Computer Numerical Control-PCB Drilling Machine with Efficient Path Planning – Case Study_2

Motaz Daadoo[1], Derar Eleyan[2] Saed Tarapiah[3], Shadi Atalla[4] , Amna Eleyan[5]
[1 2]Department of Computer Systems Engineering, Palestine Technical University- Kadoorie (PTUK), Tulkarm, Palestine.
[3]Department of Telecommunication Engineering, An-Najah National University, Nablus, Palestine.
[4]College of Information Technology (CIT), University of Dubai, Dubai, UAE.
[5]Department of Computer Science and Information Systems, Manchester Metropolitan University, Manchester, UK.

P.O. Box 7 Tulkarm-Palestine, E-mail: m.daadoo@ptuk.edu.ps

ABSTRACT

In Printed Circuit Board (PCB) drilling machines, the location of the drill holes are fed into the machine and the PCB will be drilled at the corresponding coordinates. Some machines do not choose the optimal route when completing their tasks. Hence, this paper proposes an approach, which is based on the Algorithm Shortest Path Search Algorithm (SPSA), for finding the optimal route in PCB holes drilling process. In SPSA, when the robotic arm at the initial position, the algorithm calculates the nearest point to the initial position from all points that the wires starts or ends with. If the nearest point is a start-of-wire point, it will use SPS algorithm 1. If the nearest point is an end-of-wire point, it will use SPS algorithm 2. This process is repeated until drilling all the lines. Then, the robotic arm will drill all the holes according to the proposed Simulated Annealing Algorithm (AS) in order to determine the optimal machining parameters for milling operations. The results of the different optimization algorithms Genetic Algorithm (GA) and AS are compared and conclusions are presented. . The proposed Computer Numerical Control (CNC) machine consists of driver, drill, three stepper motors, cables and microcontroller PIC16f877A to control the movement of the machine. The SPSA algorithm optimizes the use of the motors and other mechanical paths involved in the process while reducing total time taken to traverse all the drill holes. This paper also explains the detailed problem of interest and the mathematical formulation of the problem is defined. Experimental result indicates that the proposed SPSA-based approach is capable to efficiently find the optimal route for PCB holes drilling process.

Keywords: Shortest Path Search Algorithm, PCB Drill Holes, Path Planning, Routing Problem.

1. INTRODUCTION

Computer Numerical Control (CNC) machines have advanced the holes drilling process as this manufacturing process now has been completely automated. CNC drilling machine can be classified as CNC Printed Circuit Board (PCB) drill, CNC vertical drill, CNC deep-hole drill, drilling center and other large CNC drilling machine. This machine is used for drilling holes with numerical control and widely used in hole processing technology for the PCB. Optimal route planning is necessary for reducing the time for the CNC machine to complete its task. Currently, route planning in CNC machine is done using Nearest-Neighbor Algorithm (NNA). The algorithm might be simple to implement. However, use NNA where the route planning obtained from this algorithm does not guarantee optimal route. For that reason, many researchers and academicians attempt to solve the problem by proposing numerous algorithms.

To achieve more effective results, optimization systems approach is required to be equipped with a drilling machine. Euclidean Traveling Salesman Problem (TSP) is one of optimization method that gives fast near optimal solution for the drilling machine movement. The objective of this paper is to give the best solution in solving the routing PCB holes drilling process. In this case, the lines to be drilled are the cities, and the cost of travel is the time it takes to move the robotic arm from one hole to the next. 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 require 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.

Genetic algorithm (GA) and simulated annealing algorithm (SA) are two optimization approaches that have been developed independently. Both of these algorithms are probabilistic search algorithms that are capable of finding globally optimal results to complicated optimization problems.

This research presents the solution of the optimal path optimization for holes drilling using the SA technique. The results of the different optimization algorithms GA and AS are compared and conclusions are presented.

The objective of this paper is to give the best solution in solving the routing PCB holes drilling process and verify the viability of using SA to solve the holes drilling path optimization problem effectively, with minimum cost and shortest time.

We [8] designed the frame of hardware in a way that achieved the aims of this paper. This paper aims at describing the design of a CNC drilling machine. The said machine is designed with a view to keep the cost of the machine at a minimum, hence making is suitable for use in small or medium scale industries. Along with the design of the mechanical components, the electronics and the software have also been designed. In this paper, we used a C# language to create the proposed software application, which allows the easy integration of input and output functions with any software that we develop in C#. The system consists of three main parts: a mechanical setup that can move in X, Y and Z directions, a driving circuitry and a software program that controls the overall operation of the whole system. In this initial work, the system is developed such that it produces a trace line on a PCB board and drill holes on two pads at both ends of the trace line. We show that our system successfully performs both of the above tasks.

This paper also explains the detailed problem of interest and the modeling of route optimization in holes drilling process using SPSA is explained. Next, the mathematical formulation of the problem is defined. Followed by the discussion of the implementation and the experimental results obtained based on the proposed approach and findings will be summarized.

2. RELATED STUDIES

Using the same case study in [5], this paper attempt to analysis the performance of SPSA compared to other mentioned algorithms: [1], [3], [4], [5].

SA belongs to a class of local search algorithms known as threshold algorithms. Local search is an improvement type algorithm that starts with a complete solution from which a series of better solutions is generated. SA was first introduced by [6] to solve optimization problems. It has been successfully applied to many combinatorial optimization problems in such diverse areas as a computer-aided design of integrated circuits, image processing and code design, and scheduling and neural networks.

GA mimics the process of natural evolution by incorporating the "survival of the fittest" philosophy [7]. In GA, a point in search space is represented by binary or decimal numbers, known as string or chromosome. Each chromosome is assigned a fitness value that indicates how closely it satisfies the desired objective. A set of chromosomes is called population. A population is operated by three fundamental operations, viz., reproduction (to replace the population with a large number of good strings having high fitness values), crossover (for producing new chromosomes by combining the various pairs of chromosomes in the population), and mutation (for slight random modification of chromosomes). A sequence of these operations constitutes one generation. The process repeats till the system converges to the required accuracy after many generations. The GA has been found very powerful in finding out the global minima. Further, these algorithms do not require the derivatives of the objectives and constraints functions.

