PARTICLE SWARM OPTIMIZATION (PSO) FOR CNC ROUTE PROBLEM

NUR AZIA AZWANI BINTI ISMAIL

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Faculty of Electrical & Electronics Engineering
Universiti Malaysia Pahang

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ABSTRACT

The purpose of this study is to develop the application of Particle Swarm Optimization (PSO) which applicable to CNC machine route problem. In this project, the problem of CNC machine can be identifying by routing problem which it become more complicated to solve without use of any optimization method. The mathematical equation become more complexes and it will be difficult to solve using manual calculation without any optimization technique or algorithm in this project. We often see many of the method of Genetic Algorithm (GA), Ant Colony Optimization (ACO), Simulated Annealing Algorithm (SAA) and PSO are used for any optimization problems. Basically, this project is mainly concerned on Particle Swarm Optimization (PSO) to optimize the routing of CNC machine. The algorithm used in this project is the Global Best (*gbest)* algorithm where it is a basic algorithm of Particle Swarm Optimization which applicable the shortest time and path of CNC machine to complete the process of drilling. In addition, the software Microsoft Visual Basic 6.0 has been used which is provide a graphic user interface (GUI) for the user to determine the coordinate of holes (particles) and desired parameters at the search space given. The user can also monitor the result and performance of the system through this software. This software will optimize the result which is to determine the path and time to complete the drilling process. In t the end of this project, it can be concluded that the Particle Swarm Optimization (PSO) method can be used and available to apply in the CNC Route Problem.

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LIST OF SYMBOLS

ω	-	Inertial Weight
c_1	-	Cognitive Coefficient (position acceleration constant)
c_2	-	Social Coefficient (position acceleration constant)
r_1& r_2	-	Random Parameter
S_i^k	-	Particle Position
v_i^k	-	Particle Velocity
k	-	Iteration
i	-	Particle Number
T_x &T_y	-	x and y coordinates of the target
P_x &P_y	-	x and y coordinates of a given individual

CHAPTER 1

INTRODUCTION

1.1 Background

A Computer Numerical Controlled (CNC) machine is a computer controlled machine for composites, aluminum, steel, plastics, wood and foams. A CNC router can reduce waste, frequency of errors and the time the finished product takes to get to market. A CNC machine gives more flexibility to the manufacturing process. It can be used in the production of many different items such as: door carvings, interior and exterior decorations, wood panels, sign boards, wooden frames, moldings, musical instruments, furniture manufacturing and so on.

For FKEE, CNC machine was used to drill the holes for PCB board. All CNC machine types share this commonality which is have two or more programmable directions of motion called axes. For drilling, common linear axis name are x,y,z which can be linear (along a straight line) or rotary (along around circular path).

In this project, the problem of CNC machine can be identifying by routing problem which it become more complexes when the number of holes was increased (too many holes) depends on the design. Occasionally, increasing the number of holes will increase the possibility of route. The mathematical equation become more complexes and it will be difficult to solve using manual calculation if any optimization technique or algorithm did not used in this project. CNC machine route problem will delay the process of drilling because the longest time taken needed to finish up the start, center, and end process.

In order to solve the problem of CNC route problem, optimization techniques are the best way for solving this problem. This project proposed to use the PSO algorithm as the main method to optimize the length or path of the CNC route and the time taken of path drilling holes can be reduced occasionally.

Particle Swarm Optimization (PSO) is one of the best optimization techniques which is an evolutionary computational technique developed by Australian Scientist, James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer) in 1995 [1]. It is a robust stochastic optimization technique based on the movement and intelligence of swarms that finds a solution to an optimization in a search space or model and predict social behavior. This optimization techniques was inspired by social behavior and movement of insects, birds and fish to solve the routing problem in this project. It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution.

1.2 Objectives

The main objective of this project is to develop the Particle Swarm Optimization (PSO) algorithm and applied to CNC route problem and also find the shortest time and path of CNC machine to complete the process of drilling by using the Particle Swarm Optimization (PSO).

1.3 Scope Of Project

In order to achieve the objectives of this project, several scope of project have been decided includes :

a. Use software Microsoft Visual Basic 6.0 with Graphical User Interface (GUI).
b. The type of CNC machine is X-Y-Z Cartesian Coordinates and it develop into two-dimensional in the software.
c. The minimum and maximum number of holes to be drilled in this project are about range between one to ten.
d. The time taken for drilling is classified to t_d (5 sec)
e. The time taken for CNC Machine moving up or down is classified to t_p(3 sec)
f. The time taken for CNC Machine moving from one point to another point at the Cartesian Coordinate is classified to t_m (1 sec).

1.4 Problem Statement

CNC Machine routing problems that occur in drilling process is very complex to solve without the help of optimization techniques. It includes optimization algorithms and mathematical formula which is difficult to solve by calculate manually. Basically, PSO technique with a calculation method is designed to provide solutions to the optimization problems.

