIBRARY BY USING ANT COLONY OPTIMIZATION

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Report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Computer Systems & Software Engineering
(Graphic & Multimedia Technology) with honors

Faculty of Computer Systems & Software Engineering
UNIVERSITY MALAYSIA PAHANG

JUNE 2012

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Computer Systems and Software Engineering (Graphics & Multimedia Technology) with honors.

Signature :

Name of Supervisor : ZALILI BINTI MUSA

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Date : 10 JUN 2012

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :

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Date : 10 JUN 2012

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Miss Zalili Binti Musa for her great ideas, invaluable guidance, continuous encouragement and constant support in making this research possible. I appreciate her hard work to guide me from the first day I approach to her to have her as my supervisor to these concluding moments. I am truly grateful for her progressive vision about my training in writing good documentation and she often impress me with creative idea in designing the system flow. I often make naïve mistake but she able to tolerance with me n lead me back to the correct way.

I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. I appreciate for their devotion, support and faith in my ability to attain my goals and studies. They consistently encouraged me to carry on my studies and make achievements in life. I also sincerely thanks to all my friends in the university who helped me in many ways and their excellent co-operation, inspiration and support.

ABSTRACT

A research is proposed based on Ant Colony Optimization for solving the shortest path problem in library. This is a research that the algorithm is aim to implement on a robot. The robot is used to walk around in the library to collect books from all the tables and put on book shelves. However, command prompt window will use to shows the result which is the shortest path. People nowadays are more concern about the efficiency of work, this may happen in library as well. Therefore, by determining the shortest path will help in reducing the time consume problem. This project is developed by starting with designing the workflow diagram as well as the design of the output interface. The work flow is the guide for the process of development. In between, Heuristic Approach is used to determine the entire possible paths at first, then Ant Colony Optimization algorithm will be implemented to search for the final and the shortest path. The system is used to be error free and the algorithm can effectively solve the shortest path problem.

ABSTRAK

Penyelidikan yang dicadangkan berasaskan Ant Colony Optimization adalah untuk menyelesaikan masalah laluan terpendek di perpustakaan. Algoritma dalam penyelidikan ini adalah untuk melaksanakan pada robot. Robot ini digunakan untuk berjalan di sekitar perpustakaan demi mengumpulkan buku-buku daripada semua meja-meja dan meletakannya ke atas rak buku. Walau bagaimanapun, hasilnya akan menunjukkan laluan yang merupakan laluan terpendek. Pada masa kini, orang ramai lebih prihatin tentang kecekapan kerja, hal yang demikian berlaku di perpustakaan. Oleh yang demikian, dengan menentukan laluan terpendek akan membantu dalam mengurangkan masalah penggunaan masa. Projek ini mula dibangunkan dengan merekabentuk gambarajah aliran kerja seperti reka bentuk hasilnya. Aliran kerja tersebut merupakan pembimbingan kepada proses pembangunan. Di antaranya, Kaedah Heuristic digunakan untuk menentu keseluruhan laluan yang berkemungkinan pada permulaan, kemudian, algoritma Ant Colony Optimization akan dilaksanakan untuk mencari laluan terpendek dan yang muktamad. Sistem ini bebas daripada ralatan dan algoritmanya dapat menyelesaikan masalah laluan terpendek dengan berkesan.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Generally, optimization has been use for several purposes till nowadays. Optimization is considered as a procedure that used to reduce complex problems to a more simple way. It can also define as modifying a system to make it work to be more efficiently or use fewer resources. The studies of optimization are now implementing widely, it also a command field that will mostly explore by researcher.

While shortest path problem is one of the fundamental problem that used to find a short and minimum distance to reach the destination, with the minimum time consume as well. People nowadays are more concern on time consuming and efficiency of work. Therefore, by finding the shortest path, destination can be reached faster and result in saving time. There are several technique that used by researchers to determine shortest path, such as Ant Colony (ACO), Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Dijkstra's algorithm and so on. Besides shortest path, all of these algorithms have been used in some other combinational optimization problem, for example, scheduling, travelling salesman problem, robotic motion planning and so on.

In this project, a system develops by using the optimization method to find the shortest path walkway in library. The technique that use in this project is Ant Colony Optimization which is an idea that comes from ant behavior. The concept is that, when ants search for food and return to the nest, they will discover many path in the area. The more times the ants go and back between the food and nest, the more times the trails will be evaporated. From the trails that discovered, the shortest path

can be determined by comparing among it. Therefore, the longer the time those ants used to go and back from the food, the higher the probability for the ants to discover the shortest path. This is because ants will follow the largest pheromone concentration, while shortest path is the highest probability, since shortest path can reduce the time of returning to nest.

In addition, in the library there is a need to have librarian to collect books from tables to put back to the bookshelves that prepared. But unfortunately, human energy may not greater than robot. Since robot does not need to rest and can work up to the duration of battery. By implementing Ant Colony Optimization (ACO) in shortest path, robot will able to determine the shortest path between two locations and manage to bring the books to the bookshelf in short period. It will consequently saving time and human energy. Besides, it may increase the efficiency of work as well.

1.2 PROBLEM STATEMENT

Library is a place that people used to study and borrow books. There are some people that like to stay at the library to pass their reading time. Therefore, for each day, they may have some books that will leave on the table and need to be collected.

Nowadays, most of the libraries are using men power, librarian to arrange and collect books from tables. As for some other places, there may have robot to replace the men power, since robot can bring lots of the benefits to human being. Although human being are more intelligent than robotic, but still there are some constraints that we can see from human being, such as human may not afford to work for a day, 24 hours, as human will feel tired. Therefore they may need rest and take meal so that they have the energy to continue their work. This will consequently reduce the efficiency of work. Therefore, robot may more useful in this situation.

Besides that, it is hard to hire a librarian nowadays. Since most of the people wish to get a job that is more professional and paying wit high salary. So that there is lack of people that willing to sit in the library, arrange books and collect books. They

will think that the job is boring yet low salary. In this situation, robot may replace human resource, as robot is program is program to help people in any situation.

Salary is another reason for replacing men power with robot. People work is to get salary to go on their live. Therefore, the higher the salary, the more people will interview to be a librarian. But the problem is, not all the library can afford the high salary and it is paying month by month. The amount may consider a huge number. Therefore, this will result in the creature of robotic.

On the other hand, although robot is more convenient and helpful in library, there are several things that need to be considered. Firstly is the cost of the robot. Robotic can be considered as a costly technology that creates to help people. Therefore some library may not afford to prepare a large number of money for few robots to increase the efficiency of work. Besides that, the monthly electric fee has to be concerned, as the robot need to be charged.

The faster the work can be done, the more the works can be finish up, and then the reputation of the library can be upgraded. This can be helped by applying shortest path on robot. The more the robot move, the more the battery will used. Therefore, battery is an important part that user needed to be always concern. If the power duration is 8 hours, then the robot needs to finish up work within 8 hours. If the robot moves a lot, then the duration may decrease. Therefore, the less the robot move, the more duration of the power and result in more work can be done.

Robotic is a technology that programmed by human being and controlled by human being. What the programmer wish the robot to do, he will program and implement in it. Some of the robots are able to move, but the problem is to determine the shortest path from the origin of the robot to its target destination. This will result in wasting the power duration, and then less work will be done, efficiency of work will decrease. If the robot able to determine the shortest path to reach a bookshelf, this will save the time consumed and increase the work performance even with 1 robot in a library. Therefore, there is a need to do a research on this topic.

1.3 OBJECTIVES

The objectives of this project are:

i. To study Ant Colony Optimization technique in shortest path for library use.
ii. To develop a shortest path using Ant Colony Optimization for library.

1.4 SCOPE

The scopes of the project are:

i. A library that arranged with minimum 9 tables with 2 book shelves and maximum 25 tables with 3 book shelves.
ii. Microsoft Visual Studio will be used to develop the system.
iii. The system using C programming language and implement Ant Colony Optimization concept.

1.5 Thesis Organization

This thesis consists of six chapters and each chapter is to discuss the different issues in the project. Below that is the summary of the content for each chapter.

i. Chapter 1 – Introduction
    - This chapter provides background information about the project which includes problem statement, objectives and scope.

ii. Chapter 2 – Literature Review
    - Some literature and research which related to this project will be review and discuss in this chapter.

iii. Chapter 3 – Methodology

- Data analysis, method and the procedure of this project development will be discussed.

iv. Chapter 4 – Implementation

- The implementation of the system using Genetic Algorithm will be explained in this chapter.

v. Chapter 5 – Result and Discussion

- This chapter will present the testing result of the system and result on the discussion.

vi. Chapter 6 – Conclusion

- A complete summary of the project will be present in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter briefly explains about the review for Identifying the Shortest Path walkway in Library by using Ant Colony Optimization. There are 3 main sections that will be discussed in this chapter. Firstly, we will discuss about the type shortest path problem that exist with different algorithm. Then will follow by the definition and the history of Ant Colony Optimization. Lastly, the usages of Ant Colony Optimization will be discussed.

2.2 SHORTEST PATH PROBLEM

Shortest path problem is one of the fundamental problems that studied in computational geometry and other areas including graph algorithm, geographical information systems (GIS), network optimization and robotics [21]. Shortest path problem is a problem of finding a path between two places that having the minimum length in order to minimize the time consumes and cost [18, 20]. In graph theory, shortest path problem is to find a path between two nodes or vertices in a graph by calculating the sum of the weight if the edges and define the shortest distance.

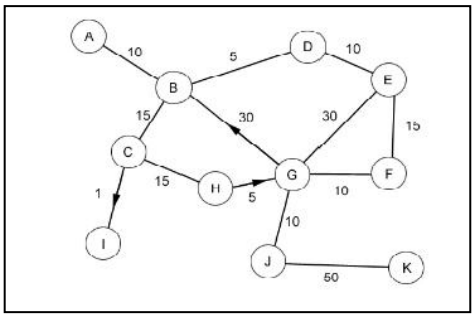

Figure 2.1 Model shortest path. Source from [21]

The purpose of finding the shortest path is to minimum the distance to reach the destination and result in saving the time consume, as well as saving cost. Besides that, the efficiency of job can be increase. These are the benefits of finding the shortest path. These had leaded some of the researcher to propose their research on it. Therefore, nowadays, there are a lot research investigate their research on shortest path problems by using different algorithm as well as in different type of shortest path problem. The algorithms are such as Ant Colony Optimization [4, 6], Genetic Algorithm [19], Particle Swarm Optimization (PSO), Dijkstra's algorithm and so on. There are some others shortest path problems that proposed by researchers, for example, Traveling Salesman Problem (TSP) [8, 9], Robot Motion Planning [13], Scheduling [14, 16] and so on.

2.2.1 Type Of Shortest Path Problem With Different Algorithm

In this particular part, the different type of algorithms such as Genetic Algorithm, Particle Swarm Intelligent and so on, which use to solve different kinds of shortest path problems will be introduce. Based on some of the papers, each of the algorithms shows their effectiveness on solving the problems. Some of the algorithms have been improved by adding others technique, and it shows the advance of the improvement.

2.2.1.1 Traveling Salesman Problem (TSP)

Traveling salesman problem is the problem that tends to find a shortest closed path which visits all the cities in given set and return back to the starting point [1, 9, 11, 22]. It is one of the NP-hard problems in combinatorial optimization [7, 11]. The purpose of solving the traveling salesman problem is to find the minimal cost for visiting each of the cities. Besides that, there is always hope that the time consume can be minimize as well. Traveling salesman problem can e differentiate in 2 types, which are asymmetric and symmetric. Symmetric Traveling Salesman Problem means that the distance between two cities is the same in each opposite direction and this form an undirected graph. Asymmetric Traveling Salesman Problem is the paths may not exist in both directions or the distances might be different, this will form a directed graph [7]. There some researcher had did some research on traveling salesman problem by using some other algorithm, such as Genetic Algorithm, Dijkstra's algorithm and so on. These algorithms had successfully solved the traveling salesman problem.

2.2.1.1.1 Genetic Algorithm

Genetic Algorithm is considered as evolutionary algorithms. It is a probabilistic search algorithm which simulates natural evolution [24]. Basically, genetic algorithm is use for combinatorial optimization problems. Genetic algorithm is the idea of Charles Darwin, who proposed the basic concept that, genetic algorithm, is designed to simulate processes in natural system necessary for evolution [23]. In this recent years, there are several evolutionary optimization of NP-hard problems have been proposed, one of it will be Traveling Salesman Problem.

There is a paper [23], by Li-Ying Wang, Jie Zhang and Hua Li. They proposed a research which is about An Improved Genetic Algorithm for TSP. In this paper, they were tried to improve the Genetic Algorithm to solve Traveling Salesman Problem (TSP). In between, they had introduce a method of untwist operator to improve the performance of Genetic Algorithm. Generally, there are three operator is needed for the algorithm, which are selection operator, crossover operator and mutation operator. But there is the extra untwist operator that proposed by them.

Mainly, selection operator is used to select the individual, means the chromosome from the last generation, to keep the quality based on the fitness value. Crossover operator is the method that combining those selected individuals into new individuals. For the mutation operator, it is use to maintaining the diversity of individuals in the population. According to this paper, when routing the cities, it may produces a diagram of twist route, this will result in increasing the length of route. In order to solve the problem, untwist operator is introduced.