3. ROUTING PROBLEM FORMULATION

The routing problem is a subset of TSP and many works of literature had covered TSP formulation in great details [1], [3]. This concern for calculation of the minimum tool path length between holes the drilling device has to visit all the lines and holes only once, the machine sequence optimization of the lines is similar to TSP.

So, the distance of the path can fundamentally be calculated using TSP which formula is written as in equation (1) [1], [4].

$$\boldsymbol{M_{total}} = \sum_{i=0}^{n} \sum_{j=0}^{n} (|\boldsymbol{x_i} - \boldsymbol{x_j}| + |\boldsymbol{y_i} - \boldsymbol{y_j}|) \times \boldsymbol{P_{ij}} \qquad (1)$$

Where n is the number of holes needed. P_{ij} is the decision variable related to the assignment of the drill bit from hole i to j. If the movement of the drill bit from hole i to j, thus, $P_{ij} = 1$, otherwise, $P_{ij} = 0$. Coordinates of hole i and j are (x_i, y_i) and (x_j, y_j). The case study used in this paper, as shown in Figure 1, is similar to the previous work, which has been carried out by [5], where the objective is to find the shortest distance for the drill bit to travel in completing its task.

The case study is a PCB, which consists of 14 holes. In the case study, all the holes are having the same size. The initial position is located at the top left corner of the PCB image. The cost (or distance) from the initial position to the first hole and the last hole to the initial position are ignored to standardize the distance calculation obtained with [1], [3]. As stated in [1], [3], this case study produced two optimal solutions, it is either sequence: 2-3-4-7-8-13-14-10-11-12-9-6-5-1 or inversed, 1-5-6-9-12-11-10-14-13-8-7-4-3-2. The distance of the optimal solution is 280mm. Figure 2, shows the route of the optimal route for the case study.

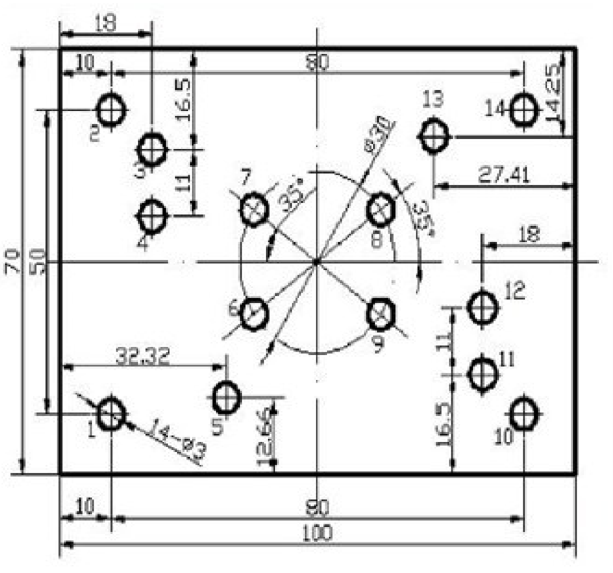

Figure 1: PCB image of the 14 holes case study.

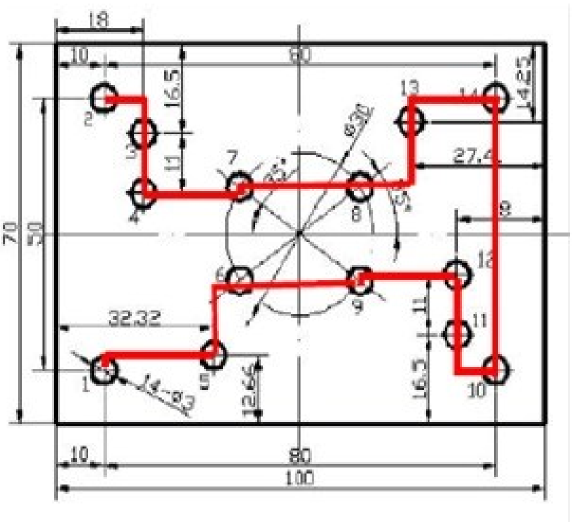

Figure 2: The optimal route for the case study.

4. DESIGN

We [8] designed the frame of our hardware in a way that achieved the aims of this paper. This paper aims at describing the design of a CNC drilling machine. It is designed with a view to keep the cost of the machine at a minimum, hence making is suitable for use in small or medium scale industries. Along with the design of the mechanical components, the electronics and the software have also been designed. In this initial work, the system is developed such that it produces a trace line on a PCB board and drill holes on two pads at both ends of the trace line. We show that our system successfully performs both of the above tasks. Our PCB CNC drilling machine is equipped with three dimensional-movements and considered to produce good precision accuracy for a competitive development cost comparing with another machine products manufactured by other machines which is that are not accurate, especially in drilling holes or trace line and with high-cost material that is used in design. Therefore, our design of this machine can be widely applied to various small and medium scales manufacturing industries, such as we can use our machine in anywhere places you need especially in electronic industries to processing and production PCBs.

So, from our experiment we can see the result of our work piece when using non–traditional tool of CNC drilling machine, is this machine didn't have a heavyweight comparing with another and past CNC machine that is used a traditional tool, so any person can take it with no complex operation to easy to use our CNC machine.

The existing machine features are compared with the professional CNC machine. After comparison and making the required improvements, the machine is in a position to mill complex contours on PCB, soft wood and soft metals with considerable accuracy and speed. Achieving this primary goal is the result of the improvements in both electrical and mechanical design. Exploring new software with better capabilities also helped us in achieving this goal. The workspace and job clamping system are also improved. In addition, our machine is super adjustable and is designed to draw on all kinds of things that are normally "impossible" to print on.

As a basis for further development of the drilling machine, the maximum component size (maximum travel along the axis) is selected as:

- X = 450 mm.
- Y = 300 mm.
- Z = 180 mm.

