ANT COLONY OPTIMIZATION (ACO) ALGORITHM FOR CNC ROUTE PROBLEM

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ABSTRACT

Printed Circuit Boards (PCB) have copper tracks connecting the holes where the components are placed. They are designed specially for each circuit and makes constructive very easy without any wires. The holes on the PCB had been drilled by using Computer Numerical Controlled (CNC) machines. However, the CNC machines do not choose the optimal route when completing their task and this caused the high cost problem on the machining. This project proposes a new optimization technique which applies ant behavior, for finding the optimal route in PCB holes drilling process. The amount of phenomenon on the shortest path proves that ACO-based approach is capable to optimize the route taken for CNC machine in order to drill the holes on PCB. This project is about to develop a software which applying ACO algorithm in order to calculate the shortest path available that can reduce the time taken to drill the entire hole of PCB. The GUI will be display the shortest path that should be taken by user and give user authority to manipulate the coordinate based on the requirement.

ABSTRAK

Papan Litar bercetak (PCB) mempunyai trek tembaga yang menghubungkan lubang di mana komponen diletakkan. Ia direka khas untuk menghubungkan setiap komponen dalam litar dengan sangat mudah tanpa sebarang wayar. Lubang-lubang pada PCB digerudi dengan menggunakan Komputer mesin Kawalan Berangka (CNC). Walau bagaimanapun, mesin CNC tidak memilih laluan optimum apabila melaksanakan tugas dan ini menyumbang kepada kos yang tinggi untuk setiap proses. Projek ini mencadangkan teknik pengoptimuman baru yang mengaplikasikan konsep yang semut gunakan untuk mencari laluan optimum dalam proses penggerudian lubang pada PCB. Jumlah pheromone yang banyak pada laluan yang pendek membuktikan bahawa pendekatan berasaskan ACO mampu untuk mengoptimumkan laluan yang diambil untuk mesin CNC bagi proses menggerudi lubang di atas PCB. Projek ini adalah untuk menghasilkan perisian yang menggunakan algorithm ACO untuk mengira laluan terpendek yang boleh dilalui oleh mesin CNC bagi mengurangkan masa yang diambil untuk menggerudi lubang pada seluruh PCB. GUI akan memaparkan laluan terpendek yang perlu diambil oleh pengguna dan memberi kuasa pengguna untuk memanipulasi koordinat berdasarkan keperluan yang dikehendaki.

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LIST OF SYMBOLS

η	-	Heuristic Function
β	-	Parameter
τ	-	Parameter of the pheromone
ρ	-	Pheromone Decay Coefficient
C^{nn}	-	Length of Tour Generated Randomly
$\sum$	-	Summation

LIST OF ABBREVIATION

ACO	-	Ant Colony Optimization
ACS	-	Ant Colony System
GUI	-	Graphical User Interface
VB	-	Visual Basic
CNC	-	Computer Numerical Control
PCB	-	Printed Circuit Board
PSO	-	Particle Swarm Optimization

CHAPTER 1

INTRODUCTION

1.1 Project background

A printed circuit board (PCB) is used to connect electronic components using conductive pathways, tracks or signal traces etched from copper sheets laminated onto a non-conductive substrate. Holes trough a PCB are typically drilled with Computer Numerical Control (CNC) machines. CNC has been around since the early 1970's in order to replace some existing manufacturing process includes drilling PCB holes. In the CNC machining, determining optimal cutting conditions or parameters under the given machining situation is the problem we faced on. The problem will be solved by using Ant Colony Optimization (ACO) algorithm. Ant colony optimization (ACO) takes inspiration from the foraging behavior of some ant species. These ants deposit pheromone on the ground in order to mark some favorable path that should be followed by other members of the colony. Ant colony optimization exploits a similar mechanism for solving optimization problems [1]. After that algorithm has been applied, the program will be implemented by using Visual Basic 6.0 software.

