

## Route Planning Analysis in Holes Drilling Process Using Magnetic Optimization Algorithm for Electronic Manufacturing Sector

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**Abstract:** Electronic manufacturing sector uses computer numerical controlled machines for drilling holes. Most of the computer numerical controlled machines used nearest neighbour algorithm to plan the route for the drill bit to travel. Based on this motivation, this paper proposes an approach which is based on the experimentation of Magnetic Optimization Algorithm. In this implementation, each magnetic agent or particle in Magnetic Optimization Algorithm represents a candidate solution of the problem. The magnitude of the magnetic force between these particles is inversely proportional to the distance calculated by the solution they represented. Particles with greater magnetic force will attract other particles with relatively smaller magnetic force, towards it. The process is repeated until the stopping condition meets and the solution with lowest distance is taken as the best-found solution. Result obtained from the case study shows that the proposed

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approach managed to find the optimal solution. With this method, electronics manufacturing sector can optimize the drilling process hence will increase the productivity of the manufacturer. This study can be extended further by tuning the parameters of MOA in order to enhance the drilling route process.

**Key words:** Magnetic Optimization Algorithm % Swarm Intelligence % Route Planning % Holes drilling process % Computational Intelligence

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## INTRODUCTION

Computer Numerical Controlled (CNC) machines have advanced the holes drilling process as this manufacturing process now has been completely automated. Currently, most of the CNC systems, the end-to-end component design is computerized using Computer Aided Design (CAD) program. The program will produce a computer file called Numerical Controlled Drill (NCD) that can be interpreted by CNC machines. This file listed the sequence, location and sizes of each hole to be drilled. However, the NCD file only use Nearest Neighbour (NN) algorithm where the route planning obtained from this algorithm does not guaranteed optimal route.

The (Printed Circuit Board) PCB holes drilling route optimization problem is a subdivision of the Travel Salesman Problem (TSP). The TSP problem is a combinatorial problem where the objective is to find the sequence of cities to be visited for the salesman to complete his tour of  $n$  cities provided the inter-city distance. Similar to TSP, the optimized route in holes drilling process can be obtained by finding the holes sequences that requires minimal distance travelled by the drill bit. By obtaining the optimized route, the CNC machine is able to reduce its operational time per item, which leads to an increase in its yield as more tasks can be completed at a given time. The importance of improving of the CNC process is significant; this can be seen by numerous studies published.

Based on the reviewed literature [1-12], the earliest studies in holes drill routing was conducted by Kolahan and Liang [1] in 1996. The researchers suggested the use of Tabu search algorithm in solving case study, which consist of variable holes sizes. In addition, they have proposed an improved version of Tabu search algorithm [2]. Onwubolu and Clerc [3] proposed a Particle Swarm Optimization (PSO) algorithm for holes drilling problem. Another new algorithm called Record-to-Record Travel with Local Exchange Moves (RRTLEM) in finding the optimized sequence is proposed [4].

Focusing into CNC machine, the earliest work in holes drill routing problem was done by Sigl and Mayer [5] in 2005. They introduced the 2-Opt Heuristic Evolutionary (HE) algorithm in solving drill routing for Computer Numerical Control (CNC) machine. Quedri *et al.* [6] have implemented Genetic Algorithm (GA) to search the optimized route for holes cutting process in CNC machine tool. Similarly, Ghaiebi and Solimanpur [7] have introduced an Ant Algorithm for holes drilling of multiple holes sizes.

In 2006, Zhu [8] has found that the standard PSO algorithm does not promise global convergence in holes drilling problem. The author proposed an improved PSO based on a model with components: Order Exchange List (OEL) and Order Exchange Unit (OEU). These components are able to solve the constraints encountered in modeling standard PSO for PCB holes drilling problems. The author then implemented the proposed algorithm on a case study, which consists of a PCB with 14-holes. Later, the proposed approach has been applied to different set of problems [9].

Several authors benchmark their proposed approaches by using the same case study. In 2010, Adam *et al.* [10] proposed a different model of PSO to tackle the case study. In the following year, Othman *et al.* [11] suggested that Binary PSO (BPSO) has shown better performance than [10] using the same case study. In the same year, Saealal *et al.* [12] have implemented Ant Colony System (ACS) in the case study. The results show that ACS performed really well as compared to other Swarm Intelligence (SI) approaches.

The objective of this paper is to use the MOA to solve the routing PCB holes drilling process. This paper also explains the detailed problem of interest and the mathematical formulation of the problem is defined. Next, the modeling of MOA in holes drilling route problems is explained, followed by the discussion of the implementation and the experimental results obtained based on the proposed approach and findings will be summarized.





In this paper, the proposed approach uses maximum iteration as the stopping condition. Then, we enter the second phase of any nature-inspired optimization techniques: the fitness evaluation. The fitness of the particles are calculated using equation (4) and stored as magnetic field,  $b^z$ . For example, fitness calculation of  $x_{31}^{7,0} = [12-7,2]$  is 12 units. Not that the distance from home to the first hole and distance from last hole to home are not counted.