The different configurations are considered from a fabrication point of view, and it is found that the gantry configuration is most suitable because of the following qualities:

- Provides better rigidity.
- Better accuracy.
- Ease of operation and programming.

The drilling machine is divided into three subsystems. These are:

- The mechanical setup.
- The driving circuitry.
- The software program.

4.1 Machine Design

The machines have designed with three movements coordinate, X, Y and Z. Hole position consists of X, Y coordinates, and Z coordinate is a parameter to move the drill machines up and down. The drill is moved horizontally to X, Y coordinates of a hole, moved down in the Z direction to make the hole, then withdrawn and translated to another place.

Holes data file supplied and calculated the route with Euclidean TSP by the software to control the drilling machine movement. The electro-mechanical system is responsible for the 3D motion to position the drill and should be of real industry standard to guarantee the force, torque, precision, and robustness requirements.

4.2 Method

This paper demonstrates hardware and software implementation of a PCB machine that is able to draw trace lines and drill holes to designated places on a board. The system consists of a mechanical setup of that can move in X, Y and Z directions, a computer, a driving circuit and a software program. The driving circuit is developed to control the mechanical setup as well as to communicate with the computer. The software program is developed to control overall operation of the machine. In this initial work, we[8] have demonstrated that the machine can produce a trace line on a single layer PCB board and drill holes on two pads that are on both ends of the trace line. We continue studying to enhance different aspects of working on the system as they will be demonstrated in the future works.

The mechanical setup has a flat layer on which PCB is put on it to be processed. Above the flat layer, there is a drill that can move along X, Y axis. The drill can also move up and down for a specified amount of distance. There is a bit connected to the bottom of the drill. Both trace lines and holes are produced using this bit. To produce a trace line on a single layer PCB, we first adjust the drill such that it only moves down to 0.5 mm below of the surface of the board. We then send start coordinate of a trace line to the PIC. Upon receiving this signal, PIC moves the drill to the location of starting coordinate. During this movement, the drill is at up position. When the drill receives the specified location, PCB machine puts the drill at down position, starts drilling and move continuously according to the coordinates sent from the computer. The coordinates have to belong to edges of a trace line that is to be drawn. During this process, the drill bit carves the copper layer on the surface of the PCB continuously as deep as 0.5 mm. Hence the trace line is separated from the remaining part of the copper on the PCB when the process is completed.

In order to drill a hole on the same PCB, we let the machine to finish up the tracing, and then readjust the drill so that it moves down approximately 2 mm below of the surface of PCB. After that, we specify coordinates and let the drill go to those positions and perform drilling one at a time.

4.3 Driving Circuitry

In this study, the machine drills the wires first, and then it drills the holes at the beginning and the end of wires. The previous study drills the holes first, and then it drills the wires. A feasible solution in PCB wires drilling is simply a complete sequence such that all wires must be visited and each wire is visited once only.

We designed and developed a driving circuit given in Figure 3 in order to operate the PCB machine.

The driving circuitry is developed using a PIC16f877A microcontroller. It controls and runs specific functions of the machine such as running step motors to move the machine in X, Y-axis, running the drill and enabling or disabling an actuator that moves the drill up or down, it also communicates with the computer port.

The computer is used to perform specific tasks such as sending coordinates of trace lines and pads to the driving circuitry and receiving acknowledge signals from the PIC.A program is written in C# to achieve overall control of the machine and to perform data communication between the computer and driving circuitry.

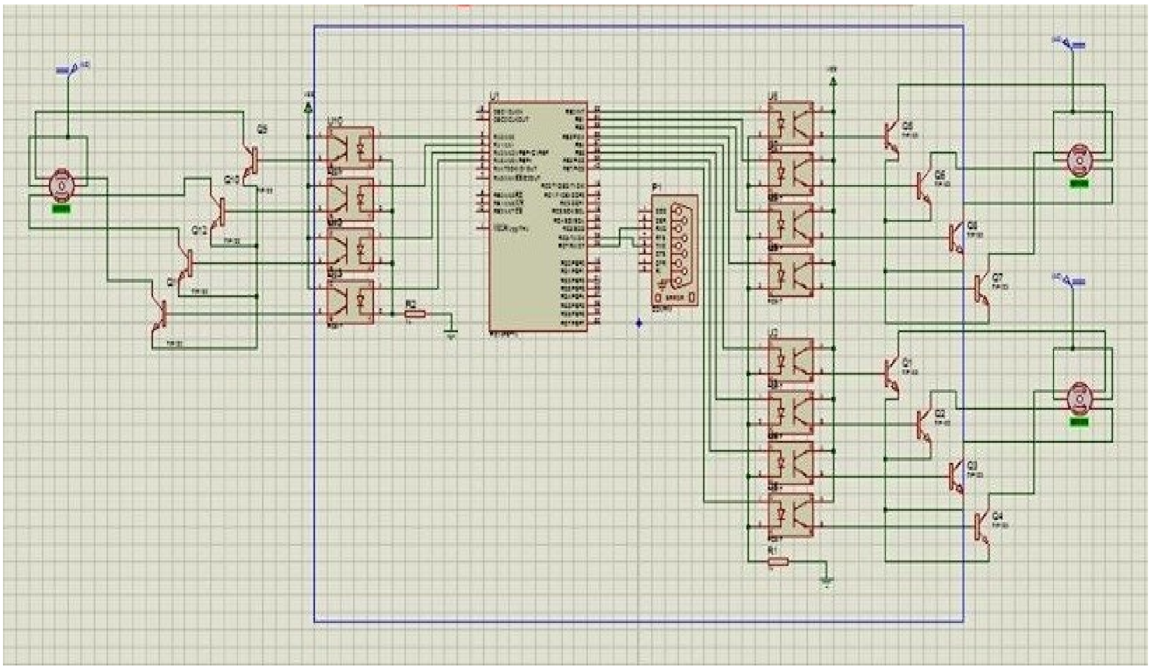

Figure 3: The schematic of the driving circuitry.