1.2 Ant Behavior

Ant Colony Optimization (ACO) mimics the way real ants find the shortest route between a food source and their nest. The ants communicate with one another by means of pheromone trails and exchange information about which path should be followed. The more the number of ants traces a given path, the more attractive this path (trail) becomes and is followed by other ants by depositing their own pheromone. This auto catalytic and collective behavior results in the establishment of the shortest route. Ants find the shortest path from their nest to the food source with the help of pheromone trail. This behavior of ants is captured on ant colony optimization algorithms to solve real problems with using exactly some characteristics of ants.

Actually, if there present a difficulty on the path while going to the food source (Figure 1.1), ants lying in front of this difficulty cannot continue and has to account a preference for the new outgoing path. In the present case, selection probability of the new direction alternatives of ants is equal. In other words, if ant can select anyone of the right and left directions, the selection chance of these directions is equal (Figure 1.2). Namely, two ants start from their nest in the search of food source at the same time to these two directions. One of them chooses the path that turns out to be shorter while the other takes the longer path. But it is observed that following ants mostly select the shorter path because of the pheromone concentration deposited mostly on the shorter one.

The ant moving in the shorter path returns to the nest earlier and the pheromone deposited in this path is obviously more than what is deposited in the longer path. Other ants in the nest thus have high probability of following the shorter route. These ants also deposit their own pheromone on this path. More and more ants are soon attracted to this path and hence the optimal route from the nest to the food source and back is very quickly established. The instrument of ants uses to find the shortest path is pheromone.

Pheromone is a chemical secretion used by some animals to affect their own species. Ant deposit some pheromone while moving, they deposit some amount of pheromone and they prefer the way deposited more pheromone than the other one with a method based on probability. Ants leave the pheromone on the selected path while going to the food source, so they help following ants on the selection of the path (Figure 1.3).

