AUTOMATED PRINTED CIRCUIT BOARD (PCB) DRILLING MACHINE WITH EFFICIENT PATH PLANNING

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ABSTRACT

In PCB drilling machines, the location of the drill holes are fed into the machine and the PCB will be drilled at the corresponding coordinates. This paper presents the design of a PCB drilling machine, where the drill holes are automatically detected from an image of the circuit eliminating the need to manually enter the drill hole coordinates. Further, the drilling machine uses a path planning algorithm, which is capable of estimating an efficient traversing path for the drill bit minimizing the length of travel. The path planning 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.

Key words: shortest path algorithm, PCB drill holes, path planning

1. INTRODUCTION

Making a PCB is an involving process that those who are involved in electronic circuit manufacture have to go through. Not least among its many tasks is the act of drilling the PCB holes which needs both precision and patience. Often, the repetitiveness of the task can lead to countless frustrations among the labourers particularly the beginners. Further, the time taken to drill a PCB can have a significant effect on the production efficiency in mass scale production. Therefore the main goal of this project was to enable beginners in the field to use an automated PCB drilling machine with path planning capability to complete the job efficiently.

The whole project can be divided into two areas one is the drill bit traversing mechanism and the other is the path planning algorithm.

Two types of mechanical systems can be used for the drill bit traversing operation. One is a robotic arm similar to a SCARA system the other is a Cartesian Gantry system. Almost all PCB milling and drilling systems use a Cartesian Gantry system as opposed to a robotic arm. This is because PCB drilling point coordinates are generally given in Cartesian form. Furthermore Cartesian Gantry systems enable the carrying of a heavy load around a particular pre-defined area more easily than a robotic arm based on a lever like system. They also can be easily programmed to navigate to a point with precision and are easier and cheaper to manufacture. However the only limitation is that they cannot move along a curvy linear pathway with ease [1]. This would not be an issue in PCB drilling as the shortest between any two points is a straight line.

The concept of using a frame within which the drill moves about is seen in previous projects by Yildirim (2003) [3] and Basniaks' PCB milling project (2012) [4]. In our project we have eliminated the need of the two supporting columns for the x axis as seen in these two projects by bringing the entire y axis to the same level as the x axis. This makes the design more stable and reduces the risk of buckling and the threads getting stuck. Another important decision we had to make was whether we are going to move the board, the drill or both. The two projects cited above both move the drill while Kumpf (2003) [5] in his project moves the board while keeping the drill stationery. The problem we faced with this approach would be that our system would only be able to machine a particular size of PCB boards but in moving only the drill all PCB boards that are smaller than the machine work space could be drilled.
Path planning was the other goal of our project. Path planning optimizes both the distance travelled by the drill as well as the time. Tahir, Abu, Sahib and Herman (2010) [6] in their paper observe the need for optimization in PCB drilling not found in most CNC machines and suggest the use of TSP algorithms as a method to solve the problem. In our project we have employed a TSP solution known as the nearest neighbour solution to give the optimum

2. DESIGN AND IMPLEMENTATION.

The main challenges of this project were path planning and obtaining the drill hole coordinates from a PCB layout. MATLAB® was used to write the program and the Proteus® ARES PCB layout development software was used to design the PCB schematic.

2.1. System Overview

The block diagram in figure 1 explains the sequence of events.

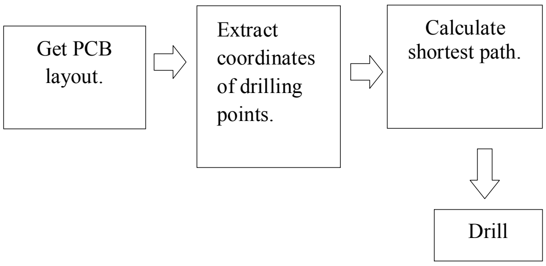


Figure1: Sequence of events from extracting coordinates to drilling.

The first step in the block diagram is getting the PCB layout. This is simply done by getting an image of the drill plot using a web camera or as an bitmap image produced by the PCB design software. A simple enough task for a beginner in PCB designing as is our goal. The bmp image should be that of the inner 1 copper layer and inverted in colour with a resolution of 600 DPI. Figure 2 shows a sample schematic with the bmp image file.

Once the image is obtained it is loaded into the MATLAB program which will extract the coordinates for plotting . The logic used is to find all the connected points using the bwconncomp function and to then to find the centroids of each point as the point of drilling. The scale of the image is 127mm to 5 points in the Cartesian plane. Figure 2(c) gives a sample of the plot generated by MATLAB.

After extracting the coordinates, path planning for drill bit traversing is performed. For this we have considered two methods, a row by row scanning algorithm and a TSP nearest neighbour algorithm where an optimal shortest path is found.

2.1.1 Row by row scanning method

In the this algorithm the pointer moves up along the y axis keeping the x coordinate zero from the smallest y coordinate in the array up to the largest. As it reaches each y coordinate the pointer will move along the x axis keeping the y coordinate constant until it reaches each point corresponding to that y coordinate. It will then return back to the y axis after it has covered all the points having that particular y coordinate. In this way the pointer will reach each point by moving sequential up the y axis and along the x axis much like a type writer. Figure 3 gives a sample solution.