Coordinates of trace lines and pads are kept in a file in the computer. It is also a job of the C# program to open this file, read coordinates and send them to the PIC in order to have the PCB machine to perform desired tasks.

5. EFFICIENT PATH PLANNING

Many previous papers discussed the holes drilling path optimization, but the main challenges in this paper was getting the shortest distance path, then drilling the holes on the start and the end of wires in an optimization path, also the machine will cover the PCB to drill all the wires stored in arrays in program, starting from initial point (0, 0), and it will return back to initial position again once the task is completed. The initial position will set as the point (0, 0) in this paper.

Whatever algorithm is used, when the robotic arm arrives the other side of wire, it will again calculate the nearest point to the current position, and apply the appropriate algorithm, each Line is drilled, it's two points (the start and the end points) are removed from array which all the terminate points are saved in.

So, the distance between holes is as in equation (2):

$$M_{1min} = \sum_{i=0}^{n}\sum_{j=0}^{n}(|x_{i\,nearest} - x_{j\,nearest}| + |y_{i\,nearest} - y_{j\,nearest}|) \times P_{ij} \qquad (2)$$

The distance, which the robotic arm drills wires is as in equation (3):

$$M_{2min} = \sum_{K=0}^{N-1} L_K \qquad (3)$$

Where: $N$is the number of lines. L_k is the length of the line K.

So, the whole Distance which the robotic arm walk is as in equation (4):

$$M_{totalmin} = \sum_{i=0}^{n}\sum_{j=0}^{n}(|x_{inearest} - x_{jnearest}| + |y_{inearest} - y_{jnearest}|) \times P_{ij} + N\sum_{K=0}^{N-1} L_K \qquad (4)$$

The case study as shown in Figure 1 consists of 14 holes of same sizes PCB [3]. This case study, the distance between start position to the first hole and last hole to start position, was ignored and this leads to equation written stated in equation (5):

$$min(M_{total}) = min\left(\sum_{i=1}^{n}\sum_{j=1}^{n}(|x_{i\,nearest} - x_{j\,nearest}| + |y_{i\,nearest} - y_{j\,nearest}|) \times P_{ij}\right) \qquad (5)$$

Like any other optimization techniques, SPSA consists of two main parts: initialization and fitness evaluation. The algorithm starts by initializing PCB routing problem and SPSA parameters. Then, moving to the second phase fitness evaluation. The fitness of the particles is calculated using equation (5).

The generation and optimization of the tools path is an important role. Efficient tool path optimization algorithm can reduce the tool traveling distance and can improve production efficiency. In the process of generating numerical code, the point is optimized by shortening the changing and moving path to reduce idle travel time, then can improve processing efficiency. Therefore, it is worth studied to select the reasonable processing path. So, it is very important to reduce the tools changing times to improve the processing speed.

For the above reasons, we aimed to reach the best time to drill all wires, so, the least time is as in equation (6):

$$T_{Least} = \sum_{i=0}^{n}\sum_{j=0}^{n}(|x_{i\,nearest} - x_{j\,nearest}| + |y_{i\,nearest} - y_{j\,nearest}|) \times P_{ij} \times \tau + N\sum_{K=0}^{N-1} L_K \times \sigma \qquad (6)$$

Where: τ is the time, which needed to move from current line to another line. σ is the time which needed to move from current position to next position at the same line.

The algorithm is repeated until maximum iteration reached. Lastly, the algorithm will return the best-found sequence with the lowest distance as the recommended sequence.

5.1 Track Drilling Process

High-quality and optimal solutions can be obtained by Modeling our Algorithm SPSA, for wires drilling process, It depends on TSP algorithm, with more instructions to achieve the path optimization in moving between tracks. we apply SPSA on several cases, The result clearly proves that this algorithm are able to find the optimal route for robotic drilling route problem at a faster rate than other proposed models, making it better than other proposed models.

In this study, we drill the wires first and then drill the holes at the beginning and the end of wires. The previous study drills the holes first, and then it drills the wires. A feasible solution in PCB wires drilling is simply a complete sequence such that all wires must be visited and each wire is visited once only. The algorithm calculates the nearest point to the initial position from all points that the wires start or end with. With the contribution in this issue, electronics manufacturing sector can optimize the drilling process hence will increase the productivity of the manufacturer.

If the nearest point is a start-of-wire point (all points are on the right or down of the first point), it will use SPS algorithm 1, as shown in Figure 4:

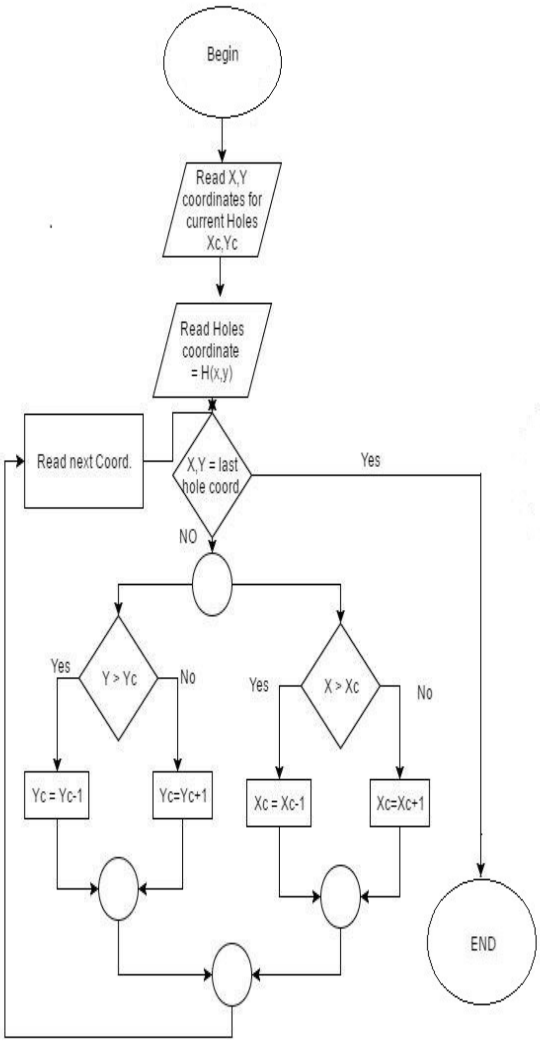

Figure 4: SPS algorithm for routing in PCB drilling problem when the nearest point is a start-of-wire point