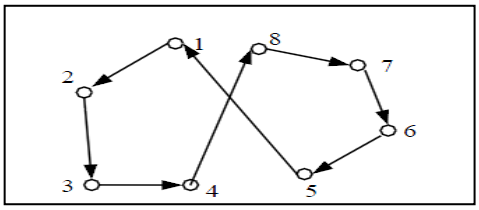

Figure 2.2 Twisted route

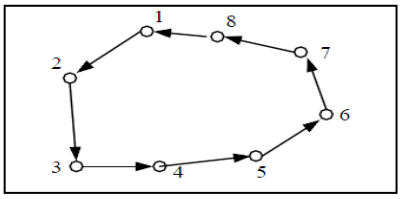

Figure 2.3 Route after untwisted. Source from [24]

The following is the algorithm that proposed by them [24]:-

Step 1: Generate *p* valid routes at random, where *p* is the scale of population.
Step 2: According to formula

$$f(X)=\sum_{i=1}^{n-1} D(X_i,X_{i+1})+D(X_n,X_1)$$

,

calculate the fitness vaue of each individual.
Step 3: If the best route satisfies the request or the stop condition is met, then output
the best route and terminate the loop; otherwise go to step 4.
Step 4: Find the best route from current population and copy directly to new population.

As the result, they had proved that, untwist operator can break the knots if route and result in improve the genetic algorithm for solving traveling salesman problem.

2.2.1.1.2 Particle Swarm Optimization

Particle Swarm Optimization is first proposed by Kennedy and Eberhart in 1995 [26, 25]. It is a computational method that used to optimizes a problem by iteratively trying to improve a candidate solution based on the given measure of quality [25]. It also consider as evolutionary computation technique as it has common evolutionary attributes. Particle swarm optimization is concern of the position and the velocity. It optimizes a problem by having a population and moves the particles around in the search space, n-dimension according to some mathematical formulae [25]. The particles will represent the potential solution of the problem and it can remember the best solution it has reached [27]. In the search space, all particles will share their information, therefore there will be a global best solution. Since Particle Swarm Optimization is used to optimizes problem, therefore it can also been used for solving Traveling Salesman Problem that need to figure out a best path among the paths.

A paper of Modified Particle Swarm Optimization based on Space Transformation for solving Traveling Salesman Problems [26], is proposed by Wei Pang, Kang-Ping Wang, Chun-Guang Zhou, Long-Jiang Dong, Ming Liu, Hong-Yan Zhang and Jian-Yu Wang. This paper is discuss about a modified Particle Swarm Optimization is proposed to solve the Traveling Salesman Problem (TSP). In between, the algorithm is searched in Cartesian continuous space and space transformation is proposed to construct a mapping from continuous space to discrete permutation space.

The following is the description of the algorithm [26] that proposed:-

Step 1: Initialization
1-1. Parameters Initialization:
P_MAX,V_MAX, inertial weight ω, local search probability *TwoOptProb*, chaotic factors C_v = C_l= DispitiveProb, max iteration number MAX_GEN, and the population size MAX_NUM.
1-2. Population Initialization:
Initial the position and the velocity of each particle in the swarm randomly according to the parameter P_MAX and V_MAX.
Step 2: Iteration
If current number of iteration *IterNum* > MAX_GEN, GOTO Step 4
For id=1 to MAX_NUM,id++
{
2-1. Exert chaotic operation with the probability of *DispitiveProb*
if Rand()<*DispitiveProb*, calculate the velocity V_{id} and position X_{id} of particle P_{id} according to formula (9),(10).
Else, calculate the velocity V_{id} and position X_{id} of particle P_{id} according to formula (1), (2).
2-2. Calculate the corresponding permutation π_{id} for position X_{id} according to GVP rule, and further calculate the fitness of the particle P_{id}.
2-3. Local search for π_{id} with the probability of *TwoOptProb*, and restore the better solution to the search space according to the *LSR* strategy.
2-4. Update the local best of the particle P_{id} if we get a better solution.
}
Step 3: Finishing one iteration, update the global best of the swarm. *IterNum*++, GOTO Step 2.
Step 4: Output the best solution.

The formulae that need in the algorithm:-

$$V_i^{t+1} = \omega V_i^t + C_1 * \text{Rand}() * (P_i^t - X_i^t) + C_2 * \text{Rand}() * (P_g^t - X_i^t) \quad (1)$$

$$X_i^{t+1} = X_i^t + V_i^{t+1} \quad (2)$$

$$\textbf{IF} \ (rand() < C_v) \ \textbf{THEN} \ v_{id} = rand() * V\_MAX \quad (9)$$

$$\textbf{IF} \ (rand() < C_l) \ \textbf{THEN} \ x_{id} = rand() * P\_MAX \quad (10)$$

According to the paper, they found that, when the algorithm is operating, the swarm often falls into local minima too early, due to the introduction of local search, and the fast evolve of the swarm. To solve this problem, chaotic operation is introduced. At the end of the research, they found that chaotic operation and space

transformation were effective for solving Traveling Salesman Problem by using Particle Swarm Optimization as the performance had been improved as well.

2.2.1.2 Robot Motion Planning

Due to the fast development of the technology, mobile robot is widely used in many sectors nowadays. To complete a mobile robot, there is a need of robot motion planning which it will help robot to perform a smooth action, based on the algorithm used. According to [12, 14], motion planning is to produce a continuous motion that connects the starting point and the goal point. In between, the collision that known as obstacles needs to be avoided. The objective of planning robot motion is to find an optimum path from the start to the goal without any collision in barrier area [13]. While planning the path for robot, there are two main thing that need to be consider, which are the time and the path that robot walk through is safe. This is because, nowadays, robots are mostly used to replace man power on every sector, therefore, robot is as similar as human being. They do need a safe path to walk through. The guidelines for the for robot path planning are shortest path, least energy consuming or shortest time [14]. Therefore, robot path planning is considered as constrained optimization problem. Since robot path planning is a NP problem, so, there are some of the algorithms or techniques that currently use to solve this problem, for example, Neural Network, Genetic Algorithm, Particle Swarm Optimization and so on.

2.2.1.2.1 Neural Network

According to [28], Neural Network is a mathematical model or computational model that is inspired by the aspect of biological neural networks. Neural network consists of an interconnected group of artificial neurons and it processes information using a connectionist approach to computation [28]. Neural network is consider as adaptive system that will changes it structure based on the external or internal information that flow through the network during the learning phase.
Figure 2.4 is the model of the Neural Network [28].

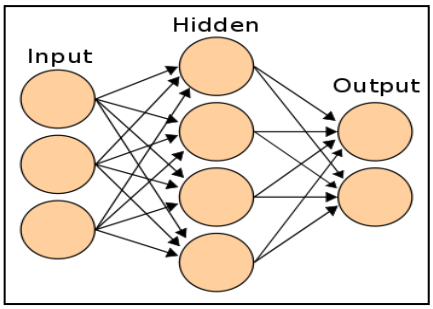

Figure 2.4 Model of Neural Network

In computational of robotic, neural network is from the wish of understanding principles leading in some manner to the comprehension of the basic human brain functions and then will build in the machine that are able to perform complex tasks [29]. It includes cognitive tasks such as learning, adaptation, generalization and optimization [29]. These will solve by using algorithm then will implement into robotic. Besides, recognition, learning and decision making are the need for a robotic, which robotic is used to replace man power in the future.

There is a paper of [30] Neural Network to Path Planning for two Dimensional Robot Motion by Christopher Kozakiewcz, and Masakazu Ejiri. The purpose of this paper is to propose a method for robot obstacle avoidance and path planning. The algorithm that used is based on camera image feedback loop utilizing Neural Network for image processing. Their research can be described in Figure 5 [30].

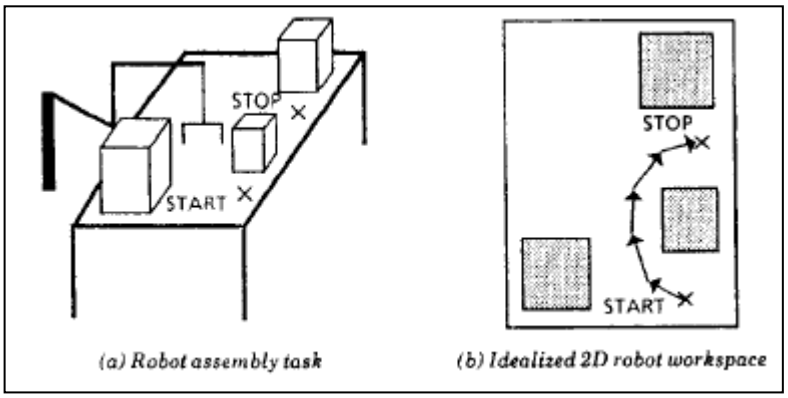

Figure 2.5 The block diagram of the Neural Network controller [30]

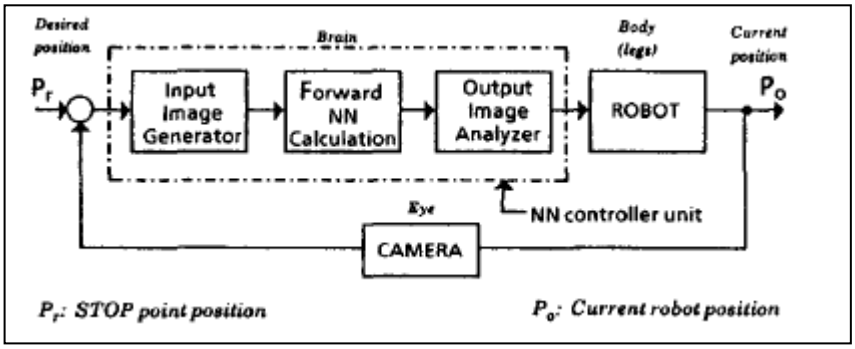

Figure 2.6 Block diagram of the Neural Network training algorithm [30].

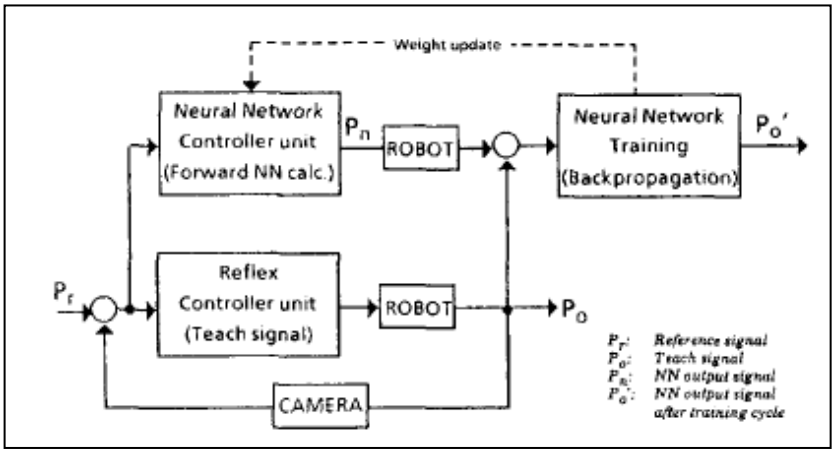

Figure 2.7 Neural Network Controller [30]

Reflex controller is depending on interaction of four low level instinctive behaviors:

1. Do not hit the obstacles
2. Get closer to the STOP point
3. Do not approach obstacles too closely
4. If no progress is made for several steps, take a short random walk.

Figure 2.8 is the block diagram of the Reflex controller:

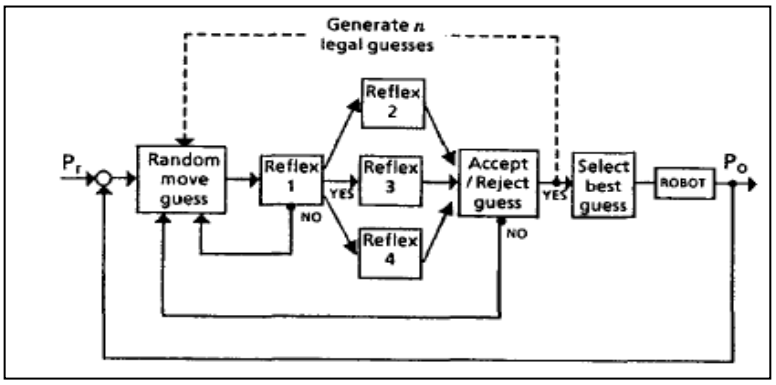

Figure 2.8 Block diagram of the Reflex controller [30]

Figure 2.9 shows the flow of finding the shortest path by using the Reflex controller [30]:

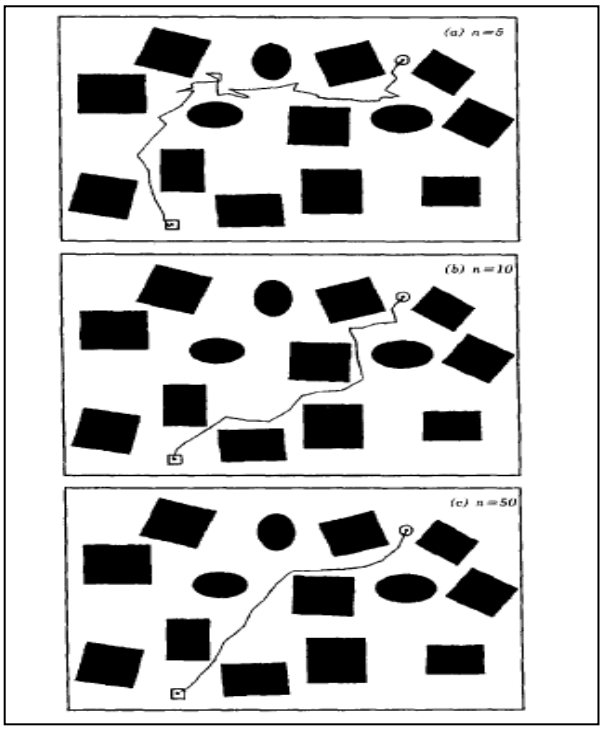

Figure 2.9 of finding the shortest path by using the Reflex controller [30]

As the result of this paper, it have been proved that the method of using robot camera-feedback image processing with the added of Reflex controller is generate a collision free for robot path.