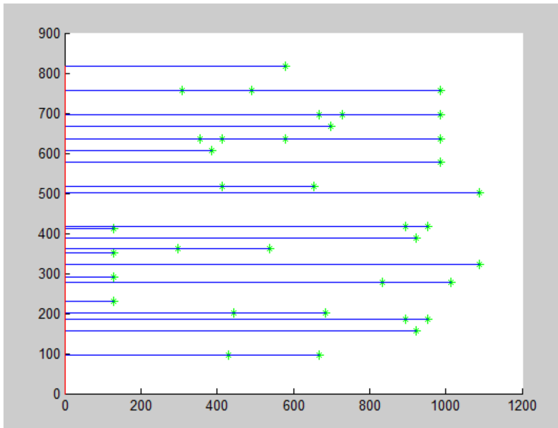
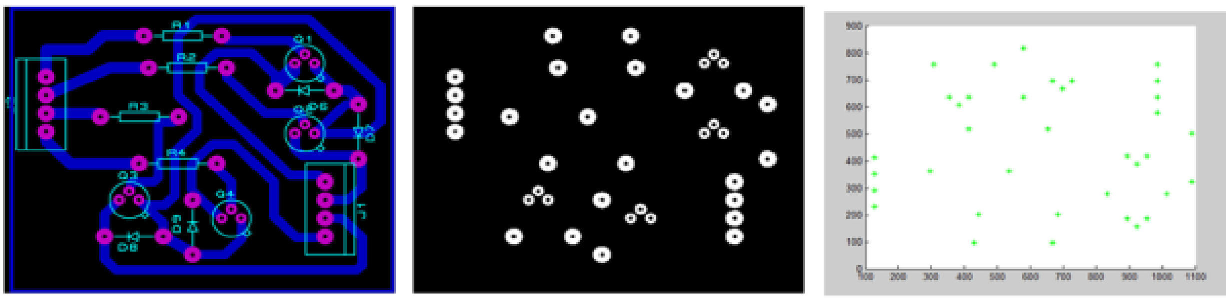


Figure 3: Row by Row algorithm solution for 2(a) schematic [7].



2(a) 2(b) 2(c)

Figure 2: 2(a) ARES PCB schematic 2(b) bmp image of drill plot [7] 2(c) Drill hole coordinates of the same schematic as in 2(a) (The points are inverted). [7]

2.1.2 TSP Algorithm.

In the TSP algorithm a nearest neighbour path finding algorithm is used to navigate through all the points. The nearest neighbour algorithm is one of the standard heuristic solutions to the travelling salesman problem [2] and involves going to the nearest point until all the points have been visited and involves the following steps.

Step1 : Starting from the origin and calculating the distance to all points from the starting point.

Step2 : Finding the nearest point to the starting point.

Step3: Let this nearest point be the new starting point and repeating the steps from 1 with this new starting point. Each nearest point should be removed from the coordinate array after it becomes the starting point.

The program ends when all the coordinates have been visited at which point the coordinate array becomes empty. Figure 5 gives a sample solution.

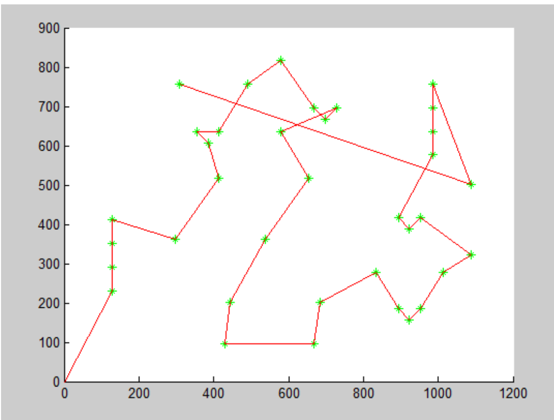


Figure 5: TSP solution for schematic in 2(a).[7]

The final stage in the sequence is the drilling operation itself.

The mechanical design as seen in figure 6 for this operation consists of three thread screws and a ribbon system for the three axis of motion x,y,z. Two threads will be used on either side for the x axis while the third thread screw will be used as the y axis and will be mounted on top of the x axis. The pointer will be mounted on the y axis and will only move about the y axis. The ribbon will be used to move the pointer/drill up and down that is to bring it to the PCB board level for the drilling operation.

Two stepper motors are used for the x and y axis while a cogwheel and chain system is used to turn both x axis thread bars simultaneously using one stepper motor. A dc motor is used for the z axis.

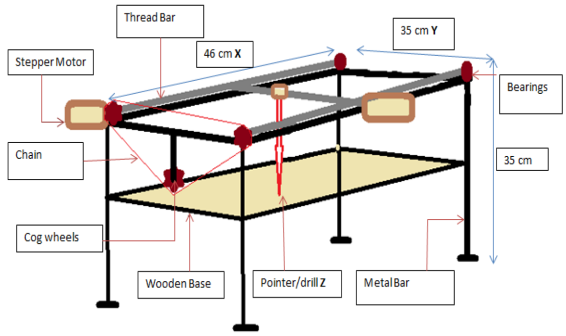


Figure 6: Mechanical design.