If the nearest point is an end-of-wire point (all points are on the left or up of the first point), it will use SPS algorithm 2, as shown in Figure 5:

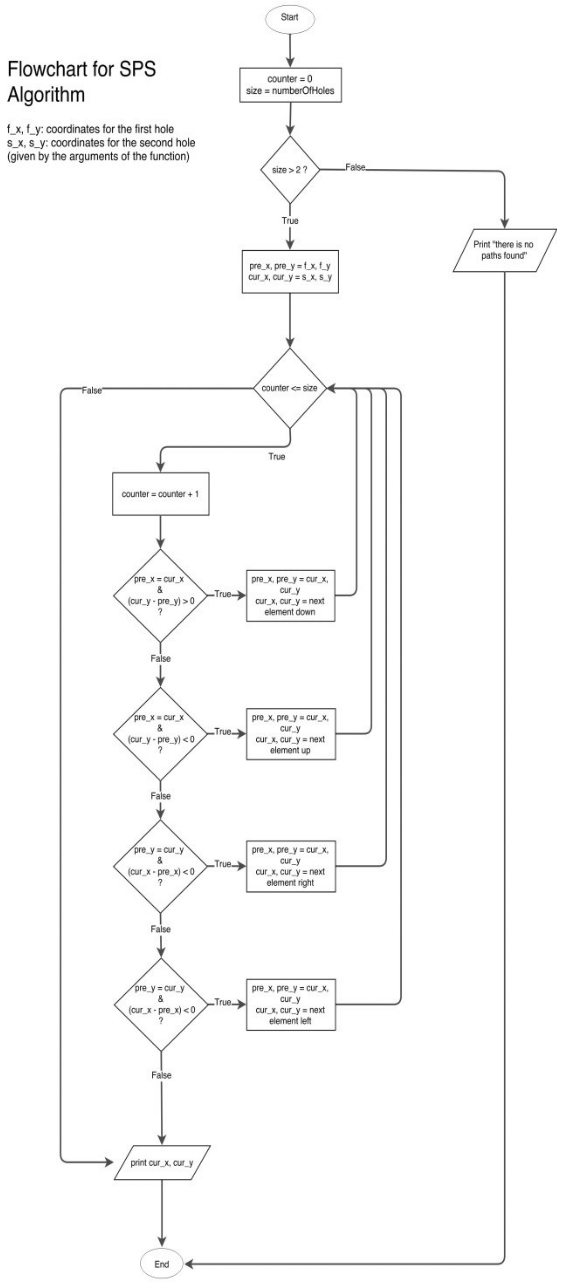

Figure 5: SPS Algorithm for Routing in PCB Drilling Problem When The nearest point is an end-of-wire point

5.2 Holes Drilling Process

Many available algorithms can achieve good solutions for holes drilling problem, so we have decided to implement the best among them. Since its introduction in 1983, SA has been applied to a fairly large amount of different problems in many different areas, with high-quality solutions to the problem in these areas. Holes Drilling problem is not one of these areas, no one implements it to find the optimal path for drilling in PCB's.

SA is an algorithm that starts with some solution that is totally random and changes it to another solution that is "similar" to the previous one. It makes slight changes to the result until it reaches a result close to the optimal [2].

SA is a stochastic algorithm, meaning that it uses random numbers in its execution. So, every time you run the program, you might come up with a different result. It produces a sequence of solutions, each one derived by slightly altering the previous one, or by rejecting a new solution and falling back to the previous one without any change.

When SA starts, it alters the previous solution even if it is worse than the previous one. However, the probability with which it will accept a worse solution decreases with time, (cooling process) and with the "distance" the new (worse) solution is from the old one. It always accepts a new solution if it is better than the previous one. The probability used is derived from The Maxwell-Boltzmann distribution, which is the classical distribution function for distribution of an amount of energy between identical but distinguishable particles.

In this Study, we use this algorithm to get the best holes drilling optimization. The matrix designates the total distance from one city to another (nb: diagonal is 0 since the distance of a city to itself is 0), the following pseudo-code describes simulated annealing [2].

Table 1: The simulated annealing algorithm in pseudo-code.

The AS Algorithm , Parameters
01: Procedure SIMULATED. ANNEALING;
02:begin
03:Initialize(i_{start}, c_0, L_0) ;
04: *K :=0;*
05:*i:=* i_{start};
06:repeat
07:for *l:=1* ***to***L_k***do***
08:begin
09:GENERATE*(j from* S_i*) ;*
10:if *f(j) ≤ f(i)* ***then****i:=j*
11:else
12:ifexp $\frac{f(i)-f(j)}{c_k}$ *>random[0,1)* ***then*** *i:=j*
13:end*;*
14: *k= k+1;*
15:CALCULATE _LENGTH*(*L_k*);*
16:CALCULATE _CONTROL*(*C_k*);*
17:until *stop reiteration*
18:end*;*

6. EXPERIMENTAL RESULT

It was necessary to build a strong software, which operates the hardware and computer elements. So, a software is built to help the user to draw his own circuit accurately and easily, and then press on button "start" to send it to the hardware to have his own PCB. The optimization procedures developed in this work are based on the various non-traditional approaches that have been implemented using C# language. So, the program is written in C# and the simulation is performed 50 times on a laptop that is equipped with 2.20 GHz Intel(R) Core(TM) 2 Duo T6600 processor with 4 GB RAM. As stated, in order to test the approach, Zhu's 14 holes drilling problem [5] has been chosen due to its popularity.

Table 2 lists the information related to the case study shown in Figure 1. Table 3 contains the comparison between the common parameters used in several works of literature with this study. Table 4 contains the comparison between the results obtained by other related works and this study.