Then, the magnetic value using is normalized as in equation (7).

$$b_{ij}^z = \frac{b_{ij}^z - \min_{i,j=1 \rightarrow S}(B_{ij}^t)}{\max_{i,j=1 \rightarrow S}(B_{ij}^t) - \min_{i,j=1 \rightarrow S}(B_{ij}^t)} \quad (7)$$

Next, the mass of the particles,  $m_{ij}^z$  is calculated using equation (8). The  $a$  and  $D$  are constant parameters of MOA. Following are the third phase of any nature-inspired optimization algorithm, the improvement of the agents or the learning phase.

$$m_{ij}^z = a + r \times b_{ij}^z \quad (8)$$

In the implementation,  $a = 1$  and  $D = 1$ . Then, identify the lattice neighbours of the particles. Next, the magnetic force  $f_{ij}^z$  is calculated using equation (9).

$$f_{ij}^z = \frac{(x_{uv}^{z,t} - x_{ij,k}^{z,t}) \times b_{uv}^z}{\sqrt{\frac{1}{n} \times \sum_{k=1}^n \left( \frac{x_{uv}^{z,t} - x_{ij,k}^{z,t}}{uk - lk} \right)^2}} \quad (9)$$

Based on the force, the particle velocity and the particle position are updated using equations (10) and (11).

$$v_{ij,k}^{z,t+1} = \frac{f_{ij}^{z,t}}{m_{ij}^z} \times R(u_k, l_k) \quad (10)$$

$$x_{ij,k}^{z,t+1} = x_{ij,k}^{z,t} + v_{ij,k}^{z,t+1} \quad (11)$$

After updating the particle position, it is necessary to check for any redundancy in the value of the voting. For example,  $x_{11}^{1,1} = [9,9,6]$  leads to an invalid solution.

Here, it can be simply corrected by initializing that particle using equation (6). The process is repeated until maximum iteration is met. Then the global best solution is taken as the final solution.

## RESULTS AND DISCUSSION

The proposed approach is written in MATLAB and the simulation is performed 50 times on a desktop equipped with 1.86GHz Intel Pentium Core 2 processor with 2GB RAM. Table 1 lists the information related to the case study shown in Figure 1. Table 2 lists the parameters values used throughout this study in solving the case study. Table 3 contains the comparison between the results obtained by other literatures and this study. Each computation takes an average duration of 1.5 hours to complete.

From Table 3, the proposed approach is able to find the optimal solution of the case study, which has a fitness of 280mm. This indicates that the proposed approach able to solve the problem given the common parameters values are the same as in equation [8]. In terms of average fitness, the proposed approach has a better fitness compared to GCP SO, PSO and BPSO but has a higher fitness value compared to ACS. It is not surprise that ACS performs well compared to the proposed approach as ACS was initially designed to solve TSP, which inter related to routing problem. Lower average fitness translates to a better choice of path selection by the CNC machine in completing its task.

Table 1: Information of PCB used in the case study

Number of holes, $n$	14	Length	100mm	Wide	70mm		
Hole Number	Coordinate (x, y)	Hole Number	Coordinate (x, y)	Hole Number	Coordinate (x, y)	Hole Number	Coordinate (x, y)
0	(0,0)	1	(10,60)	2	(10,10)	3	(18,16.5)
4	(18,27.5)	5	(32.32,57.34)	6	(37.7,43.6)	7	(37.7,26.4)
8	(62.3,26.4)	9	(62.3,43.6)	10	(90,60)	11	(82,53.5)
12	(82,42.5)	13	(72.59,14.25)	14	(90,10)		

Table 2: Parameters used by related literatures

	Zhu's [8]	Adam [10]	Othman [11]	Current study
<b>Common Parameters</b>				
Number of agents, $q$	100	50	50	50
Number of iterations, $t$	10000	5000	2500	10000
Number of computations	50	50	50	50
<b>PSO Parameters</b>				
Inertia weight, $T$	0.0, 0.5, 1.0	0.9 6 0.4	Not applicable	
Cognitive component, $c_1$	Not available	1.42	Not applicable	
Social component, $c_2$	Not available	1.42	Not applicable	
$r_1$ and $r_2$	Random number [0,1]	Not applicable		
<b>MOA Parameters</b>				
"	Not applicable	1		
$D$	Not applicable	1		

Table 3: Comparison of results obtained by related literature

	Zhu [8]			Adam [10]	Othman [11]	Saeel [12]	Current study
	GCP SO			PSO	BPSO	ACS	FA
Inertia weight, $T$	0	0.5	1.0	0.9 6 0.4		Not Applicable	Not Applicable
The least iteration number while global convergence	70	601	93	118	71	193	159
The average iteration number while global convergence	1784	3549	2104	1415	783	1037	2830
Length of optimal solution	280	280	280	280	280	280	280
Average fitness after computing 50 computations	305.7	307.3	289.6	292.3	296.0	283.6	287.8

### CONCLUSION

This paper presents the application of MOA with voting modeling in PCB routing problem. The process of finding the shortest distance for the drill bit to drill all the holes using MOA has been achieved. Result obtained from the case study shows that the proposed approach managed to find the optimal solution. With this method, electronics manufacturing sector can optimize the drilling process hence will increase the productivity of the manufacturer. This study can be extended further by tuning the parameters of MOA in order to enhance the drilling route process.

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