A Study of Different Optimization Methods of Tool Path Machines (Tool Path Optimization by Using Genetic Algorithm)

Seyyed Meisam Taheri[1, a], Minoru Sasaki[2, b], Kojiro Matsushita[3, c], Harrison Ngetha[4, d], Satoshi Ito[5, e]

[1,2,3,4,5] Department of Mechanical Engineering, Faculty of Engineering, Gifu University

[a] s3812005@edu.gifu-u.ac.jp (corresponding author), [b] sasaki@gifu-u.ac.jp, [c] kojirom@gifu-u.ac.jp, [d] s3812007@edu.gifu-u.ac.jp, [e] satoshi@gifu-u.ac.jp

Keywords: Production Line, Optimization, Tool Path Machine, Genetic Algorithm, CNC

Abstract. Operation optimization for the computer numerical control (CNC) machines is an important issue in the industry since it directly influences the cost of production. So far, lots of researchers have applied some optimization techniques and made achievements in improving the speeds of the CNC machines. The Tool Path Machine (TPM) is a cutting machine which has been used for cutting, drilling or some other operations on a specific object. The current TPMs are not that much flexible in handling operations on different objects and on different planes, as well as, cutting sequences are not efficient enough for some tasks and situations for the CNC machines. In this research study, we also aim to optimize the Tool Path Machine (TPM) with one of the optimization techniques - Genetic Algorithm(GA) for enhancing the manufacturing process time efficiency. By changing the condition in system and the coordinate of points, the machine will be able to reconfigure the processes and find another way to accomplish the task in the fastest possible way. This makes the TPM more flexible to accept new tasks just by giving the machine the coordinates. To achieve this goal, a study of the previous works which had been done in this area of interest was undertaken and a comparison of their techniques and methods was carried out to better understand the optimization techniques and the GA methods which have been used in their study.

1. Introduction

In the manufacturing it is vital to reduce processing time to achieve manufacturing efficient leading time [1,2]. Some researchers have dome some researches to reduce the cutting time [3]. Moreover, Castelino et al. proposed a heuristic algorithm to reduce the non-productive time of a tool by connecting the tool paths optimally [4]. Sequence selection of cutting tool aimed to minimize the cost of the tool wear and machining time.

In this paper, the combination of GA and the modified Traveling Salesman Problem (TSP) has been introduced. TPM is representing the sales man, and the operations are representing cities in TSP. In this paper, Genetic Algorithm (GA) will be applied to find shortest and efficient ways.

In the problem statement section, we briefly explain what are the difficulties we are facing to apply GA to TPM.

2. Genetic algorithm

In this study, genetic algorithm (GA) employed to control and find the best possible ways to minimize the total machining distance and reduce processing time. Genetic algorithms are random search methods that are a representation of natural biological evolution [5].

Genetic algorithms operate based on initial population which are potential solutions for a problem, and by applying the principle of survival of the produced fitness it goes to find a better and better solution for the problem. In each generation, individuals are created and based their finesses and this process will be continued until evolution of population of individuals getting better to suited to their environment, just as in natural adaptation the individuals keep changing to become better.

By improving the population, GA searches better solutions, and the search is based on the origin of survival of the fittest individuals.

fitness function is measuring the possible solution quality. After generating initial population, GA calculates the fitness value for each chromosome of the population based on the fitness function. Then optimization condition is considered. If the result is ideal, then the result can be considered as the best solution. new population will be regenerated by using GA operators (selection, cross- over, and mutation) if the solution is not optimal.

2.1. Chromosome definition

In GA, first step is to constructing chromosomes. To do this, we should identify the variables of given problem. In this research chromosomes are random numbers generated with GA. the numbers are coordinates of some points which need to be drilled by CNC machine.

2.2. Fitness function

Fitness function is a measure of quality of an individual. In this study, fitness function is measuring the distance and time of drilling for a node to another node.

2.3. Selection

In this section, individuals are chosen based on the fitness. There are some selections methods which can be used to select individuals, which has been said that using an appropriate selection technique is an important step in genetic algorithm [6].

2.5. Crossover

Crossover is the way of moving through the space of possible solutions based on the information gathered from the existing solutions.