From Table 4, the proposed approach is able to find the optimal solution of the case study, which has a fitness of 280mm. In terms of average fitness, the proposed approach has a better fitness compared to GCPSO [5], PSO [1], BPSO [4] and FA [3].

Table 5 shows the experimental results by applying the GA and the SA for the same circuit every time according to the length of the optimal path in each algorithm. There are many options to select the best algorithm to achieve the optimal path in drilling holes. The SA algorithm and the GA are the best algorithms according to previous studies, and also according to the results of these algorithms.

So, when implemented this algorithm in this case study apply it to several cases, the previous results led to the following general observations:

- High-quality solutions can be obtained using the implementation of this algorithm.
- In many practical situations, the simulated annealing is the best between the current used algorithms.
- It gives accurate results in a part of seconds, it is the fastest.
- Increasing number of holes doesn't affect the time and the quality of the given solution by simulated annealing algorithm.

The results show that the SA is better than GA in finding the optimal path for the holes drilling. So, the computer scientists should have taken this into consideration.

By plotting a chart diagram between the number of holes and the length of the optimal path in SA, we will have these results:

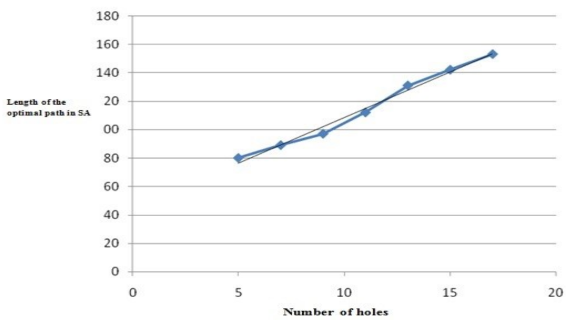

Figure 6: The relationship between the length of the optimal path in SA and the number of holes.

As shown in the above chart diagram the slope is small, so an increase in the number of holes doesn't affect the length of the path.

When we apply the SA to the case study, we get the following result:

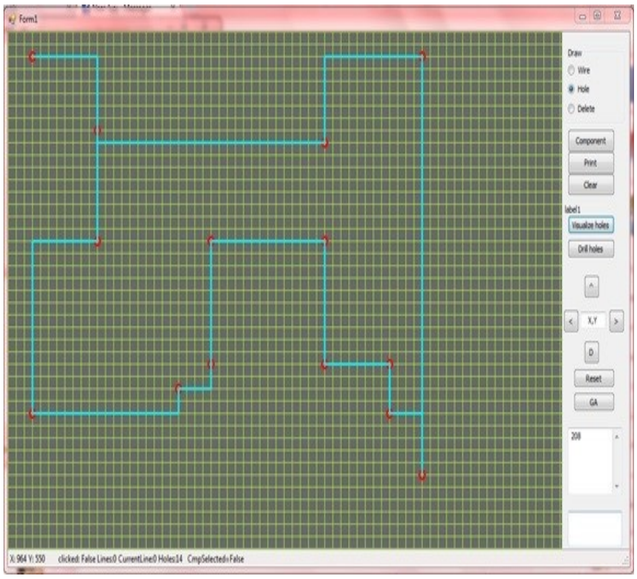

Figure 7: The simulated annealing algorithm on the case study.

So, the SA is an accurate fast algorithm and the best in finding the optimal path in holes drilling.

The following figures of UML diagrams used in this case study are:

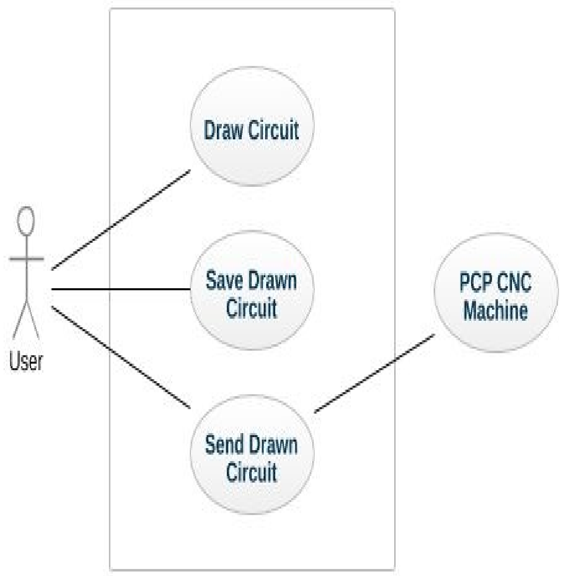

Figure 8: Case diagram.