2.2.1.2.2 Genetic Algorithm

According to previous review, genetic algorithm is use for combinatorial optimization problems. It also used to solve the evolutionary optimization of NP-hard problems. Since Robot motion planning also considers as NP problem, therefore, there are many researches on it by using Genetic Algorithm.

For example document [31], it is a research by Yanrong Hu and Simon X.Yang. They proposed a research with title of A Knowledge based Genetic Algorithm for Path Planning of Mobile Robot. This paper is discuss about a knowledge based genetic algorithm for path planning of a mobile robot which it uses problem specific genetic algorithm for robot path planning instead of standard genetic algorithm. In addition, they proposed a simple but effective evaluation method. According to them, the knowledge based genetic algorithm is able to find an optimal or near-optimal robot path in both complex static and dynamic environments. The way they apply in the algorithm is that combining the grids and coordinates representation. The grids that being adopted in the algorithm do not limit the movement of the path, but simplify the chromosome structure and genetic operation by discretizing the environment.
Figure 2.10 is the mobile robot environment and path representation [31].

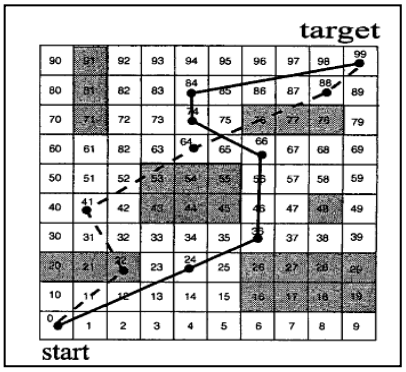

Figure 2.10 Mobile robot environment and path representation [31]

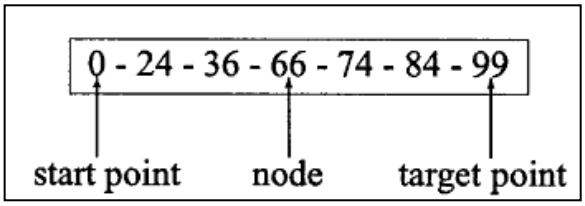

Figure 2.11 Sample of the chromosome.

To make the genetic algorithm more effective, there are some specialized operators needed [31].

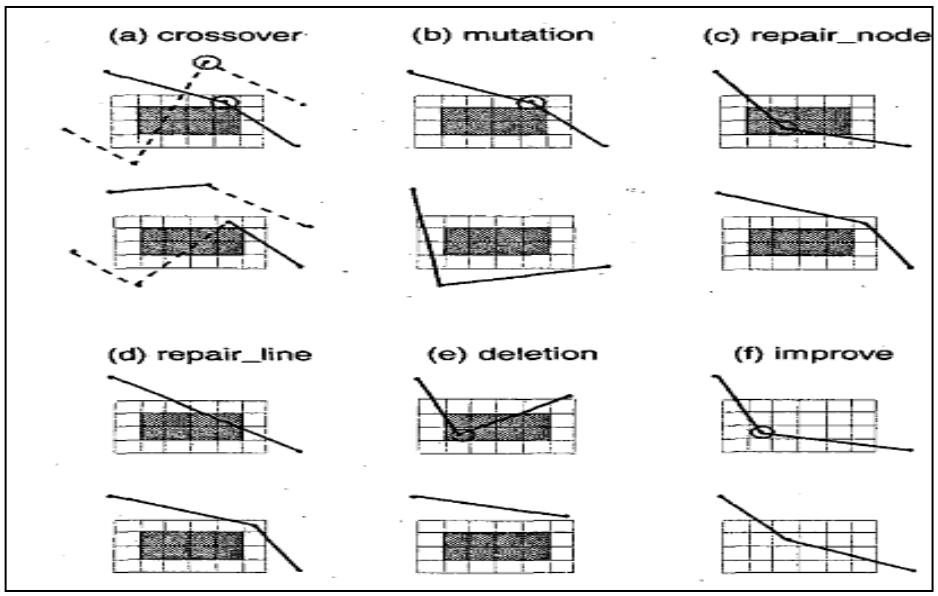

Figure 2.12 Special operators

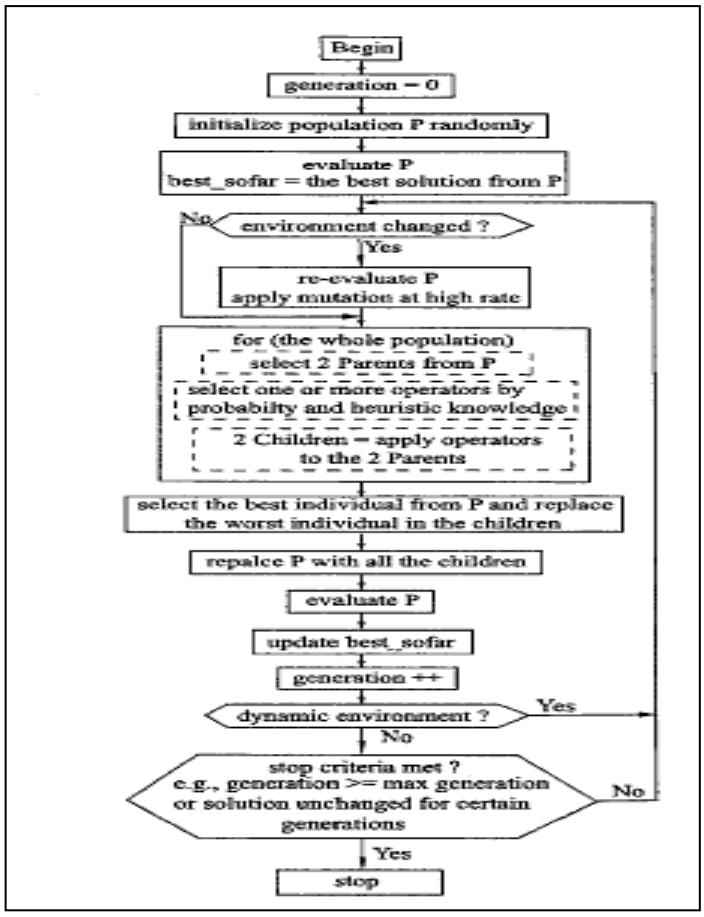

Figure 2.13 Flowchart of the knowledge based genetic algorithm for path planning of a mobile robot

Based on this paper, the effectiveness of Genetic Algorithm in solving path planning is shown. Which it is added with the knowledge based operator. The simulation results also show that the proposed genetic algorithm is effective in both complex static and dynamic environment.

2.3 ANT COLONY OPTIMIZATION

Ant Colony Optimization (ACO) algorithm is a probabilistic technique that used to solve computational problems that can be reduced to find another good path through graphs [1]. It is an idea that proposed by Marco Dorigo in 1992 in his PhD thesis, which his thesis stated that the algorithm is first used to search an optimal path in a graph, based on the behavior of ants that seek for suitable path between nest and source of food [3], [5]. Ant Colony Optimization algorithm is inspired by the

behavior of ant in how they work in finding food and return to their nest. The important thing that need to concern in the algorithm is the trails that discover by ants from each times they go and back between the food and the nest. This is because, the more time it takes for an ant to travel down the path and back again, the more time the trails will be evaporate [1]. If there were no evaporation happen, the path that traveled by the first ant would tend to be excessively attractive to the following ones, and this will cause constrain of space. Therefore, when one ant finds a short path compare to previous, other ants are more likely to follow the path and consequently lead all the ants to follow the single path.

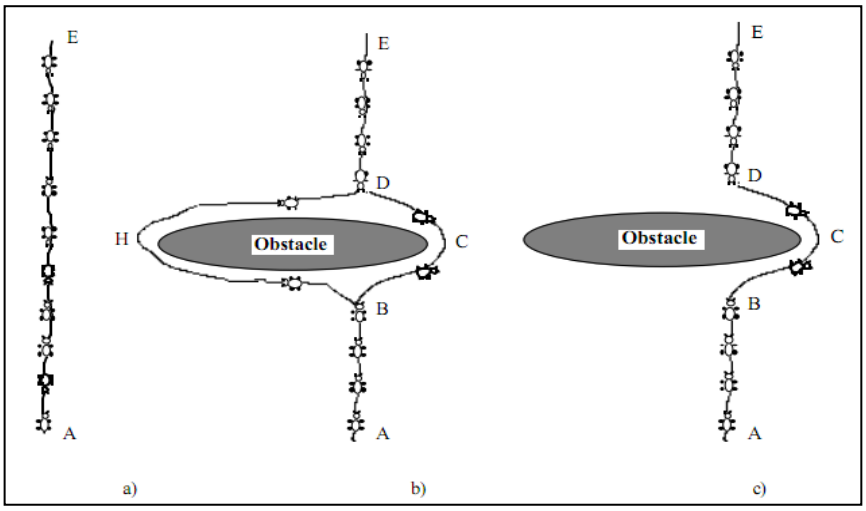

Figure 2.14 Experiment on the ability of ant to choose the path in probabilistic way. After certain time, ants are more likely to choose the shortest path to be the path that eases them. [3], [4]

```
Procedure ACO_Metaheuristic
While (not_termination)
generatiSolution()
DaemonActions()
PheromoneUpdate()
end while
end procedure
```

Figure 2.15 the simple pseudo-code and formulae [1].

1. Initialize:
   Set t:= 0
   Set an initial value r_{ij} (t) for trail intensity on every path$_{ij}$
   Place b_i (t) ants on every node i
   Set Δr_{ij} (t, t+1):= 0 for every I and j

2. Repeat until *tabu list* is full {this step will be repeated in n time}
   2.1 For i:= 1 to n do {for every town}
   For k:= 1 to b_i (t) do {for every ant on town I at time t}
   Choose the town to move to, with probability p_{ij} and move the k-th ant to the chosen location
   Insert the chosen town in the *tabu list* of ant k
   Set

$$\Delta\tau_{ij}(t,t+1) := \Delta\tau_{ij}(t,t+1) + \Delta\tau_{ij}^{k}(t,t+1) \text{ computing } \Delta\tau_{ij}^{k}(t,t+1)$$

   2.2 Compute r_{ij} (t+1) and p_{ij} (t+1)

3. Memorize the shortest path found up to now and empty all the tabu lists
4. If not(End_Test)
   Then
   Set t:=t+1
   Set Δr_{ij} (t, t+1):=0 for every i and j
   Go to step 2
   Else
   Print shortest path and Stop
   {End_Test is currently defined just as a test on the number of the cycles}

Figure 2.16 The detail of the pseudo-code [3].

Nowadays, there are a lot of researchers proposed Ant Colony Optimization in their research, such as traveling salesman problems (TSP) [8, 9], Scheduling problems [14, 16], robot motion [12, 13], network routing problems and so on. According to [4], [6], Ant Colony Optimization is different from other methods. The advantages of it are that, it can be implemented easily, this is because it is flexible for many different problems' formulation. This is why, Ant Colony Optimization research field is currently growing up.

2.4 RELATED WORK FOR ANT COLONY OPTIMIZATION

There are some of the researchers are interesting in using Ant Colony Optimization in solving some of the optimization problems. This section will discuss about the optimization problems that solved by using Ant Colony optimization. There are researcher claims that, Ant Colony Optimization is a technique that has good scalability and able to have well performance. Besides that, based on some of the research, Ant Colony Optimization has been proved to be an algorithm which is effectively and efficiently in term of minimizing total time.

2.4.1 Traveling Salesman Problem (TSP)

Traveling Salesman Problem is one of the NP-hard problems in combinatorial optimization [7] and it is a classical optimization. As stated before, Traveling salesman problem is the problem that tend to find a shortest closed path which visits all the cities in given set [9]. By finding the shortest path, it is always hope that the cost can be reduced. Therefore, there were several researcher had do the research on travelling salesman problems by using Ant Colony Optimization.