2.6. Mutation

Mutation is an innovation in GA. Mutation is really important, some of the evolutionary algorithms use this operator as the only form of search [7]. Unlike Crossover, mutation solves the local minimum problems. The heuristic and meta heuristic algorithms may face a problem in local minimum and can not find a better solution, so with mutation there is a chance to prevent to drop in a local minimum.

3. Problem statement

The problem statement in this research can be summarized in the following points:

4.1 in TSP the salesman leaving point and arriving point is the same point, where the cutting tool have two different arrival and departure points.

4.2 The salesman is not changing during his trip in TSP, but in TPM tools maybe need to be replaced many times during the trip

4.3 There are maybe different conditions, obstacles need to be avoid, as well as, changing one task which machine needs to be reconfigure as fast as possible.

The distance between each node (operations node) must be calculated. The distances between operations end point and changing point must be calculated as well.

1: If the current operation and the next operation use the same cutting tools, then it can be calculated using Eq. 1:

$$D=\sqrt{(X2-X1)^2+(Y2-Y1)^2+(Z2-Z1)^2}+ZS \quad \text{Eq.1}$$

where ($x2$, $y2$, $z2$) represents the coordinate of the end-point and (x_1,y_1,z_1) is the coordinate of the start-point.

ZS in Eq. 1 shows a constant value, which equals to the vertical distance from the surface to a safe position which the tool can move horizontally without touching obstacles or the work peace.

2: If the current operation and the next operation use different cutting tools, then, the distance, DS_i, between the two nodes can be calculated using Eq. 4. If cutting tool is different between two points, machine tool should go back to Zero point and change the cutting tool (0, 0, 2) in this case Distance equal:

Eq. 4

$$D=\sqrt{(X1-0)^2+(Y1-0)^2+(Z1-0)^2}+\sqrt{(0-X2)^2+(0-Y2)^2+(0-Z2)^2}+ZS$$

To find the edges we can find the biggest Z to avoid any collusion by using following pseudo code:

```
 if (x or y = (range of specific area) )
or ( x or y will pass the area )  {
  check the z and ( z1+new z)
}
```

TPM steps are as follow:

1. Start the machine
2. get the point (x,y,z)
3. check the highs level of points
4. check the start point of current and next point position
5. check the end of each node
6. from the current node to the next node check all Z axis
7. if there is a Z higher than current Z, then current Z+ New Z
8. if the next point is in a Lower Z and there is not any higher Z in the way to next node then new Z-Current Z

Operation conditions:

To calculate Distance, D= From the current point to the start point of moving points + moving distance to pass the current height (or any other heights on the way) + distance to the next hole

Z=CurrentZ+NextZ
Moving Time=D/Fast speed
Slow speed= Z/slow speed
Drill time=drill speed /Z
Return time=time (Z+Depth Z+2)

If we are using Multi function machine
If changing time > traveling time
Total time = changing time
If we are using a hand robot
Total time = total time + time of changing the tool

Time will be changed depends of which type of machine we are using

If the type of drill should be changed
If changing time > traveling time
Total time = changing time + traveling time

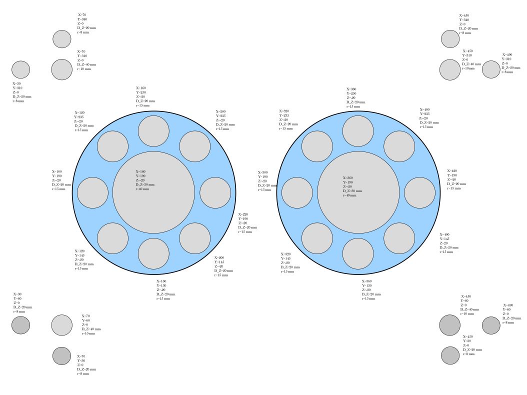

Fig.1.