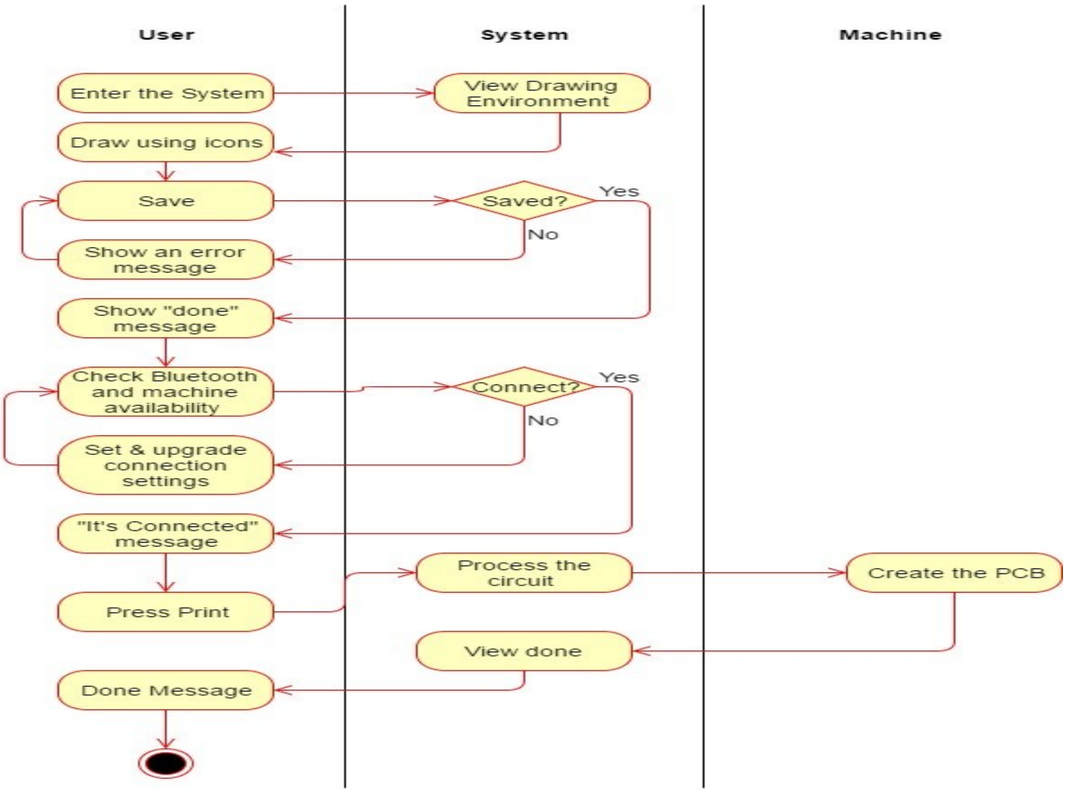

Figure 9: Activity diagram.

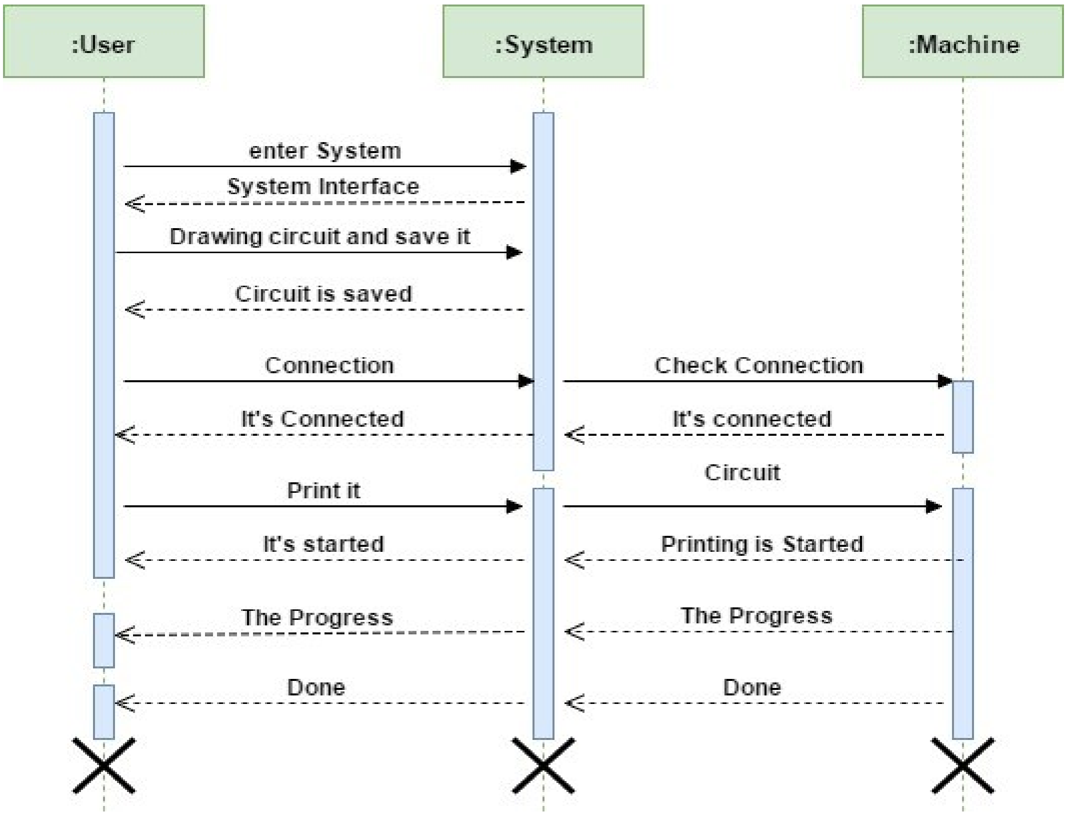

Figure 10: Sequence diagram.

The following figures of the software application interfaces:

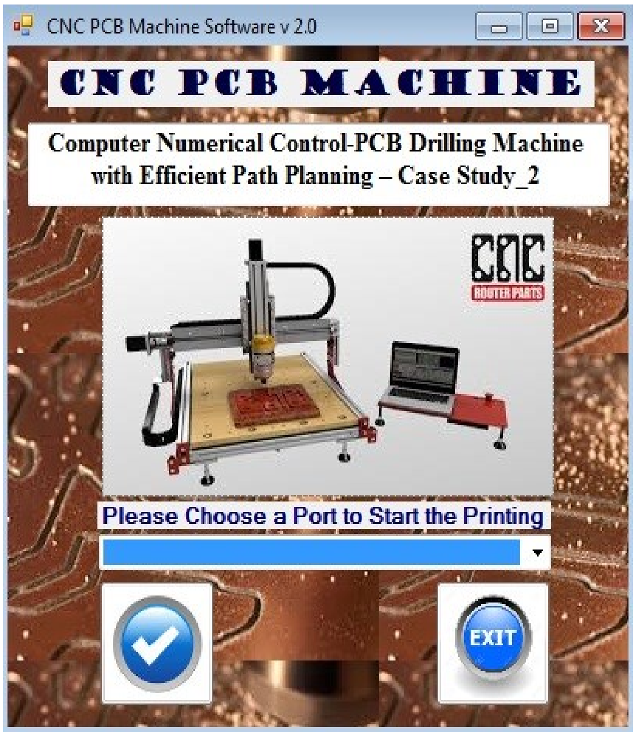

Figure 11: Start dialog interface.