According to document [8], Jun OuYang and Gui-Rong Yang proposed a multi-group ant colony system algorithm for Traveling Salesman Problems. In this paper, they had presented a new method of multi-group ant colony system algorithm and they claimed that, the algorithm is to avoid some defects of ACS and MAX-MIN ant system. ACS and MAZ-MIN is the defect that make the algorithm not iterate when it has arrived at the local optimum point, while multi-group ant system is used to solve the defects by create a new groups of ants for the iteration. As states, when ant arrived to local optimum point, a new algorithm, multi-group ant colony system is initialized and two groups of ants are implementing a new searching. If two groups of ants are still in the local optimal point, then a third group is initiated and three groups perform the searching. This algorithm implements iterations until global best optimum point is found. Figure 2.17 is the pseudo-code that proposed by them.

```
Procedure Multi-group ACO algorithm
        Set parameter, Initialize Pheromone
                While (Termination condition not met) do
                        Construct Solution According to length and pheromone
                If some condition met then
                        Modify pheromone
                        Modify
                        Real-time Update Trails
                End
End
```

Figure 2.17 Multi-group ACO Algorithm

By using same general pseudo-code, in document [10], Luca Maria Gambardella and Marco Dorigo manage to propose a research of Solving Symmetric and Asymmetric TSPs by Ant Colonies. The purpose of this paper is to test Ant Colonies system in solving both symmetric and asymmetric traveling salesman problems. Figure 2.18 will be the algorithm that discovered by them.

```
1./* Initialization phase */
    For each pair (r,s) τ(r,s):= τ0 End-for
    For k:=1 to m do
        Let rk1 be the starting city for agent k
        Jk(rk1):= {1, ..., n} - rk1
        /* Jk(ri) is the set of yet to be visited cities for
           agent k in city ri */
        rk:= rk1 /* ri is the city where agent k is located */
    End-for
2. /* This is the phase in which agents build their tours. The
   tour of agent k is stored in Tourk. */
    For i:=1 to n do
      If i<n
        Then
          For k:=1 to m do
           Choose the next city sk according to formula (1)
           and formula (2)
           If i<n-1 Then Jk(sk):= Jk(rk) - sk
           If i=n-1 Then Jk(sk):= Jk(rk) - sk + rk1
           Tourk(i):=(rk ,sk)
          End-for
        Else
          For k:=1 to m do /* In this cycle all the agents go
                              back to the initial city rk1 */
           sk := rk1
           Tourk(i):=(rk ,sk)
          End-for
      /* In this phase local updating is computed and
         τ-values are updated using formula (3)*/
      For k:=1 to m do
          τ(rk ,sk):=(1-ρ)τ(rk ,sk)+ ρτ0
          rk := sk /* New city for agent k */
      End-for
    End-for
3. /* In this Phase delayed reinforcement is computed and
      τ-values are updated */
    For k:=1 to m do
      Compute Lk /* Lk is the length of the tour done
                    by agent k*/
    End-for
    Compute Lbest-iter
    /*Update edges belonging to Lbest-iter using formula(4) */
    For each edge (r,s)
        τ(rk ,sk):=(1-α)τ( rk ,sk)+ α (Lbest-iter)-1
    End-for
4. If (End_condition = True)
      then Print shortest of Lk
      else goto Phase 2
```

Figure 2.18 Algorithm of TSP

As stated in their algorithm, they start with identify each of the variable. Then the algorithm will start where each city will be visited and then back to the starting point again. This considers to finish up one cycle. Then when the cycle is done, the agent that discovers the shortest path will be compute and use to update the current state. Lastly, the system will check whether is a termination condition, which means the best shortest path is found. If not, it will continue to walk around the city again until the best shortest path is found. They claims that, by using Ant Colony Algorithm, the length of the best solution is improved very fast in the beginning of the algorithm, then new good solution also being discovered but phenomena of local stagnation starts to appear.

To prove that Ant colony is a successful technique for solving traveling salesman technique, there is another research [11] by Zar Chi susuHliang and May Aye Khine. They proposed an ant colony optimization algorithm for solving traveling salesman problem. Mainly, this paper is to improve the ant colony optimization as well. The algorithm may used to produce near-optimal solution for the traveling salesman problem. They claims that, when there are some path that have been walk through by ants and some other never walk through, then the shortest path will just discover from those paths that walked through. This situation may reach the local optimum solution but not the global optimum solution, which mean the best and the shortest walkway from the overall. In order to solve this problem, they had adopted a method which to distribute all the ants evenly on each cities and make sure each city will have at least one ant. They believe that, a small value of the heuristic parameter can result in good performance if the search process can be lasts long enough. Thus, to make sure that the search is last long enough and the data is being collect enough, they proposed an adaptive heuristic parameter which in the research. The following will be the algorithm that proposed by them [11].

```
Procedure Proposed ACO algorithm for TSP
Set parameters, initialize pheromone trails
Calculate the maximum entropy
Loop /* at this level each loop is called iteration*/
 Each ant is positioned on a starting node according to distribution strategy (each node has at least one ant)
 For k=1 to m do /*at this level each loop is called a step */
    At the first step moves each ant at different route
    Repeat
         Select node j to be visited next (the next node must not be visited by the ant) according to
         A local updating rule [7] is applied
   Until ant k has completed a tour

 End for
 Local search (2-opt, 2.5 opt) apply to improve tour
 A global updating rule [8] is applied
 Compute entropy value of current pheromone trails
  Update the heuristic parameter
Until End_condition
End
```

The main contribution of this paper to study the avoidance of the stagnation behavior and the premature convergence, and they have proposed the solution by using distribution of the ants and heuristic parameter updating based on entropy. In result, the performance over the ant colony optimization has been proposed well.

2.4.2 Robot Motion Planning

Besides implementing ant colony optimization in Traveling Salesman Problem, there are some research on robot motion planning as well. According to [12], motion planning is to produce a continuous motion that connects the starting point and the goal point. In between, the collision that known as obstacles needs to be avoided. The objective of planning robot motion is to find an optimum path from the start to the goal without any collision in barrier area [13]. Currently, there are a lot of researchers proposed the idea of Ant Colony Optimization in robot motion planning, due to the effectiveness of the algorithm.

There is a research [14] by Gengqian Lie, Tiejun Li, Yuqing Peng and Xiangdan Hou, with the title of The Ant Algorithm for Solving Robot Path Planning Problem. This paper proposed about using ant algorithm for robot path planning in two-dimension environment. In this paper, they will propose a new method for robot path planning, besides the mathematical model is established as well.

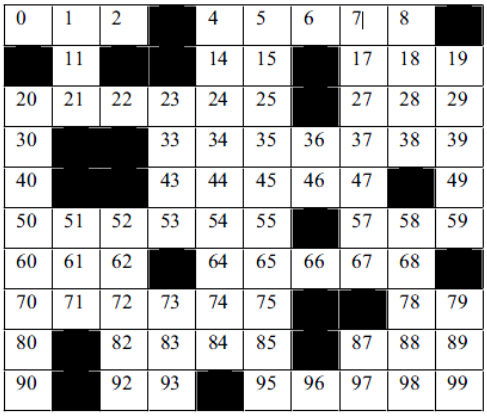

Figure 2.19 Two-dimension work space

Figure 2.19 shows the two-dimension work space that set by them with 10 x 10 grids [14]. Each grid will having the same size and the size of barrier will not change. Again similar as the general pseudo-code, firstly, it will start with defining the parameter that will use, then only proceed to the main part that described as below.

step1 nc =0(nc is a loop counter.)
initialize each τ_{ij} and $\Delta\tau_{ij}^{o}$
put m ants to start point or intention node.

step2 set all start node into current $tabu_k$
for each ant （ $k = 1,2,\cdots,\mathrm{m}$ ） move to
next j according to P_{ij}^{k}

$$p_{ij}^{k}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha} * [\eta_{ij}]^{\beta}}{\sum_{u \in allowed_k} [\tau_{iu}(t)]^{\alpha} * [\eta_{iu}]^{\beta}} & \text{if } j \in allowed_k \\ 0 & \text{others} \end{cases}$$

$allowed_k$ is free grids adjacent to i and not in $tabu_k$,put j into $tabu_k$

step3 computer f_k （ $k = 1,2,\cdots,\mathrm{m}$ ）
record the current best answer
step4 update equation of intensity of pheromone
step5 for each grid(i, j), set $\Delta\tau_{ij} \leftarrow 0$
$nc \leftarrow nc+1$
step6 if $nc < \mathrm{nc}_{\max}$, goto step 2
step7 output the best answer

They had simulated the robot path planning in computer, therefore, the result will look as Figure 2.20.

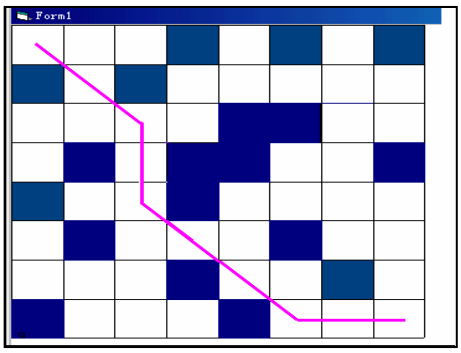

Figure 2.20 Robot path planning in computer

From this paper, they had proved that, the algorithm has good scalability and effective to solve robot path planning problem.

There is another research [13] by Xiong Chen, Yingying Kong and Xiang Fang, that they propose about A fast two-stage ACO algorithm for robotic path planning. The fast two-stage that mention in the paper is splitting the heuristic search into two stages which are preprocess stage and path planning stage. At the preprocess stage, the scent information is broadcasted to the whole map and then the ants will do the path planning under the direction of the scent information. In the stage of preprocess, scent pervasion principle is utilized in, while at the path planning stage, they proposed "1 minus" search policy. They believe that, this will help in overcome the main inconsistency problem between the premature convergence and the optimization of final path.

The following is the rule of the preprocess stage:-

1. Each node has a tag representing the honey scent intensity, while the source point has the lowest value of 0
2. The cause of diffusing is carried out step by step, using "equal intensity class" as a process unit.

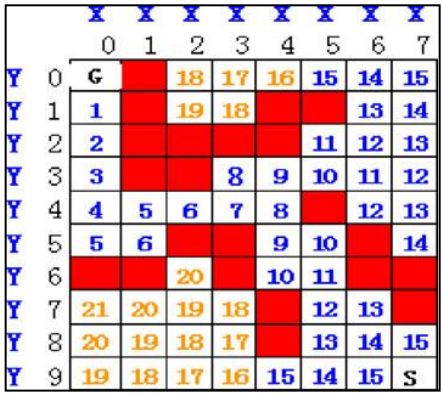

Figure 2.21 Colored grids

The Figure 2.21 shows that each grid represent a node, the colored grids mean barrier space.

The algorithm step that proposed by them will shown as below.

Step 1: Initialize the main parameters
Set $t := 0$ {t is the time counter}; NC := 0 {NC is the cycle counter}
For the whole ant colony, set the initial coordinates to be start point. Give each ant agent an initial life value L.

Step 2: Preprocess the grid map, get the matrix of scent information tags.

Step 3: According to the "1 minus search" strategy, the ant moves to a candidate node;
if more than one path existed, the transaction probabilistic function is activated.
After a move, $L := L - 1$

Step 4: For the ant k, which is still lived (the life value >0) and have not arrived at the goal point, return to step 3.

Step 5: For the ant which reached the goal, first declare it is "died", and compute the path length. Once all the ants in the colony died, pick out the best solution.
Update the pheromone on the current best path.

Step 6: Compare the current best path with former cycles, save the better one.
Update the pheromone on the final best path according to the updating rule mentioned above.

Step 7: Active the evaporation component for the whole environment, set NC := NC + 1.

Step 8: If NC < Nmax and no stagnation behavior, go to step 2;
else output the solution and stop.

In this paper, there are two new method is added, therefore, the time consume for searching the right optimized path have been decreased, due to the search space is minimized.

2.4.3 Scheduling

Scheduling problem has been differentiated in many types as well, for example job-shop scheduling (JSSP), First Order Parallel Shop scheduling (FOP), Open Shop scheduling problem (OSSP) and so on [15]. Scheduling is the process of deciding on how to arrange the resources between the varieties of possible tasks [16]. According to [17], optimal scheduling system may enhances business operating efficiency, reduces idle capacity and delivers products and services on time to final customers. Although there are several of the scheduling problems, but there are researchers use the ant colony optimization to solve each of the problems as well.

Rong-Hwa Huang and Chang-Lin Yang [17], proposed Ant colony system for job shop scheduling with time windows. In this paper, they focus on the plain and the arrangement of job-shop production scheduling. In the business, completing shipment too early or too late is disadvantages to upstream manufacturers and downstream the customers as well. Therefore, they proposed this paper to search for efficient approximate solution by using Ant Colony Optimization with time windows. There are four main steps in this research,

Step 1 Initialize ACO parameters.

Researcher will set the parameter for the variable that need to use in the calculation. After that, the operation for ant is start.

Step 2 Local update of the pheromone trail

When an ant establishes a complete solution, which mean the ant had chosen all the nodes and back to the beginning, then the pheromone on the route must be updated. When there is a lot of ants generate a complete solution during iteration, then the chance of finding the best path is higher. The following demonstrate the local updating rule

$$\tau(r,s) = (1-\rho)\cdot\tau(r,s) + \rho\cdot\Delta\tau(r,s)$$

Where ρ is a local evaporating parameter with a value of 0-1.

Step 3 Globally update the pheromone trail.