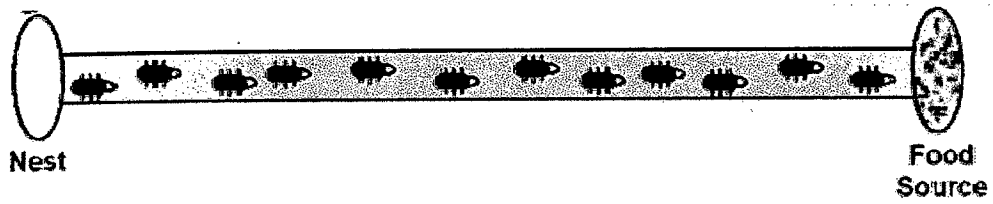

Figure1.1: Ants following a path between their nest and food source

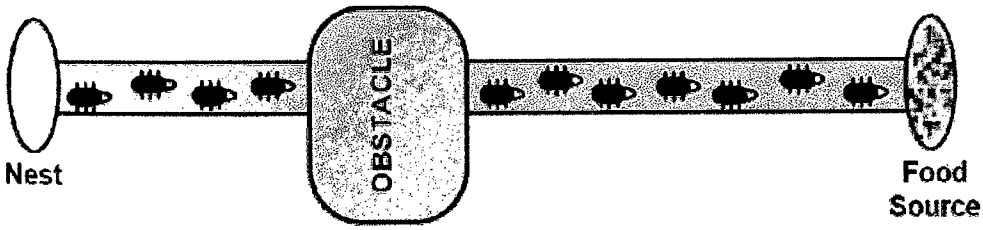

Figure1.2: Ants encountering an obstacle

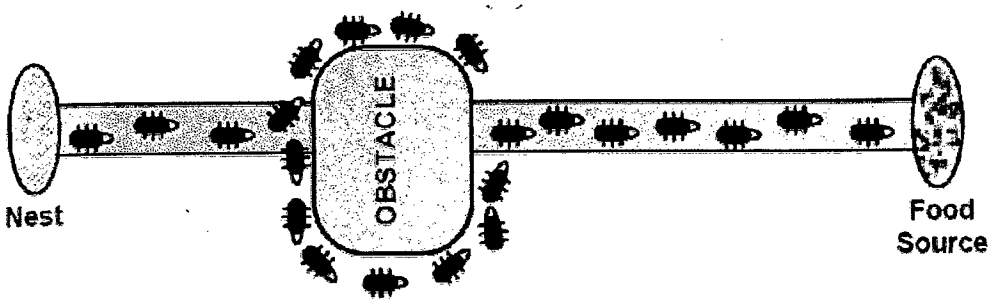

Figure 1.3: Ants selecting the path

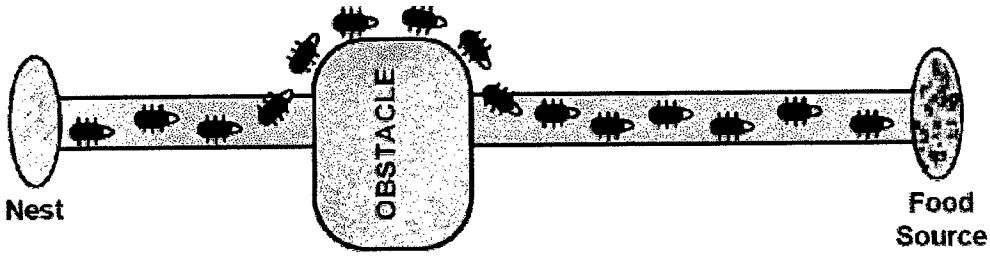

Figure 1.4: Ants finding the shortest path

1.3 Problem Statement

Today, computer numerical control (CNC) machines are found almost everywhere, from small job shops in rural communities to Fortune 500 companies in large urban areas. Truly, there is hardly a facet of manufacturing that is not in some way touched by what these innovative machine tools can do.

The CNC control will interpret a CNC program and activate the series of commands in sequential order. As it reads the program, the CNC control will activate the appropriate machine functions, cause axis motion, and in general, follow the instructions given in the program.

However, without any optimization, the cutting and drilling process will be take much time and energy wasted. Optimization of operating parameters is an important step in machining, particularly for operating CNC machines. Although there are enough handbooks to provide recommended cutting parameters, they do not consider the economic aspects of machining. For minimizing the time taken for drilling and cutting process, the machines need to go to each point (holes) in the shortest path which is high efficiency and without any complex formula.

Fortunately, CNC control has several other purposes. All current model CNC controls allow programs to be modified (edited) if mistakes are found. The CNC control allows special verification functions to confirm the correctness of the CNC program. The CNC control allows certain important operator inputs to be specified separate from the program, like tool length values. In general, the CNC control allows all functions of the machine to be manipulated. It makes works easier in order to change the program on how to choose the shortest path to work.

So, some optimization method needs to apply on the program. For this project, ACO is the main optimization algorithm and shall be able to choose the best path in order to cut off time taken and cost needed to finish up the task.

1.4 Project Objectives

The purposed of these projects are to study and analyzed the CNC machines in order to have shortest parameters to drill holes on PCB. The objectives of the projects are:

- To develop Ant Colony Optimization (ACO) algorithm for CNC route problem.
- To optimize parameters taken for minimizing production cost
- Implement the program by Visual Basic 6.0 software

Developing of GUI shall be able to give an authority to user for setting up all specification needed such as coordinates of point, drilling time, number of holes and etc. At the end of process, all point will be drilled and each point must be drilled only once.

1.5 Project Scope

Project scope is the combination of objectives and requirements necessary in order to make sure that project run in the limited boundary. This project is about to create GUI by using Visual Basic 6.0 based on CNC drilling machine. For the first step of designing, the maximum number of holes that can be accepted will be set up to 15

holes including origin. The GUI had been develop with the consideration of Ant Colony Optimization algorithm and able to get the input from user.

1.6 Report Outline

This report consists of five chapters which Chapter 1 cover about the background, problem statement, objectives, project scope and report outline as additional part to summarize for the whole chapter of the report.

There will be discussing on how ACO works and where ACO comes from. The source had been taken from some source such as internet, magazines, encyclopedia and other thesis that have similar problem statement and different approach. All reference had been cited on the last part of this thesis.

For the Chapter 3, there will have a discussion about the methodology. Having a clear description of the methods that will be used and accomplish the project objectives to make a strong application even more competitive. For this project methodology, there will have some discussion on how to implement the ACO into problem and how the equation works.

