A Generative Computer-Aided Process Planning for Mill Parts by Firefly Approach

[1]Hemanth Gowda M, [1]Kiran B, [1]Jerome Prajith Royan, [1]Humaid Khalifa, [2] Pramod Kumar S K

[1]Student,School of Mechanical Engineering, REVA University, India
[2] Associate Professor, School of Mechanical Engineering, REVA University, India

Abstract – **Process Planning is one of the key steps involved in production of any part in a manufacturing plant and also a key factor for achieving easiness in production processes. The process planning aides the engineers and workers in understanding sequence of operations to be performed thereby reducing the time production time. The past research works performed on process planning mainly concerned on development of variant approach and do not focus on generative computer-aided process planning (CAPP). Optimization of process planning based on time is the key factor in reducing the time taken for process planning. In this paper, optimization of process planning is done by considering machining time as the key variable. Firefly approach is developed for the optimization process and the results are compared with conventional methods of process planning.**

Keywords **- Process Planning, Algorithm, Firefly algorithm, Optimization**.

I. INTRODUCTION

Process Planning is preproduction step that gives a manufacturing unit the exact sequence of operations and the tooling required for the operation. Process planning is a vital step in manufacturing of any component as this helps workers and engineers understand the sequence of operations that need to be done and also provides production managers a rough estimate of how the part is going to evolve during the manufacturing process. In this age of atomization manual process planning can take up a sizeable chunk of time during the manufacturing process which could be used elsewhere for better optimization and control over the process. Manual Process Planning can be very tedious and tiring as this is a lengthy process and can take up a lot of time.

Calculating the machining times manually can be quite lengthy as the number of features increase on the part model and hence begs for a generalized algorithm that can calculate the machining times and the sequence of operation easily and in a logical manner.

In recent years many algorithms have been developed and used for solving and optimizing tough engineering problems and one of the more recent and effective algorithms has been the firefly algorithm. Firefly Algorithm has been shown to simplify hard problems and is very efficient in dealing with global optimization.

In this paper we discuss the application of Firefly Algorithm to simplify Process Planning and discuss a generalized code for process planning of mill part and its implications. We also discuss the how the algorithm can easily simplify Process planning and compare the results with conventional methods that revolve around the process.

1.1 Firefly Algorithm

Firefly algorithm (FA) was developed in the late 2007 and 2008 at the Cambridge University[1], which was based on the flashing patterns and behavior of fireflies. This algorithm was developed to study the movement patters or biological creatures and to study distributed data and for the optimization of distributed data[2].

FA uses the following three idealized rules:

- Fireflies are unisex and that one firefly will be attracted to every other firefly.
- The attractiveness of the fireflies is base on the perceived brightness of the fireflies which is a function of the intensity of the light at the source and the distance between the fireflies. If there is no one brightest firefly then a particular firefly will move randomly.
- The brightest firefly is determined by the landscape of the objective function.

As the fireflies attractiveness is a function of distance as the intensity varies over distance, we can defined the variation of intensities **I** based on distance **r** by

$$\mathbf{I = I_o e^{(-\gamma r * r)}} \qquad \mathbf{(1)}$$

Where $\mathbf{I_o}$ is the brightness at $\mathbf{r=0}$ and $\boldsymbol{\gamma}$ is the light Absorptive factor of the medium.