This step is the continuous step from step 2, which the best solution is chosen from the step 2, then it will treated with global updating rule to update the pheromone trail. The global updating rule is:-

$$\tau(r,s) = (1-\alpha)\cdot\tau(r,s) + \alpha\cdot\Delta\tau(r,s)$$

where

$$\Delta\tau(r,s) = \begin{cases} (L_{gb})^{-1} & \text{if } (r,s) \in \text{best route presently} \\ 0 & \text{others} \end{cases}$$

α is a global parameter for pheromone evaporation and is in the range of 0-1.

Step 4 Stop and generate a best sequence.

In this paper, they had proved that, Ant Colony Optimization is both effective and efficient, which are two qualities favored in business management.

There is another research by Siriluck Lorpunmanee, Mohd Noor Sap, Abdul Hanan Abdullah and Chai Chompoo-inwai. Which they proposed An ant colony optimization for dynamic job scheduling in grid environment [18]. The purposed of this paper is to developing a general framework of grid scheduling using dynamic information and ant colony optimization to improve the decision of scheduling. Besides improving the decision of it, they hope that the grid scheduling algorithm can perform efficiently and effectively in terms of minimizing total tardiness time.

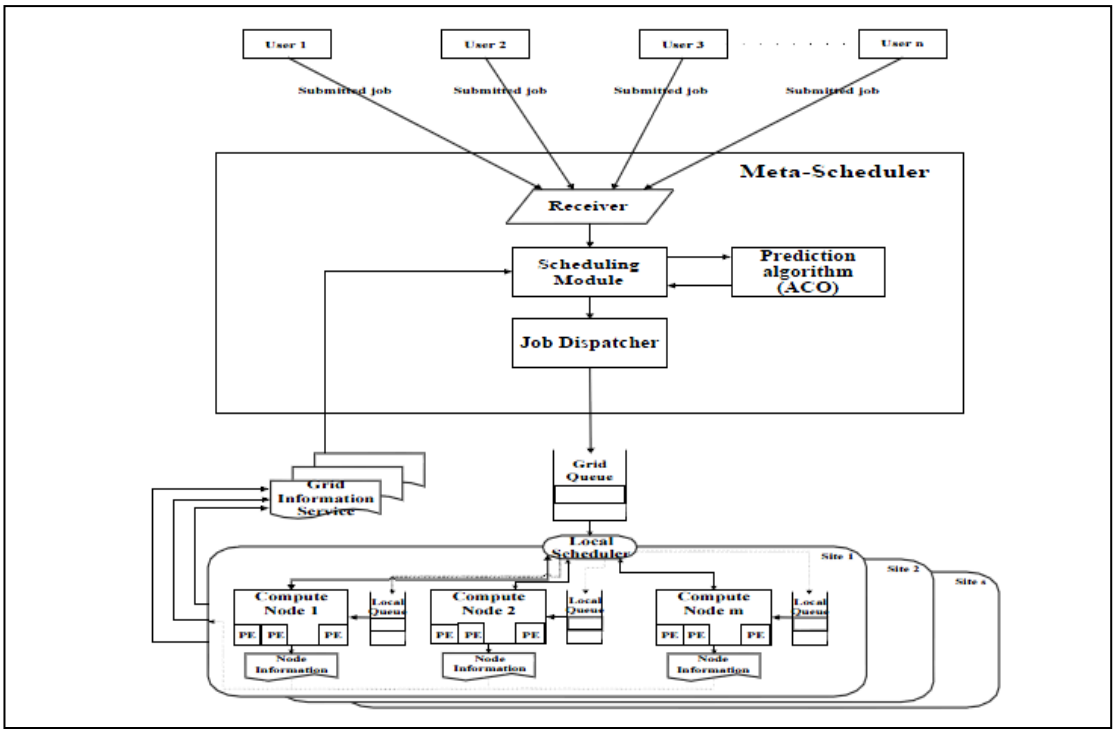

Figure 2.22. The layer of Grid Simulation Architecture

In this paper, Ant colony optimization is use to solve the problem by considering the requirements of each job. The problem that mentioned is, when a job is submitted to the system at different times, they will have different time steps, then people will consume different resources.

```
Procedure ACO
begin
    Initialize parameters, the pheromone trails
    while (stopping criterion not satisfied) do
        Each ant position starts at starting machine
        while (stopping when every ant has build a
            solution) do
            for each ant do
                Chose next machine by applying
                the state transition rate
            end for
        end while
        Update the pheromone
    end while
end
```

At the end of the research, they can conclude that, the ant colony optimization algorithm can find an optimal processor for each machine to allocate to a job which it can minimizes the tardiness time of a job when job is submit to the system.

2.5 CONCLUSION

In this chapter, three main sections had been discussed, which is about the type of existing shortest path problems, the definition of Ant Colony Optimization and the use of Ant Colony Optimization.

From the previous review, shortest path is a fundamental problem that studied in computational geometry. It is a problem of finding the path between 2 nodes, which the path is the shortest path among the area. By solving the shortest path problem, it will benefits human by minimize the time consume and also the cost. Besides that, it also minimum the human energy. Currently, there are a lot of researchers interesting in solving the shortest path by using many types of technique and algorithm, for example, Neural Network, Genetic Algorithm, Particle Swarm Optimization, and other algorithm. The types of shortest problem are such as, Traveling Salesman Problem, Robot Motion Planning, Scheduling and so on.

Ant Colony Optimization is one of the algorithms that used to solve optimization problems. Ant Colony Optimization is a probabilistic technique that used to solve computational problem, just as others algorithm do. The advantages that from the previous review is that, Ant Colony Optimization is easy to be implemented this is because the flexible of it to many type of different problems. Therefore, there are amount of researcher willing to use Ant Colony Optimization as the research algorithm.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will briefly explain about the methodology of developing a system on Simulation of Identifying Shortest Path Walkway in Library by using Ant Colony Optimization. In this chapter, project planning, analysis, design and development will be discussed. Therefore, this chapter is the chapter that will clearly explain the flow of developing the system.

3.2 MODEL PLANNING

Software process model is needed as a guide for developing a system. Therefore, a model is planned based on the requirement and environment that needed for this project. In this model, there are five phases concluded, which it start with planning, then analysis, design, implement and testing. This model is a systematical model, which it has to work from one phase to another phase in a downward fashion but not backward. In this fashion, every phase of the developing process can be control well. This is because, before proceed to the next phase, there is a need to fulfill the previous phase of the system. Therefore, if there is a fault or error in the system, it will be detected during one of the initial phases and will be sealed off for correction. Besides that, this model will bring the benefit of guiding developer to be more careful and concentrate on each phases.

The flow of the process model is shown as below.

Figure 3.1 Flow of Development

3.2.1 Planning Phase

The project of Simulation of Identifying Shortest Path Walkway in Library by using Ant Colony Optimization is a project that developing an algorithm which can help robot to determine the shortest path in the library. Therefore, first of all, the survey of problem that face by librarian is need to be conducted. From this survey, the problem statement can be known, as well as objective. Consultations with supervisor also important, since supervisor can guide us and help in rearrange the idea.

3.2.2 Analysis and Requirements Phase

After getting all the needed information, it will proceed to the analysis and requirements phases, which this phase will analysis all the information that from librarian and supervisor. The problem and the objective that planned can be more clear after analyze all the information. Besides that, the requirements for developing this system will be determined.

3.2.3 Design Phase

This is the phase that the flow of the system and the interface will be designed based on the information that analyzed. The design phase and the analysis and requirement phase will make a cycle. This means that, if there is any problem with the design requirements, it will always refer back to the analysis and requirement phase.

3.2.4 Implementation Phase

After the design phase, there is implementation phase, which this phase is to change all the information to code. Implementation phase makes another cycle with design phase. This is because, the implementation is based on the design. Therefore, while implementing, there is a need to refer to the design phase.

3.2.5 Testing Phase

The final phase is testing phase. This phase then makes the third cycle with implementation phase. Testing phase is the phase to check the errors that occur in the system. When there is any error, new ideas and so on, it can always back to the implementation phase to implement the new ideas, as well as correction if there is any error.

3.3 PLANNING

Planning phase can be considered as the preparation phase before start on development. In this phase, information should be corrected and gathered. So that it can be help in the next phase, which is analysis phase.
There are few preparations that need to be done in this phase:

1. Consultation with supervisor
2. Meeting with librarian of Universiti Malaysia Pahang
3. Gantt Chart planning

3.3.1 Consultation With Supervisor

Before starting with any procedure, there are few discussion have been done with supervisor, Miss Zalili Bint Musa. In the discussion, project's title that will be proposed is discussed. Besides that, some of the details will be consulted as well, such as the objective, problem statement and the scope of the project.

3.3.1.1 Choosing Project Title

After consultation with supervisor, the title of the project had been decided, that is Simulation of Identifying Shortest Path Walkway in Library by Using Ant Colony Optimization.

3.3.1.2 Definition of Problem Statements

Problem statements of the project had been defined based on the current procedure that experience by librarian of Universiti Malaysia Pahang, while this system is developed to solve the problem that face by them.

3.3.1.3 Definition of Research Objective and Project Scopes

The objective and scope are come after the problem statements. When the problem statements had been decided, objectives and scope should be set as a guide for the development. Other than that, it also can be a guide when searching some relevant paper for review.

3.3.2 Interview with Librarian of Universiti Malaysia Pahang

To be more clear about the flow and procedure that used by librarian, there is a need to meet and discuss with a librarian who know the whole procedure of the library. Therefore, an interview session had been done with one of the librarian. They had provide many of the information such as how they collect the books from table and arrange to the shelves, how long they use to finish their arrangement in routine and how they walk around the area. These are the important and useful information that needed in this project.

Some of the questions that had been while the interview session are stated as below:

1. How the procedure of collecting and arranging the book in routine?
2. When will librarian collect and arrange books?
3. How long it will take for the procedure?
4. Is there any technique used to walk around the area?
5. Will it be a problem if there is any librarian on leave?
6. When is the peak season for library? And what is the effect?
7. Is the time for leaving is consistent for everyday?

3.3.3 Gantt Chart Planning

As a guide to complete the research, there is a need to have a Gantt chart, which it can help to schedule the procedure that need to be done. Therefore, for every step that make, it can make sure that whether the step is relevant and suppose to bring it on to the research. Gantt Chart can be referred at Appendix A.

3.4 ANALYSIS AND REQUIREMENT

Analysis phase is the stage of analyzes all the information and requirements that gets from the previous phase. In this phase, the initial functionality of the system can be determined based on the information that had been collected. All the information will be rearrange and analyzed in detail to produce a guideline for algorithm as well as prototype design. Therefore, in this phase, problem statements and main objective will be determined. The requirement for developing the system also will be determined.

In this phase, there are two main issues have been analyzed.

1. Paper review
2. Analysis on interview session with librarian
3. Requirements

3.4.1 Paper Review

After consultation with supervisor and decide the title of the research, the next step will be review on research papers which is related to the title of research, this is done in the Chapter 2, Literature Review. Based on this research papers, there can be find some of the ideas will be obtained, and it might useful in completing the system.

In this research, the research papers that related on shortest path problem and use of Ant Colony Optimization have been analyzed.

3.4.1.1 Shortest Path Problem

According to some of the paper, shortest path is considered as a fundamental problem that studied in computational geometry and other areas. It is also an optimization problem which needs to solve by finding the optimal way. The purpose of finding shortest path is always to minimize the time consume and cost [8]. There are several types of command shortest path problems, such as

1. Traveling Salesman Problem
2. Scheduling problems
3. Robot motion path planning
4. others

These problems have been test and solve by many kind of optimization technique like

1. Genetic Algorithm
2. Particle Swarm Intelligent
3. Ant Colony Optimization
4. Djikstra algorithm
5. Others

All of these techniques had solved the problems successfully.

3.4.1.2 Ant Colony Optimization

The technique that used in this project is Ant Colony Optimization. Therefore, some of the research paper that related to the technique has been study as well. According to research papers, Ant Colony Optimization is a probabilistic technique that used to solve computational problem, such as shortest path problems. This technique had been used to solve some other computational problems, such as Traveling Salesman Problem (TSP), Scheduling Problem, Robot Motion Path Planning Problems and so on. Those problems had been solved successfully. There are researchers claim that, Ant Colony Optimization is a technique that has good scalability [26] and able to have well performance. Besides that, based on some research this technique has been proved to be an algorithm which is effectively and efficiently in term of minimizing total usage time. This can support the reason why Ant Colony Optimization is used in this system.

3.4.2 Analysis on Interview Session with Librarian

From the previous phase, an interview session had been conduct with librarian of University Malaysia Pahang. From the interview, librarian had provided the information of procedure of how they arrange books that used by students daily. The arrangement of the tables in the library also explained well. Besides, she also explains some of constrains and problems that face by them.

3.4.2.1 Arrangement in the library

Based on the interview session, the librarian stated that, the arrangement of the tables is in grid form, which it is either 6 X 3 or 6 X 4. The book shelved will be arranged in 5 in a row, after the tables. Then there is a trolley that used to collect the books from the tables that being used, and put at the book shelves area, only the books will be arranged on the shelves.

The arrangement and the trolley will be shown in the following figures.