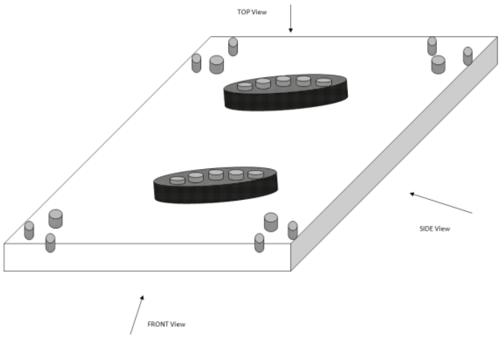

Fig.1. work piece model

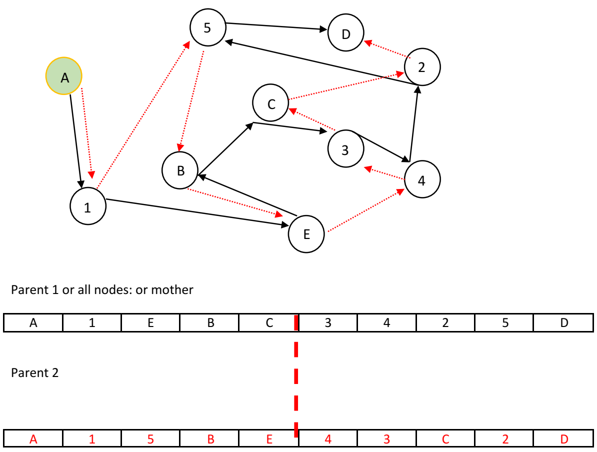

Fig.2. Initial phase of TSP

Code 1:

```
For ( i=0;i<cross2;i++){
      For (j=0;j<cross1;J++) {
if(cross1[i]==cross2[j])
{
Cross2[i]==null;
Null++;
}
}
```

Fig.3. find the similar nodes code

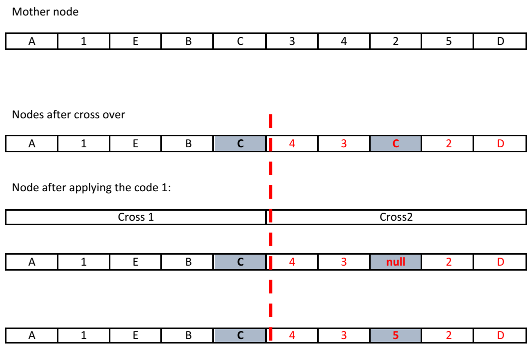

Fig.4. Searching missing nodes

Search all nodes again: find nodes which are not exist

N should be equal Null

Code 2:

```
For (m=0; m<n;m++){
  For (k=0;k<n;k++) {
     If (cross2[m]!=mother[k]){
    Nullnode[n]=mother[k];      ← 5
    n++;
    }
}
```

Indicating:

```
For (cross 2: i) {
If(cross2[i]=null ){
Cross2[i]=Nullnode[n];
n++;
}
```

Fig.5. Node searching code

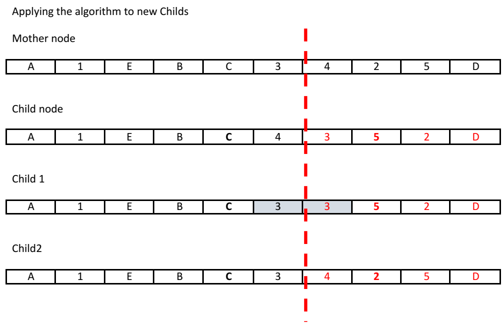

Fig.6. Applying to new child

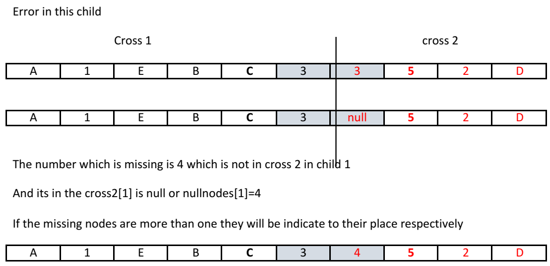

Fig.7. Finding missing data and replace them

Sort the missed data

Two ways to sort the missing nodes:

1. Sort missing nodes randomly

In this case, the data will replace in the offspring based on their sequence which saved randomly in an array,

2. Sort them based on their distance to the next node

In this case, nodes will be re-sort again based on their distance in the array and then they will be replaced in the offspring.

4. Conclusions and future works

In this research, we studied different genetic algorithm methods and TSP to find a solution for current problem in TPM. for the future work we are going to apply this algorithm and compare it with different AI optimization methods.

5. Acknowledgment

We would like to express gratitude to Prof. Sasaki for his kind support and encouragement. Special thanks are also extended to staff of Gifu University and Sasaki ito Laboratory members.

6. References

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