Electronically a PIC16F877A micro controller is used as the control unit while the L298 H-bridge IC is used to drive the stepper motors.

The stepper motor used is a unipolar motor with the following specifications. Table 1 gives the order of pulses that need to be given to drive the motor to the four inputs of the L298 IC.

Current = 0.9A
Torque = 3kgcm
Voltage = 5.04V

Table 1: Pulse sequence for stepper motor given to the 4 input terminals of the L298.

Input 1	Input 2	Input 3	Input 4
0	1	0	0
0	0	0	1
1	0	0	0
0	0	0	1

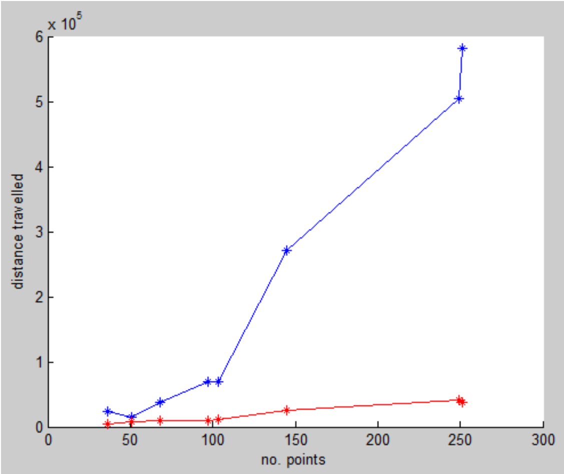
3. RESULTS

The table 2 shows the distance travelled by the pointer using the two different paths for different PCBs having different number of holes. The first example of 36 holes is for the PCB shown in figure 2(a). Fig 8 shows the result of the TSP algorithm for 249 holes.

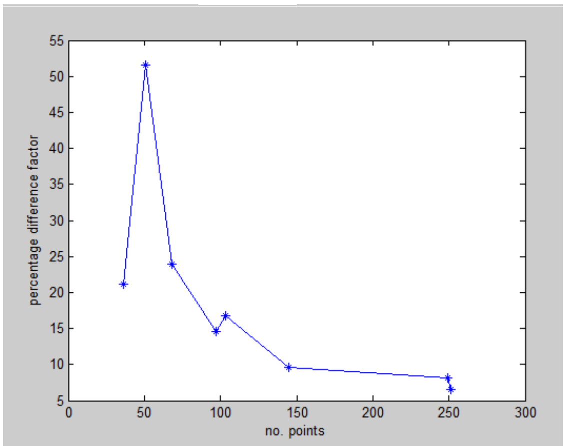
Table 2: Shows the different lengths travelled by the pointer when following the two algorithms. The distance is the number of x and y points traversed in the Cartesian plane.

Number of Holes.	Distance Row by row Algorithm (a)	Distance TSP Algorithm (b)	Difference factor as a percentage (b/a*100)
36	23156	4891.5	21.12
51	14153	7298.2	51.56
68	37087	8858.9	23.88
97	69116	10057	14.55
103	69160	11584	16.74

145	270630	26149	9.66
249	505041	40945	8.10
251	580860	37789	6.505



7(a)



7(b)

Figure 7: (a) Shows the variation of the distance travelled with the no. of holes. Blue (top) is the row by row algorithm; red (bottom) is the TSP algorithm.
(b) Shows the variation of the difference factor with the no. of holes. [7]

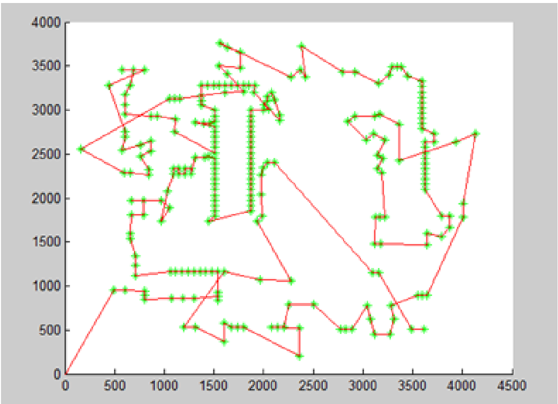


Figure 8: TSP solution for pcb with 249 holes in table 2.[7]

4. DISCUSSION

It is very clear from the results shown in fig 7(a) that there is a great difference between a path planning algorithm and a normal navigational algorithm. It is also clear from fig 7(b) that the performance of the TSP algorithm increases dramatically as the number of points increase.

5. CONCLUSION

2D Vector plotters designed as Cartesian robotic systems can be viably applied to an automated PCB drilling system due to their capabilities of load bearing, precision, simple design and programming. A simple drill hole map can be successfully used to obtain the coordinates needed to perform an automated drilling operation. The importance of path planning in vector plotting especially in the context of an automated PCB drill was clearly observed in the great difference in distance travelled by the pointer as seen clearly in the results

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