For the Chapter 4, the result and overall discussion will be presented with some of proof. Last but not least, Chapter 5 will be having the conclusion to conclude overall results of the algorithm applied.

CHAPTER 2

LITERITURE REVIEW

2.1 Background

Computer Numerical Control (CNC) Drilling is commonly implemented for mass production. The drilling machine, however, is often a multi-function machining center that also mills and sometimes turns. The largest time sink for CNC drilling is with tool changes, so for speed, variation of hole diameters should be minimized.

This study will lead on choosing the best algorithm, and know pro and cons of that algorithm. Then, develop the GUI to show the result based on the algorithm chosen.

2.2 Ant Colony Framework

The ant colony optimization algorithm system (ACO), which was developed by Marco Dorigo [6-8], has been successfully applied to several problems, such as traveling salesmen problem (TSP). The ACO algorithm is inspired from the behavior of real ant in nature world. Ants walk out from their nest to find the food, and those who find the food will leave some pheromone on the path they have walked to communicate with other ants. In the ACO algorithm, each artificial ant constructs a particular path by some probability choice rules. The walking paths are treated as the possible solution and the pheromone denotes the weights of the choices.

2.3 Printed Circuit Board (PCB)

Now days, many printed circuit boards (PCBs) are applied to compact electronic appliances which require high efficiency and high functional performance. PCB demands an increase in number of wiring layers, the density of printed circuit and the miniaturizing of through holes. Currently, micro drills of 0.1–0.3 mm in diameter are commonly used in production lines and drills of diameter 0.05–0.075 mm are tentatively used in aggressive lines [4]. The stack height of PCB is increasing more and more in order to improve the productivity in drilling. As the result, micro drills with a long body are demanded and concern for drills with aspect ratio of 15 or more is also increasing

[5]. PCB is laminated composite material consisting of copper foils, resin and glass fiber cloth. So it is difficult to drill deeper holes at high productivity and high precision. For instance, micro drills are easy to break during drilling. Therefore, it is serious for PCB manufacturing that more conservative drilling conditions chosen for safety bring lower productivity and higher cost.

2.4 Computer Numerical Control Machine

To overcome PCB problem as stated above, an automatic drilling machine (Computer Numerical Control machine) had been created. CNC machines are complete with drill and profile routing software. The entire CNC machine include a high frequency spindle (60 000 rpm) and seems to be suit for drilling holes on PCB because it has smallest drill diameter which is 0.3mm with the drill speed of 5 hits per second. Availability of the machine to move based on the program gives chances to save cost production by minimizing the route taken while drilling holes on PCB. Normally, CNC machines drills holes on PCB based on command that already set in the program and programmer do not consider on the production cost.

Minimizing route taken for drilling holes on Printed Circuit Board is an important step in machining, particularly for operating Computer Numerical Control (CNC) machine. CNC machine is commonly used in industry but the operation of this

machine take high production cost because it has long distance of route to consider. However, the optimization technique can be applied to solve those problems.

2.5 Ant Colony Optimization Algorithm

One of the best algorithms applied is Ant Colony Optimization (ACO). ACO is a recent family member of the meta-heuristic algorithms and can be used to solve complex optimization problems. It is a biological inspiration simulating the ability of real ant colony of finding the shortest path between the nest and food source. Suppose an ant were deposited on some randomly chosen city. Tours could be generated by this artificial ant. A probability is computed for each of the possible target cities that the ant can travel to from the source city that it is occupying. This probability is based on two factors which are the distance to the target city (shorter distances provide higher probability) and the pheromone that has been previously deposited on the edge from the source to target city. Artificial ants are not allowed to re-visit a city.

On each iteration of the simulation, after all the randomly placed ants have constructed their tours, the pheromone trails are updated. Firstly, all the pheromone on each edge is reduced by a constant factor (evaporation). This helps to ensure exploration and stops premature convergence to the edges on the best tour so far which at the beginning is probably not a very good tour. Then each ant deposits pheromone on the edges corresponding to the cities visited given by the reciprocal of the tour cost. So a poor tour (high tour cost) will result in less pheromone being deposited than a good tour. The best tour among the ants is found (best tour to date). Additional pheromone is