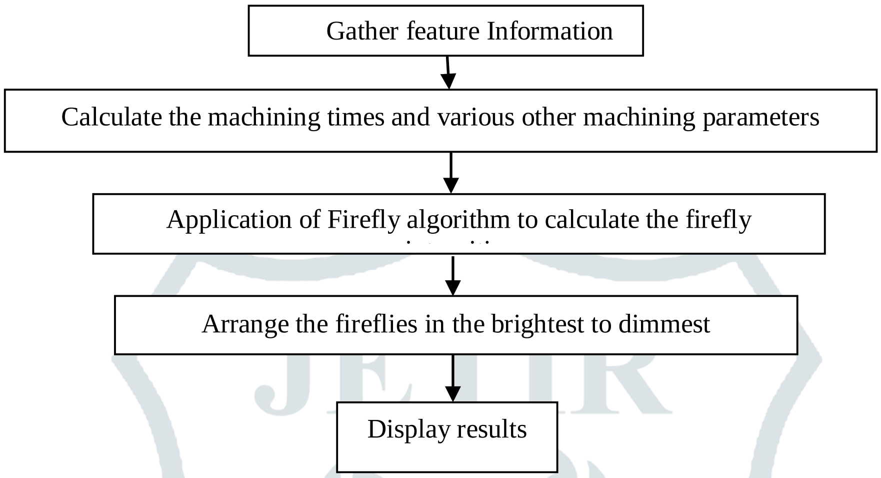
If $\mathbf{I_o}$ = 0 then it becomes a random walk or movement of the fireflies and if $\boldsymbol{\gamma}$ = 0 then it reduces to the following equation

$$\mathbf{I = I_o} \qquad \mathbf{(2)}$$

For the above equation all the fireflies accumulate near the brightest Firefly as every firefly perceives the same brightness due to no loss of light during transmission and every firefly moves towards one optimal solution.

II. METHODOLOGY

The Objective of this project revolves around the reduction of time during process planning. Firefly approach is an optimization technique that is used to study and optimize a distribution of data with the use of biological ideas. The firefly approach develops an algorithm which utilizes fireflies as distributed values and proposes that each firefly is attracted to every other firefly based on the relative brightness perceived by them. This causes accumulation of local maxima's where the fireflies are concentrated the most. Analyzing the concentrated regions, the optimal solutions are obtained.
In the current paper, the machining time is used as fireflies, and as time is not a relativistic parameter in machining processes, i.e time does not vary based on the observer hence γ =0.we only obtain one brightest firefly which has the least machining time. The feature with the least machining time is done first and so on. This reduces the time taken for planning as we get a simple sequence of operations based on machining times and can reduce the human effort for manual calculations and planning.
The process is as depicted in the flow chart.



2.1 Gathering Feature Information

In this step of the process the user enters the information of the features that are present n the prismatic part model.
This step involves taking dimensional information such as hole diameter and depth, pocket diameter an depth, slot length ,width and height. The algorithm used is the continuation to the feature recognition algorithm developed by the author mentioned in the paper mentioned in the references section[3].

2.2 Calculating the machining times

Machining time is the most important parameter its is calculated with the general formulae given below

$$Machining\ time\ = \frac{the\ total\ length\ traversed\ by\ the\ tool\ *\ no\ of\ tool\ passes}{velocity\ of\ tool\ travel} \quad (\mathbf{3})$$

- The total length of tool traverse for hole is the depth of the hole and the length of approach which is about 1.3 times the depth of hole to avoid inte3rference with the stock.
- The total length of tool travel for a pocket is the iterative perimeter of tool path around the pocket as shown in Fig.1 A study was done on minimizing the pocketing time using mathematical modeling[4].
- The total length of tool traverse is calculated similarly to the pocket but the tool width is used to calculate the tool traverse length.
- The cumulative perimeter of the iterative tool path diameter until D<d (the iterative tool path diameter becomes less then tool diameter) as shown in Fig 1