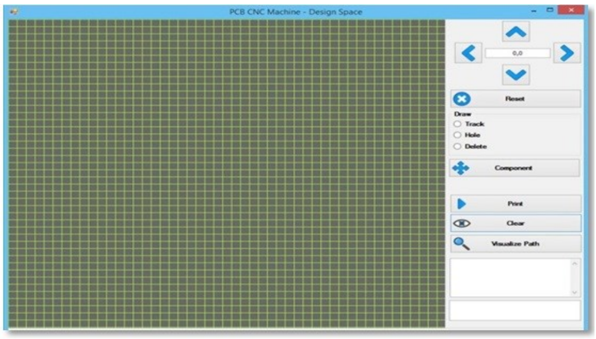

Figure 12: Main interface.

The following figure shows how the drill moves along the lines:

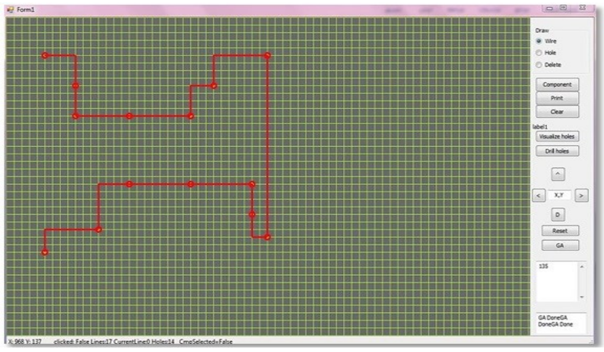

Figure 13: Path optimization interface.

Table 2: 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 3: Comparison of the common parameters used in several works of literature with this study

	[5]	[1]	[4]	[3]	Current Study
Common Parameters					
Number of iterations, t	10000	5000	2500	10000	5000
Number of computations	50	50	50	50	50

Table 4: Comparison of the result obtained in several works of literature with this study.

	[5]			[1]	[4]	[3]	Current Study
	GCPSO			PSO	BPOS	FA	SPSA
Inertia weight, ω	$0.0 \rightarrow 0.5 \rightarrow 1.0$			$0.9 \rightarrow 0.4$		Not Applicable	Not Applicable
Length of optimal solution	280	280	280	280	280	280	279
Average fitness after computing 50 computations	305.7	307.3	289.6	292.3	296.0	287.8	280.3

Table 5: A comparison between the GA and the SA.

Number of holes	Length of the optimal path in GA	Length of the optimal path in SA
5	86	79
7	94	85
9	104	93
11	120	112
13	143	130
15	169	140
17	159	151

7. DISCUSSION

The development of CNC PCB drilling machine has been done. In its development, the cost incurred is very competitive and relatively cheap compared with the drilling machines available on the market. Several tests must be conducted to adjust the appropriate parameter such as time delay or motor rotation speed for the optimal work.

8. CONCLUSION

We have designed and developed a PCB machine that is able to draw trace lines and drill holes on a single layer PCB board. We have tested our system and showed that the PCB machine successfully draws a trace line and drilled holes on both ends of the line.

In this study, the proposed approach SPSA is implemented to find the optimized path for PCB holes drilling process. It is a simple method and easy to implement to find the best route for holes drilling process. High-quality and optimal solutions can be obtained by modeling the SPS algorithm for wires drilling process. This algorithm can effectively solve the problem in the multi-point processing. It can not only shorten the processing time but also make up for the deficiency of production efficiency of CNC machines. The result clearly proves that these algorithms are able to find the optimal route for robotic drilling route problem at a faster rate than other proposed models, making it better than other proposed models.

In this paper, we verify the viability of using SA to solve the holes drilling path optimization problem effectively, with minimum cost and shortest time. Many available algorithms can achieve good solutions for holes drilling problem, so we have decided to implement the best among them. Optimizations procedures have been developed in this work based on the non-traditional approaches, i.e., GA and SA, and are implemented successfully for solving the optimization problem. Software has been written in C# language and results obtained by the different approaches are compared and the performances are analyzed for the multi-objective function of minimizing total penalty cost and minimizing total machine idleness. Through this contribution, electronics manufacturing sector can optimize the drilling process hence will increase the productivity of the manufacturer.

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REFERENCES

[1] Adam, A., Abidin, A. F. Z., Ibrahim, Z., Husain, A. R., Yusof, Z. M., & Ibrahim, I. (2010, May). A particle swarm optimization approach to Robotic Drill route optimization. In 2010 fourth Asia international conference on mathematical/analytical modeling and computer simulation (pp. 60-64). IEEE.

[2] Aarts, E., Korst, J., &Michiels, W. (2005). Simulated Annealing. Search Methodologies, 187-210.

[3] Mohd Muzafar, I., Mohd Azlishah, O., Hamzah Asyrani, S., Maizatul Alice, M. S., Mohd Harris, M., RidzaAzri, R.,& Khairuddin, O. (2013). Route planning analysis in holes drilling process using magnetic optimization algorithm for electronic manufacturing sector.

[4] Othman, M. H., Abidin, A. F. Z., Adam, A., Yusof, Z. M., Ibrahim, Z., Mustaza, S. M., & Yang, L. Y. (2011). A binary particle swarm optimization approach for routing in pcb holes drilling process. In First International Conference on Robotic Automation System (pp. 201-206).

[5] Zhu, G. Y. (2006, December). Drilling path optimization based on swarm intelligent algorithm. In 2006 IEEE International Conference on Robotics and Biomimetic (pp. 193-196). IEEE.

[6] Kirkpatrick, S., Gelatt, C. D., & Vecchi, M. P. (1983). Optimization by simulated annealing. Science, 220(4598), 671-680.

[7] Goldberg, D. E. (1989). Genetic Algorithms in Search, Optimization and Machine Learning, Addison-Wesley Publishing Company, Inc., New York.

[8] Daadoo, M., & Daraghmi, Y. (2016, April). Design and Implementation of Low Cost Computer Numerical Control-Printed Circuit Boards Drilling Machine. Journal International Journal of Engineering and Innovative Technology, 5(10), 63-67.