1.5 Outlined thesis

This thesis consists of five chapters. In the first chapter introduction, it discusses about the objectives and scope of this project which are for overall summary of works. The second chapter will discusses several theory and literature reviews had been done in this project. In this chapter, the basic theory of Particle Swarm Optimization (PSO), several related applications of PSO and several research paper about route problem around worldwide had been discussed. In Chapter 3, the discussion about PSO implementation in this project will be on the methodology part. The results and discussions will be represented in Chapter 4. Finally, Chapter 5 will discusses about the conclusion of this project and future recommendation that can improve the CNC route problem.

1.6 Summary Of Works

Implementation and works of the project are summarized into the Gantt chart as shown in Figure 1.0 and Figure 1.1 show the detail of the works of the project that had been implemented in the first and second semester.

TOPIC	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
• PSM 1 briefing session • Register subject BEE 4712														
Find supervisor and project title														
• Search literature review														
Register title and submit abstract														
• Describe the methodology • Define the objective project														
• Do the gantt chat • Describe the scope project														
Survey what component want to use														
• Submit proposal, 1A form, 1B form • Submit presentation slide • Submit evaluation form														
Survey what component want to use														
• Survey component price • Defined what component to use														
PSM seminar 1														
Design and built the hardware														
Submit report, log book, evaluation form														

ACTIVITIES\WEEK	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
-PSM 2 briefing session -Register subject BEE 4724																		
Meeting with supervisor																		
Implement basic PSO for minimization of standard test function																		
Develop a fitness function for CNC																		
Develop a software for CNC fitness function with GUI								SEMESTER BREAK										
Apply Particle Swarm Optimization (PSO) to CNC Drill Route Problem																		
Develop PSO CNC with GUI progrmming																		
Testing Simulation																		
Analysis and Results																		
Write the thesis																		
Prepare the presentation																		
Presentation PSM2																		

ACTIVITIES WEEK	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
-PSM 2 briefing session -Register subject BEE 4724								SEMESTER BREAK										
Meeting with supervisor																		
Implement basic PSO for minimization of standard test function																		
Develop a fitness function for CNC																		
Develop a software for CNC fitness function with GUI																		
Apply Particle Swarm Optimization (PSO) to CNC Drill Route Problem																		
Develop PSO CNC with GUI progrmming																		
Testing Simulation																		
Analysis and Results																		
Write the thesis																		
Prepare the presentation																		
Presentation PSM2																		

CHAPTER 2

LITERATURE REVIEW

2.1 Basic theory of Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is an evolutionary computational technique originally developed by Kennedy, Eberhart and Shi[1][2]. It was intended for simulating social behavior,[3] which is inspired by the movement dynamics of organisms in insects, birds and a bird flock or fish school as they searching the food source. The algorithm was simplified and it was observed to be performing optimization.

The PSO is stochastic, population-based computer algorithm modeled on swarm intelligence. Basically, PSO optimizes a problem by having a population of candidate which known as the particles and moving these particles around in the search-space[3]. Each particle's movement is influenced by its local best known position and is also guided toward the best known positions in the search-space which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions[4]. Each particle will produce two parameter and both parameters were communicate each other, which are the velocity of particle and the position of particle. All the particles can share their information about the search space, so there is a global best solution[5].

For this project, the particle is similar to a time of the path or route to CNC machine completing the task. We can get the shortest path among the other path from the time that solved by particles. The analogy of the particle and swarm is depending to the problem, and it can represent whatever name and value that suitable from the problem according to the formulae shown below.

The velocity of particle i, is calculated as,

$$v_i^{k+1} = \omega v_i^k + c_1 r_1 (pbest_i - S_i^k) + c_2 r_2 (gbest - S_i^k) \quad (2.0)$$

$$\omega = \omega_{max} - \left(\frac{\omega_{max} - \omega_{min}}{i_{max}}\right) \times i \quad (2.1)$$

Where,

ω = Inertia Weight

c_1= Cognitive Coefficient (position acceleration constant)

c_2= Social Coefficient (position acceleration constant)

r_1 and r_2 = Random Parameter

S_i^k=Particle position

v_i^k = Particle velocity

k = Iteration

i = Particle number

The position of particle i is calculated as,

$$S_i^{k+1} = S_i^k + v_i^{k+1} \quad (2.2)$$

S_i^k is variable for the fitness function $f(x) = f(S_i^k)$

Where

$k = 0, 1, 2, 3, 4, 5......$ (Iteration)
$i = 0, 1, 2, 3, 4, ...$(Particle number)

2.2 Global Best PSO Algorithm

Basically, the objective of this routing problem is to find the shortest time through the shortest path of CNC. In order to achieve this objective, we can control the particle to use the useful variable. For this problem, the particles stand for the route of CNC. Particles will looking around the possibility of routes and find the best solution. Particles also looking around the search space to find the time (t) and it are not allowed and avoid it moving outside the search space.