Figure 3.2 Arrangement of table in the library

Figure 3.3 Arrangement of book shelves

Figure 3.4 Trolley that use to put books at first before arranged on shelves

3.4.2.2 Procedure of Arranging Books

According to the information that provide by the librarian, the process from collecting book from tables until arrange to the shelves are all done in manually, which mean that, human energy are involve in all of the procedure. He claims that, when there is peak seasons like study week, there are a lot of student come to library for revision. Some of them will stay until almost the closing time of library. Then those books that they take will leave on the tables. Librarians have to collect it and put it back to the shelves. This is what they do in routine. The books will first collected from the table then put on a trolley that prepare in front of shelves. Then, it is either on the day or the next morning, they will arrange the book on the shelves according to the code that stated.

3.4.2.3 Constrains

For this system, there are some constraints that used to limit the system. Those constraints are come from the information that obtained. The constraints are list as below.

a. Robot

- There are only one robot will be used in the library area.

b. Area of Library

- The area of the library is based on the arrangement of the tables.
- The numbers of tables that will be used for this system are 9 tables for the minimum and 25 tables as the maximum number.

c. Number of book shelves

- Book shelves is the final destination that robot have to reach to.
- There will 2 and 3 book shelves arranged, according to the number of tables. It is recommended that if less than 16 tables, 2 book shelves will be used. If more than 16 tables, 3 book shelves will used.
- Book shelves will be arranges horizontal with the tables.
- Book shelves will be set at below of the tables.

d. Arrangement of tables shelves

- Tables is the node that robot have to go through to reach a destination. The tables will be arranged in grid form in this system. Based on the number of tables that decided, tables can be arranged in the many types that states as below with the recommend of number of shelves. The number of book shelves will be set by the system based on the number of the tables that key in by users.

Table 3.1 Arrangement of tables

Type	Tables (row x column)	Shelves
A	3 x 3	2
B	3 x 4	2
C	3 x 5	2
D	4 x 3	2
E	4 x 4	2
F	4 x 5	3
G	5 x 3	3
H	5 x 4	3
I	5 x 5	3

e. Distance between Tables

- Distance is the fitness function that used in the algorithm to find out the shortest path. In this system, the distance between each tables are set to be 1.5 meter, either in row or in column.

f. Size of tables

- All of the tables will be in the same size due to having the same distance between 2 tables either in row or in column.

The other constraints for the system is that, this system cannot solve the path with the large number of tables, this is because, the number of tables and the shelves is set, and it had been mentioned previous. This system only can solve the shortest path which is in small scale.

3.4.3 Requirements

Before enter to the design or implementation part, the requirements of this system should be clearly determined. The following tables are the software and hardware that required for this system

3.4.3.1 Hardware Required

The hardware that required to develop this system is shown as below:

Table 3.2 Hardware Requirements

Item	**Required**
Processor	Intel Core 2 Duo processor T6500
RAM	4GB

3.4.3.2 Software Required

The software that required for system development are shown below:

Table 3.3 Software Requirement

Item	Name	Purposes
Operating System	Windows 7	As a operating system
Software	Microsoft Visual Studio 2010	To develop the system coding and design the system interface
	Microsoft Office Word 2007	To do the thesis documentation.
	Microsoft Office Project 2007	To do the project Gantt Chart documentation.
	Microsoft Office PowerPoint 2007	To do the project presentation slide.
	Microsoft Office Excel 2007	To record the testing result.
	Adobe Reader 9	To read pdf file.

3.5 DESIGN

Design phase is conducted after the planning and the analysis phase. It is the phase that establishes and describes clearly the overall of the system. This phase is to transform the information into design. Based on the information that gets from the previous phase, flow of the system will be design in this phase.

3.5.1 Design of System Flow

Based on the information and requirement that correct in the previous phase, a simple flow of the system had been design. First of all, the system start with entering the numbers of tables that need in the area. Then the system will automatically arrange the tables and shelves in grid. Then it will proceed to choose

the location that robot need to pass by. Then it will follow by searching the shortest path. At the end of the system, it can be either reset again the number of table and shelves or end the system.

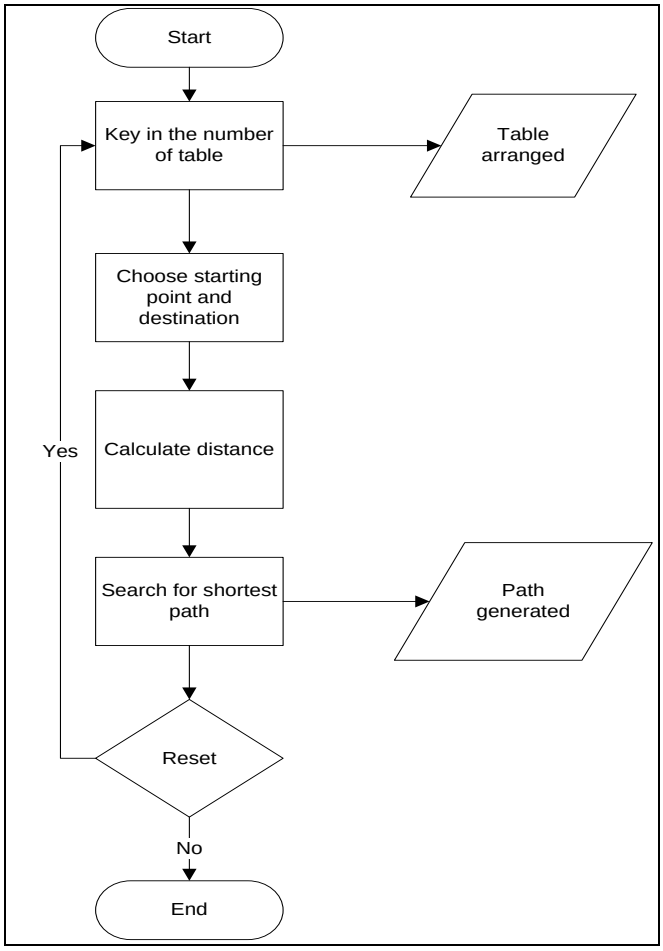

Figure 3.5 Flow Chart of the system

3.5.1.1 Key in the Number of Table and Shelves

This is the first step that user need to go through. The total numbers of tables are set to be minimum 9 tables till maximum 25 tables, which will be arranged in grid form. For this system, the system is design to allow users to key in the number of tables in row and in column. So that, users can decides the arrangement in the area. This is the part of user friendly. The number of shelves also will set by the system, which it is either 2 or 3 shelves.

3.5.1.2 Calculate Distance

The approach that used to calculate the distance is decided to be Heuristic Approach. This approach is used after user had key in the number of tables in row and column. By using this approach, all of the potential path will be calculated by using this approach.

a. Flow of Heuristic Approach

Heuristic approach is used to determine the next step that system takes to reach the destination. Following is the flow of how the heuristic work. Some of the rules need to be followed in this system.

- There are only 3 directions that the system can be move to, which is left, right and bottom.
- Cross direction is not allowed in this system.

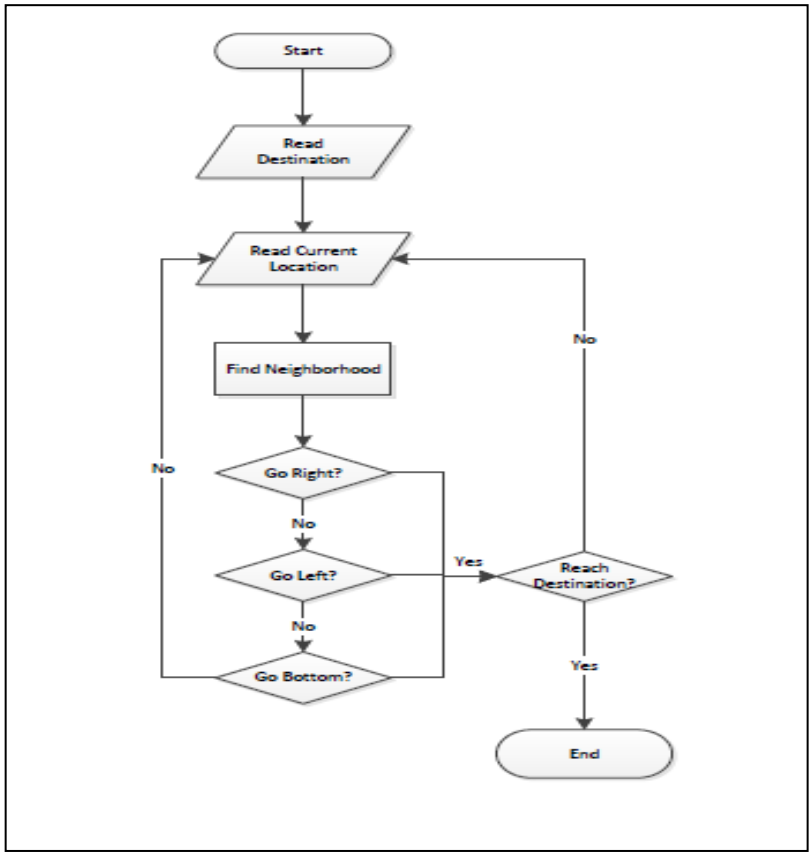

Figure 3.6 Flow of Heuristic Approach

Figure 3.6 shows the flow for the heuristic approach that used in this project.

i. Read destination

- The destination for this project is the book shelves.

ii. Read location

- The location is the tables that robot need to pass through.

iii. Find neighborhood

- After determine the destination and the starting point, the system will search for the probability path.
- From the starting point, the suitable direction should be determined.
- It is either to go left, right or bottom.
- If there is either one direction is chosen, it will proceed to determine whether step is reaching destination. If not, it will back to Read Location to repeat again the process till it reach the destination.
- If there is no direction is chosen, the system will back to Read Location until it get the suitable direction to reach the destination.

b. Design of Heuristic Approach

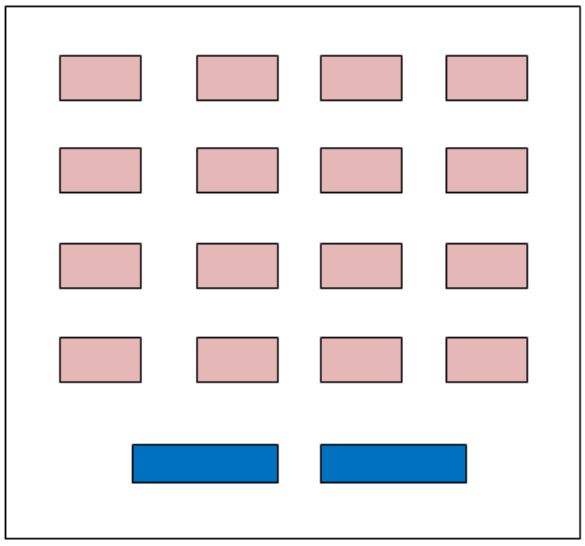

Figure 3.7 Arrange of tables and book shelves.

Pink color represents the tables, while blue color represents the book shelves.

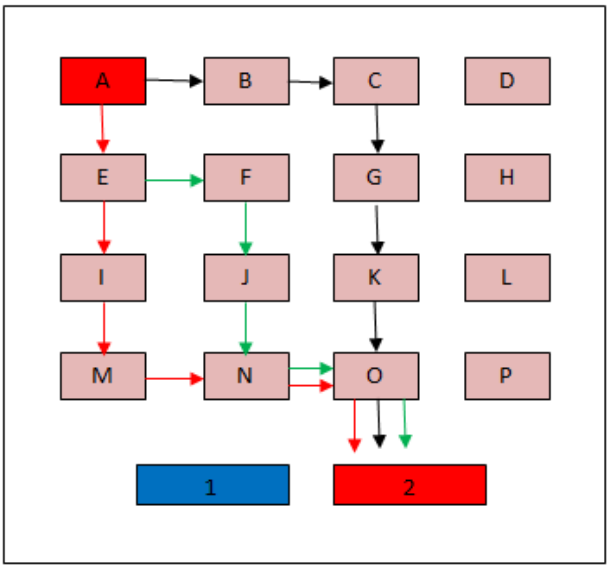

Figure 3.8 Heuristic Approach

According to Figure 3.8, the tables that in pink color are labeled as A to P. while the blue color is the book shelves which has been labeled as 1 and 2. The red color is the starting point and the terminate point for robot to pass to. Based on the figure, there are few colors of arrows. Those arrows are some of the example of the probability of the path that robot will path to.

By using heuristic approach, there is several ways to go from A node to reach the destination of 2, for example:

1. ABCGKO2
2. AEIMNO2
3. AEFJNO2

These are some of the examples. The nodes taken is by either going left, right or bottom, without going upward. This is the rule of heuristic approach. Other paths are such as:

1. AEIJKO2
2. ABFJKO2
3. ABFJNO2

3.5.1.3 Choose Location as Checkpoint

Based on the arrangement of the tables and shelves that generate on the screen, user can click on the tables and choose the destination that robot should go to. To let user know the checkpoint that have been choose, the color of the checkpoint will show in red color.

3.5.1.4 Search for Shortest Path

After arrangement all the tables and shelves and choose the checkpoints that robot need to go through, then the system will search for the shortest path as well. In this part, the calculation will done in the algorithm to find the potential path and then to get the shortest path among it. Then the path will showed in red color line.