Particles cannot repeat the value of axes which is each axes cannot use the same value from the other axes. This requirements need to follow to make sure we get the right solution when using Global Best PSO algorithm. If the system use 3 holes, we get 3 axes (3 Dimension) and if the system use up to 10 holes, we use 10 axes (10 Dimension).

Global Best PSO or gbest PSO is a basic PSO algorithm with their velocity calculation that depends on both the cognitive and social component and it is call as the full PSO model. For our routing problem, the gbest PSO represented by the minimum value among the Personal Best (pbest PSO) where the value of both is found by iteration. The Personal Best PSO is the best value that found and the values will compare to find the best value between the best and it is known as global best or gbest.

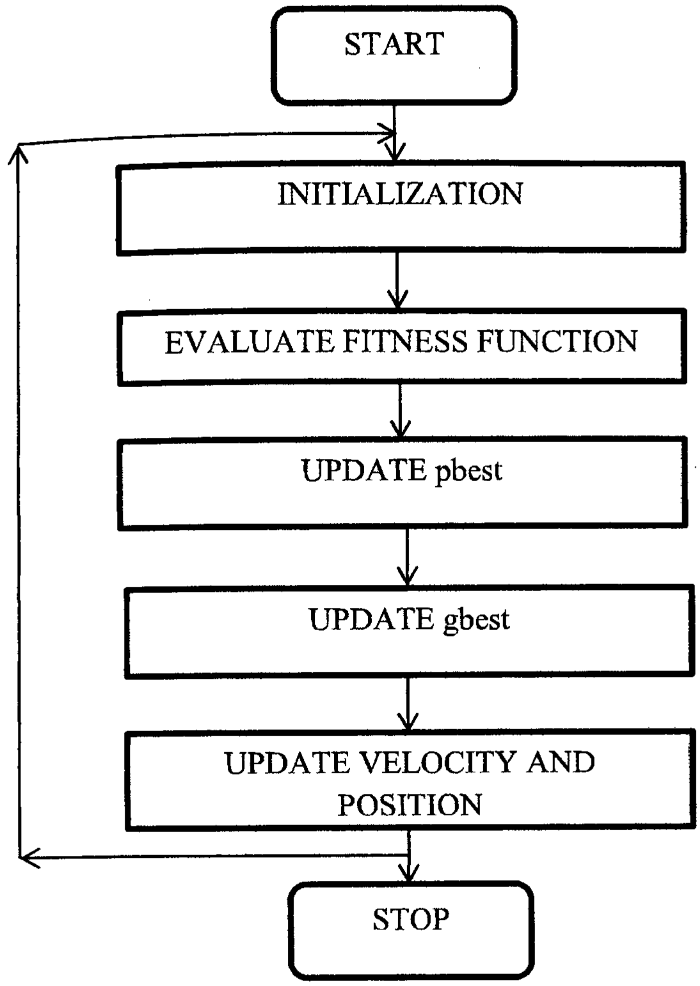

Figure 2.1 Flow chart of Global Best PSO Algorithm

Several basic step or procedure on Global Best PSO algorithm were identified and related to this project based on Figure 2.1 above.

Step 1: Initialization

- Initialize particle randomly for:
    i. Particle position
    ii. Particle velocities

Step 2: Evaluate Fitness Function

- Random value for the position of particle f(x,y)
- Calculate the fitness function for particle
- Follow the range of search space (the maximum number of holes)

Fitness Function equation:

Total time (t) = First Hole (t) + Last Hole (t) + {X-Component link 1(t) +

X- Component link 2(t)} + {Y-Component link 1(t) +

Y-Component link 2(t)} + (Robot Up (t) + Robot down (t) +

Robot Drill (t))*Number of Hole (2.3)

Step 3: Update pbest

- Evaluate each particle's position according to the position.
- If particle's fitness value is better than its previous best fitness value, update it as pbest.
- Determine the new pbest (according to the particle's previous best fitness value).

Step 4: Update gbest

- Choose the particle with the best fitness value (*pbest*) of all the particles as the gbest.
- Compare each particle where the best and the lowest velocity and position of particle will be gbest.

Step 5: Update Velocity and position of particle

- Update particle's velocities according to equation below:

$$v_i^{k+1} = \omega v_i^k + c_1 r_1 (pbest_i - S_i^k) + c_2 r_2 (gbest - S_i^k) \quad (2.4)$$

$$\omega = \omega_{max} - \left(\frac{\omega_{max} - \omega_{min}}{i_{max}}\right) \times i \quad (2.5)$$