3.5.1.4.1 Definition of Fitness Function

The fitness function of Ant Colony Algorithm is the distance of the path. Which the distance is use to calculate and compare to determine the shortest path in among the potential path.

3.5.1.4.2 Ant Colony Optimization

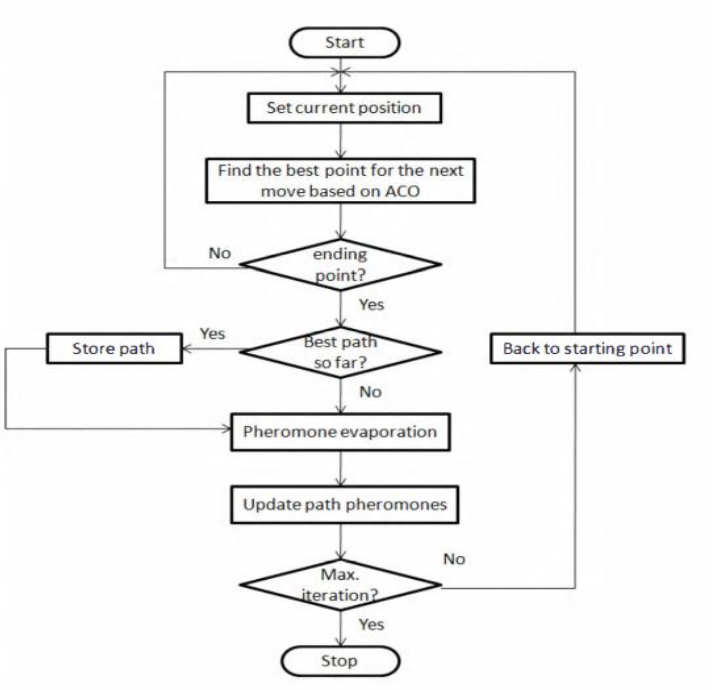

Figure 3.9 Flow Chart of ACO Algorithm

a. Set current position

- In this phase, the initial position, the starting point of the path is determined. The terminate checkpoint, which is the goal also set.

b. Find the best path point

- After set all the checkpoint, the system will start to generate the potential path that can lead to shortest path, which that, system will plan each next step that the path will go through.

c. Decision phase of ending point

- This decision phase is to check whether the path is connecting the initial checkpoint and the termination checkpoint. If it is not, then it will back to the beginning until the complete path is searched.

d. Decision phase of best path

- This step is to check the completion of the path that generated. If there is a complete path that generated, the path will be stored. In this phase as

well, the paths will be compared. For the first path that generated, it will be stored directed. For the second path, it will be compared with the first path that generated. If the distance of the second path is shorter than the first path, then the second path will replace the first path in the storage. The next step will proceed to pheromone evaporation to delete or clear the replaced data.

- If the path that generated is not complete, it will directly proceed to pheromone evaporation, which to clear the data.

e. Pheromone evaporation

- Pheromone is defined as path. This is the phase of clearing the predefined path data.

f. Update the pheromones

- This phase is come after the Pheromone evaporation phase, which the best path will be updated after the process of comparing distance of the path. This can be considered as the global best, which the last and the best path is updated.

g. Decision phase of Maximum Iteration

- This phase will check whether there is some other shortest path compare to the current shortest path. If it already reaches the maximum iteration, which mean the final decision, then the algorithm is end. Otherwise, it will back to the beginning to start the algorithm again. This will happen if the path that generated is not complete.

3.5.1.5 Reset

After go through all the steps and get the result, it is either to let users choose, whether need to reset the system and start and new path or to close the system.

CHAPTER 4

IMPLEMENTATION AND TESTING

4.1 INTRODUCTION

This chapter will explain about the implementation on the system of Simulation of Identifying Shortest Path Walkway in Library by Using Ant Colony Optimization. In this chapter, implementation and testing will be covered. Besides that, the code of generating this system will be included by explanation as well.

4.2 IMPLEMENTATION

Implementation is the phase that transforms the design and the flow that planned in the Methodology part into the code. It is an important part of the development.

This project is to identify shortest path walkway in library by using Ant Colony Optimization, therefore, the technique of implementing Ant Colony Optimization will be clearly explained. Furthermore, Heuristic Approach also used to find the possible path.

4.2.1 Heuristic Approach

Heuristic Approach is the method that used to find the possible paths that will be found in the library area, then only the Ant Colony Optimization will be implemented to get the shortest path among it. Some of the rules needed to be followed in this system.

- Only 3 directions of steps can be taken in this system, which are, left, right and bottom.
- Cross direction is not allowed.

These rules had been implemented into code form as shown in Figure 4.1.

```
while(count<totalNumAnts)
{choice=rand()%3+1;//3 direction/choice, start from 1
        switch(choice)
        {
        case 1: {
                if(j==0) break;// most left position
                else if ((prev[0]==i)&&(prev[1]==j-1)) break;// no turn back
                else{
                prev[0]=i;// store previous step
                prev[1]=j;

                printf(" -> %d",table[i][--j]); //go LEFT
                storePath[count][index]=table[i][j];
                index++;
                break;
                }}
        case 2: {
                if(j==2) break;// most right
                else if ((prev[0]==i)&&(prev[1]==j+1)) break;// no turn back
                else{
                prev[0]=i;
                prev[1]=j;

                printf(" -> %d",table[i][++j]); //go RIGHT
                storePath[count][index]=table[i][j];
                index++;
                break;
                }}
        case 3: {
                printf(" -> %d",table[++i][j]); //go BOTTOM
                prev[0]=i;
                prev[1]=j;
                storePath[count][index]=table[i][j];
                index++;
```

```
                break;
                }
                default: printf("wrong\n"); break;
                }
                if (i==3)
                {
                        i=j=0;
                        index=0;
                        printf("\n%d", table[i][j]);
                        storePath[count++][index]=table[i][j];
                        index++;
                }       }
```

Figure 4.1 Heuristic Approach

4.2.2 Ant Colony Optimization

Ant Colony Optimization is the technique that used to determine the shortest path among the potential paths that generate by the Heuristic Approach. In this system, the fitness function is set to be the distance of the path. Which the distance is use to calculate and compare to determine the shortest path among the potential path. To complete the Ant Colony Optimization, there are several steps that need to go through first.

a. Set Current Position

In this step the current position is set based on the position that set by the user. Which means that, users will choose which is the starting point, the table that the robot need to go through and the terminate point.

b. Find the best path point

This step is to find all the potential paths that can be generated from the library are. This is done by using the Heuristic Approach that shown in Figure 4.1. All of the path that match with the starting point and terminate point will generated, therefore there will have similar path among it.

c. Reduce the similar path

This step is to solve the problem that mention in previous step. Since there will be similar path that will occur in the system, so, the method used is to check and compare the each check point for each of the path. If there is similar, then 1 of the similar path will be eliminated.

```
//Ensure no repeated path
if(count==0){
		storePath[count]=temp[ind];
		count++;
		printf("Stored!\n");
		}
else {
		int idx=0;
		int flag=1;//to check same array or different, 0=same,
1=different
		while(idx<count){

		if(compareArray(storePath[idx],temp[ind])==0){//same
array
		flag=0;
		break;
		}
		else{
		flag=1;
		idx++;
		}
		}
		if(flag==1){//different array

		storePath[count]=temp[ind];

		printf("Stored!\n");
		count++;
		}}
```

Figure 4.2 Compare and Reduce Similar Path

d. Count the Number of Checkpoint/Table

When the completed path is generated, then the numbers of checkpoint for each of the path need to be calculated. The code is stated in Figure 4.4. The number of the checkpoint will used for further comparison of paths afterwards, when generating the concept of Ant Colony Optimization.

```
int countArray(int* arr)
{       int count=0;
        while(1)
        {       if (arr[count]>0) count++;
                else break;}
        return count;
}
```

Figure. 4.3 Number of Checkpoint

e. Shortest Path Determination

When the similar path is reduced, the number of checkpoint is counted, then it comes to the Ant Colony Optimization part, which is the last part. The concept is to compare the total number for each of the checkpoint. The smallest the number of the checkpoint, then that is the shortest path in the system.

```
//Find Shortest Path
        int *output=storePath[0];
        for(i=1;i<27;i++)
        {
                if(countArray(output)>countArray(storePath[i])){
                        output=storePath[i];
                }
        }
        i=0;
        printf("\nShortest Path:");
        for(;;)
                {               if (output[i]>0)
                                {
                                        printf(" %d",output[i]);
                                        i++;
                                }
                                else break;

                }
                printf("\nNumber of elements: %d \n", countArray(output))
```

Figure 4.5 Shortest Path Determination

4.3 TESTING

This system is generated by using the Visual Basic 2010. After the system is developed, testing is the next phase that will be conducted. The testing part is to make sure that the product that released is out of error and fulfill to the requirement as stated. For this particular part Black-box Testing and Alpha testing will be conducted, where programmer will test on the system in module by module. Once the error is detected, it will fix immediately.

4.3.1 Black-Box Testing

Black-box testing is to test on the system functionality. The testing is specification based where the testing is conduct component by component, unit by unit. Therefore, when a certain function is complete, then it will be tested at first before proceed to other function. There are several function will be explained.

a) Heuristic Approach

The code form for this Heuristic Approach is generated based on the rules that set. When the code is done, it will be compiled to test whether the possible paths can be generated. Then the result is shown in Figure 4.6. But still there is repeated path.

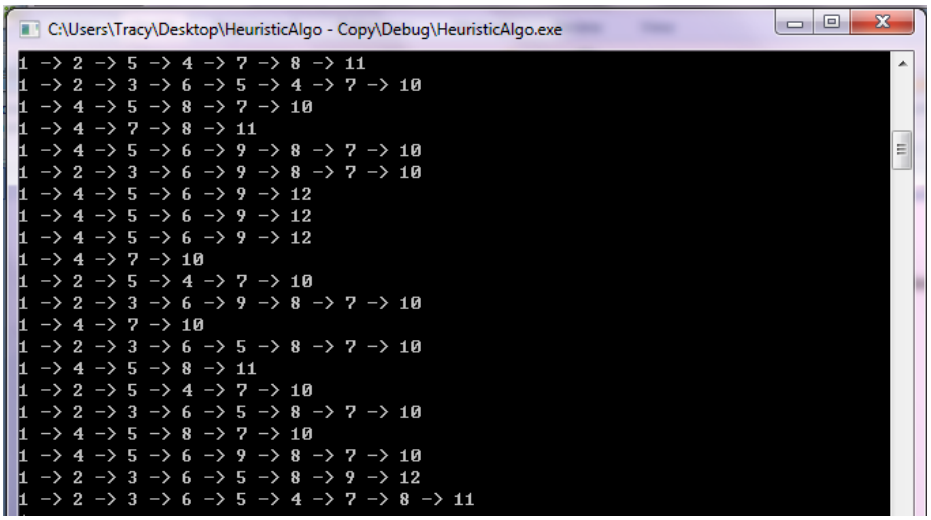

Figure 4.6 Paths Generated

b) Reduce the similar Path

This is to solve the previous problem. The path that generated will be compared, to check the similar step that taken. When there is similar, 1 of the path will be eliminated. Then the less will be non-repeated possible path.

c) Count the Number of Checkpoint/Table

When the number of checkpoint is determined, then it is easy in the comparison of the distance of path. Then the shortest path will be determined. The code will be compiled, then the result is showing the total number of checkpoint for each of the path.

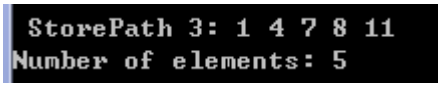

Figure 4.7 Counting Number of Checkpoint

d) Shortest Path Determination

This is the final state of the system, which is to find out the shortest path. Another comparison is generated. But this is to compare the total number of checkpoint for each of the path. The path that has the smallest number of checkpoint is the shortest path for this system.

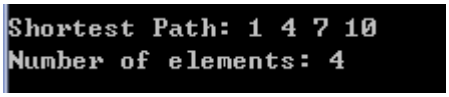

Figure 4.8 Shortest Path

4.3.2 Alpha Testing

Alpha testing is the testing that done by the programmer, where the programmer will test all the functionality of the system.

First of all, the system is tested according to the number of table that set at previous. The system brought out the result as expected. When key in the starting point and the destination, the system do show the shortest path.

Table 4.1 Testing Parameters

Type	Tables (row x column)	Shelves
A	3 x 3	2
B	3 x 4	2
C	3 x 5	2
D	4 x 3	2
E	4 x 4	2
F	4 x 5	3
G	5 x 3	3
H	5 x 4	3
I	5 x 5	3

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter will make conclusion for each of the Chapter 1, Chapter 2, Chapter 3 and Chapter 4. There will be an overall conclusion for the whole project. Besides, future research will be discuss in this chapter as well.

5.2 CONCLUSION FOR CHAPTER 1

Chapter 1 is the chapter that gives the overview of the project. It concludes the background of the project, objectives, problem statements and the scope. The background part had explained that, this system is to identify the shortest path in the library area by using Ant Colony Optimization algorithm. This algorithm is then aim to implement into robot, but for this project, the output will showed by command prompt window. This system is developed due to the time consume and efficiency of work. As shortest path is one of the ways to reduce the time consume and increase the efficiency of work. Therefore, by develop this system, there is a opportunity to study on the Ant Colony optimization, and used it to develop a shortest path for the library area. Microsoft Visual Studio is the software that used to develop this system, due to the supporting of C programming language and it can used to develop interface as well.

5.3 CONCLUSION FOR CHAPTER 2

In this chapter, three main sections had been discussed, which is about the type of existing shortest path problems, the definition of Ant Colony Optimization and the use of Ant Colony Optimization. Shortest path is a fundamental problem that studied in computational geometry. It is a problem of finding the path between 2 nodes, which the path is the shortest path among the area. By solving the shortest path problem, it will benefits human by minimize the time consume and also the cost. Besides that, it also minimizes the human energy. There are a lot of researchers solving the shortest path by using many types of technique and algorithm, for example, Neural Network, Genetic Algorithm, Particle Swarm Optimization, and other algorithm. The types of shortest problem are such as, Traveling Salesman Problem, Robot Motion Planning, Scheduling and so on. Ant Colony Optimization is a probabilistic technique that used to solve computational problem, just as others algorithm do. The advantages that from the previous review is that, Ant Colony Optimization is easy to be implemented this is because the flexible of it to many type of different problems. This is one of the reasons that this system is using Ant Colony Optimization.

5.4 CONCLUSION FOR CHAPTER 3

Chapter 3 is explaining about the methodology that used to develop this system. There is a development model that had been design, which consist of five phases, planning, analysis and requirement, design, implement and testing. In the planning part, consultation with supervisor had been done for the title decision, scope and objective. A meeting with librarian also had been done. That information will be analyzed in the next phase. Then based on the information that analyzed, flow chart for system and algorithm will be designed, as well as the interface. In the implement phase, coding will be generated based on information that analyzed as well. Finally, when the system is developed, it will reach the testing phase, which includes Black-box testing and Alpha testing.

5.5 CONCLUSION FOR CHAPTER 4

In the Chapter 4, implementation and testing part is explained in detail. To search for the possible path, Heuristic Approach is implemented. For this approach, there are 2 rules is set. Firstly, the robot can only take the next step in 3 direction, which are left, right and bottom. Secondly, the robot is not allowed to walk in cross direction. While implementing the concept of Ant Colony Optimization, several steps need to go through. When the Heuristic Approach generate the possible paths, there are some of the similar path, therefore, it need to be reduced. Then the total numbers of checkpoint need to be calculated, which can easy the comparison of those paths in order to find the shortest path. When comes to the testing part. Black-box testing is generated to test all the functionality. Then the Alpha testing that done by programmer is done as well to test the overall of the system.

5.6 OVERALL CONCLUSION

This is a project of Simulation of Identifying the Shortest Path Walkway in Library by Using Ant Colony Optimization. The system aims to implement on robot which will help to collect book in the library. However, for this system, there is only command prompt window to show the results. People nowadays are more concern on time consuming and efficiency of work. Therefore, by finding the shortest path, destination can be reached faster and result in saving time. In library, librarian may not be greater than robot, but without the implementing of shortest path concept, it will result in wasting the power duration of the robot and then less work will be done, efficiency of the work will decrease as well. This is the reason why shortest path is identified in this project. Based on previous studies, Ant Colony Optimization is a technique that has good scalability and able to have well performance. Besides that, Ant Colony Optimization has been proved to be an algorithm which is effectively and efficiently in term of minimizing total time usage. Therefore Ant Colony is the choice for this project. This project will be developed based on a development model that planned. It consists of planning, analysis and requirement, design, implantation and testing. Based on the Ant Colony Optimization concept, possible shortest path is found, the system will calculate the shortest path and show it on the interface. It is expected to be error free system and efficiency algorithms that can automatic generate an

optimum/ shortest path by using the concept of Ant Colony Optimization. This can help in minimizing the time consume as well as help in increasing the work efficiency in the library.

5.7 CONSTRAINTS AND LIMITATIONS

There are several constraints and limitation that found in the system of Simulation of Identifying Shortest Path Walkway in Library by Using Ant Colony Optimization.

According to this system, the robot is not allowed to walk in cross direction. It is only allowed to walk in three directions, which are either down, left of right. Therefore, the result showed will only have the direction in left, right and down.

Besides that, the arrangements of the tables are set to be in grid form. Where the users only insert the number of tables, then the system will auto generate the arrangement of the tables. There is a limit for the number of table. The system is set to have the minimum number of table with 9, and the maximum number of table is 25, because this range is enough to be tested.

5.8 FUTURE RESEARCH

For this current system, the robot only can walk in the small area, where the maximum number of table is 5 X 5. Further research and development can be done in a large area which is more than 25 numbers of tables. When the robot manages to walk in a large area, then robot can help in a whole library.

The current system is test that the tables are arranging in grid form. The coming research can have the idea of arrange the tables in other form to test the flexibility of the algorithm.

Besides that, for future research, the system can used to train more than one robot that walk in an area. This can used to save the battery of a robot, then the performance of work can be increase.

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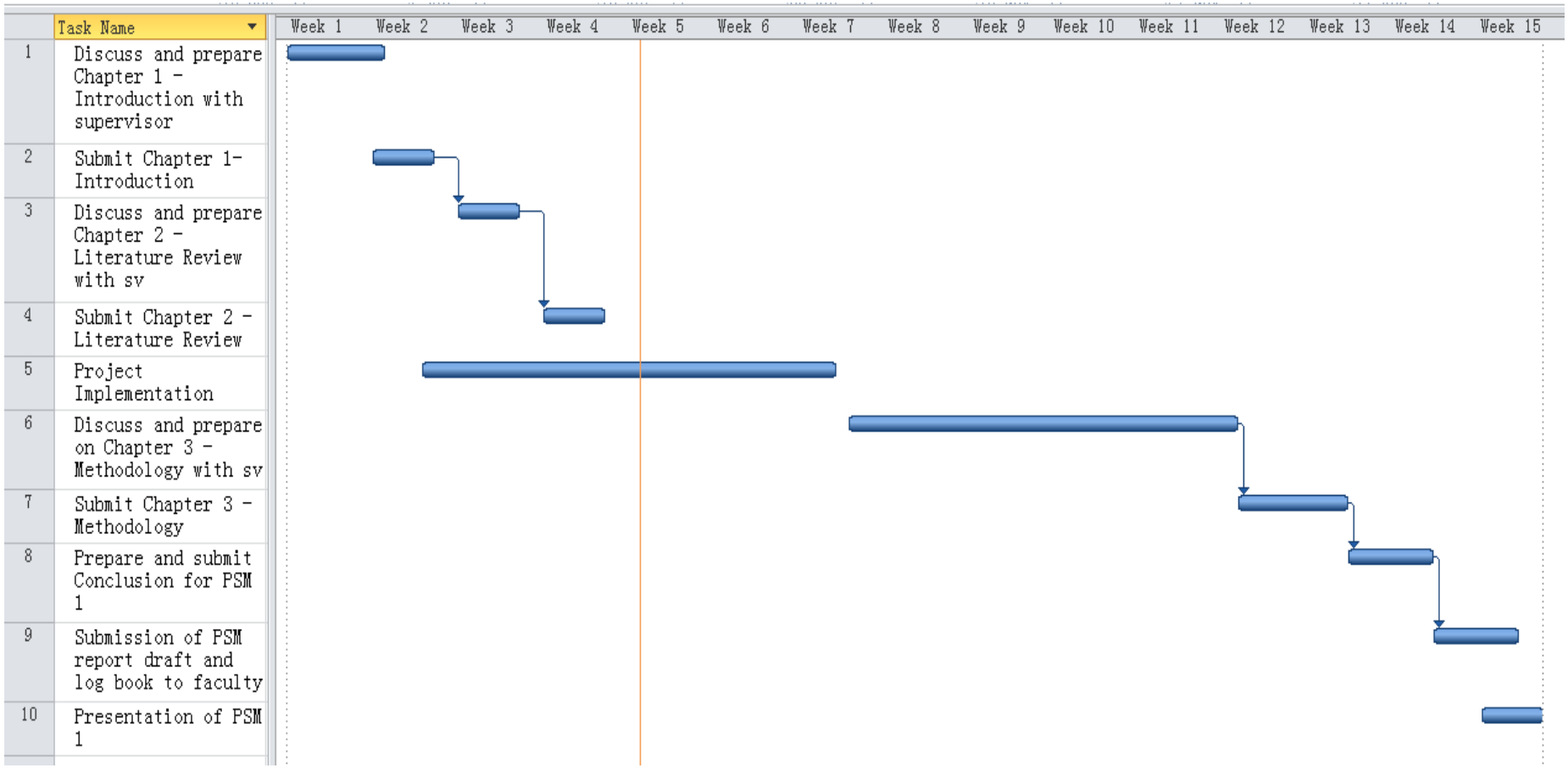
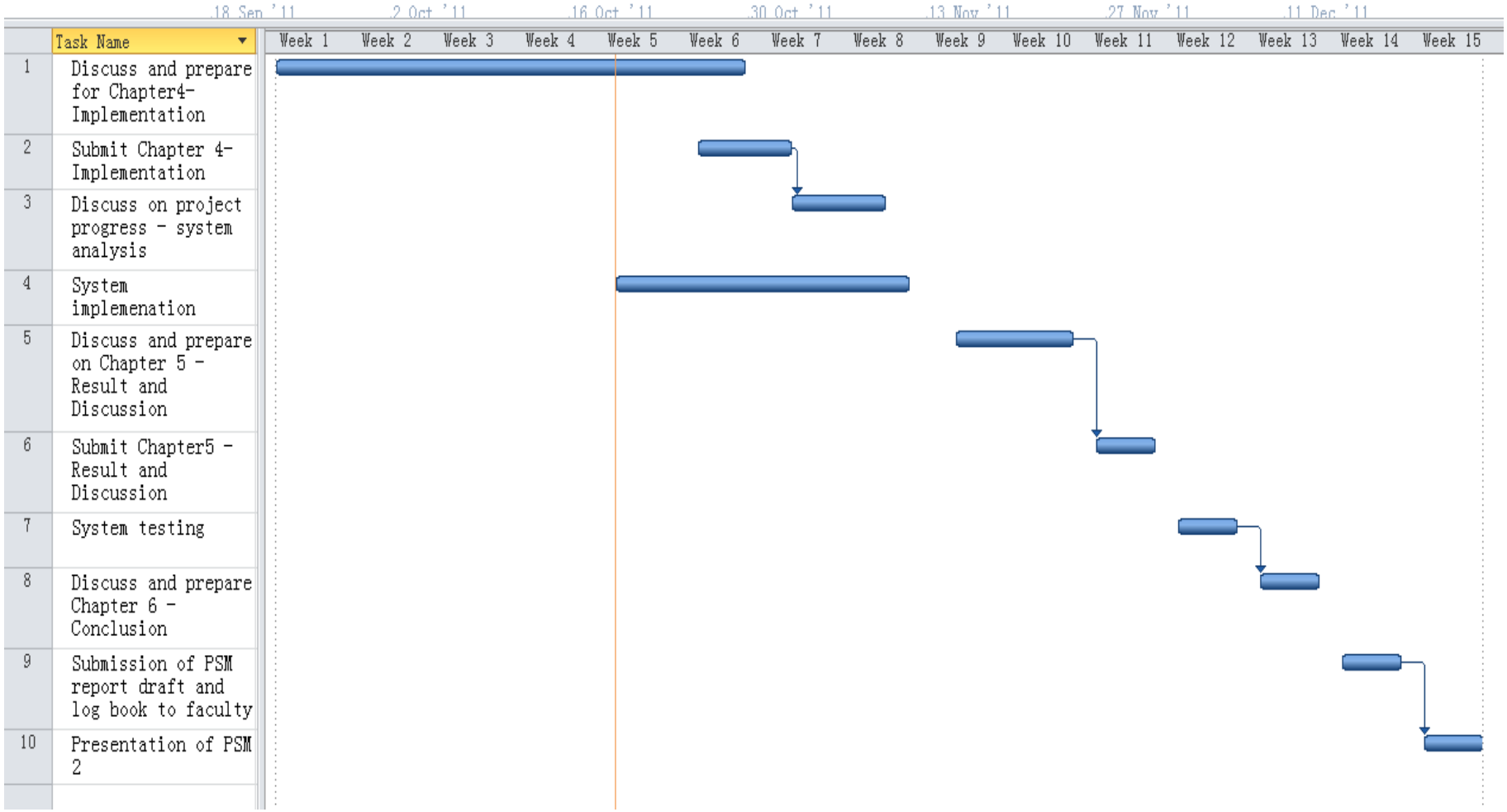
APPENDIX A- Gantt Chart




18 Sep '11
2 Oct '11
16 Oct '11
30 Oct '11
13 Nov '11
27 Nov '11
11 Dec '11
Task Name
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
1 Discuss and prepare for Chapter4- Implementation
2 Submit Chapter 4- Implementation
3 Discuss on project progress - system analysis
4 System implemenation
5 Discuss and prepare on Chapter 5 - Result and Discussion
6 Submit Chapter5 - Result and Discussion
7 System testing
8 Discuss and prepare Chapter 6 - Conclusion
9 Submission of PSM report draft and log book to faculty
10 Presentation of PSM 2