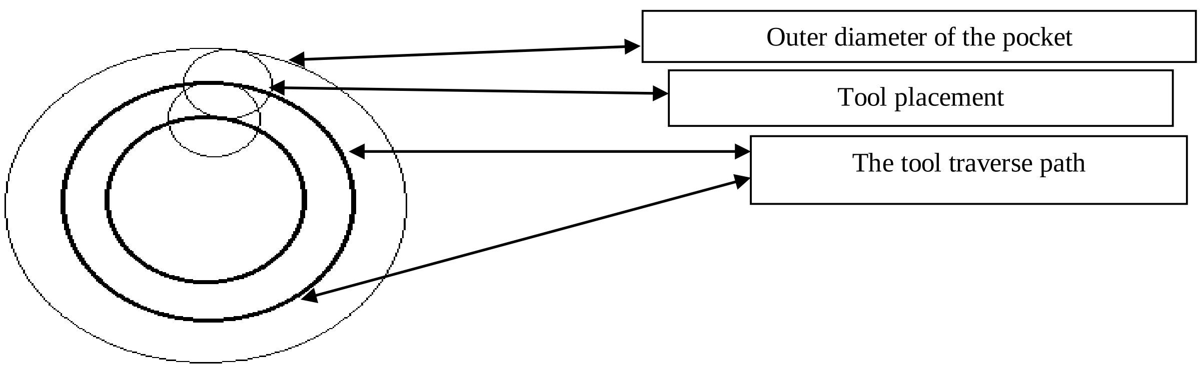


Fig.1 Iterative tool path for pockets

2.3 Application of Firefly Algorithm

In this project the firefly algorithm is implemented as follows the brightest firefly is considered to be machining time as machining time is the defining parameter that can be quantified and analyzed. **$\gamma = 0$** is zero as the machining time is not a relativistic parameter and hence considered as zero. A similar study was done to optimize cutting parameters for better surface finish in turning and end milling[5,6]. Hence the brightest firefly is the feature with the minimum time. The Global minima are considered to be the brightest firefly[7]. The basic firefly algorithm is very efficient as it can be applied to problems with huge amount of data such as study of population demographics etc [8], but we can see that the solutions are still changing as the optima are approaching. It is possible to improve the solution quality by reducing the randomness gradually[9,10].

$$I = f(t) \tag{4}$$

$$I = C/t \tag{5}$$

C is the proportionality constant.

The intensity of the firefly indicates the priority or the rank in the sequence of manufacturing i.e. higher the intensity then the more early that feature is machined. This gives us a simple yet logical sequence of operations that reduce the planning time spent in calculating and sequencing the operations.

2.4 Arranging the Fireflies According to Brightness

The algorithm compares the attractiveness of the new firefly position with the old one. If the new position produces higher attractiveness value, the firefly is moved to the new position and the value is stored in pBest; otherwise the firefly will remain in the current position i.e. if the firefly has lesser time it is stored in the sequences as the first process. If the firefly has a higher machining time then it is stored in the last. As mentioned above as we have selected machining time as the firefly , the Intensity of the Firefly is a function of time and is inversely proportional to the machining times as the machining time increases the intensity of the firefly decreases as the lesser machining time is the brighter firefly

Selection of tool is based on the dimensions of the feature. Holes usually have diameters less than 20 mm so the diameter of the tool is assumed to be equal to the diameter of the tool required. Pockets are derivatives of holes with much larger diameters. In practical applications using tool diameter equal to the diameter of the pocket is usually not feasible. Hence a standard tool of diameter equal to 20mm is considered in the algorithm. Similarly for slots the tool diameter is influenced by the width of the slots and similar to holes when the width of the slots increase over 20 mm using tools of diameter greater than 20mm is usually not feasible. Hence for slots having width less than 20 mm the tool diameter is assumed to be equal to the width of the slot and 20mm for widths greater than 20mm for simplification. The tool length required is usually determined by the depth of the feature or the amount of travel done. Because we need to consider the length of approach for tools while determining the length of tool required the length of approach is assumed to be 30% of the depth of the feature so as to avoid interference and to simplify the algorithm.

3. RESULTS AND DISUCISSION

The results shown in Fig5.1 and Tables 1and 2 show the various parameters present in a typical process planning sheet. The results indicate the sequence of operations base on machining time as constraint using firefly algorithm, tool diameters required, tool lengths required and optimal machining times using iterative tool path movement.

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the feature with machining time 0.416667 is done 1
the feature with machining time 0.500000 is done 2
the feature with machining time 15.000000 is done 3
the feature with machining time 17.000000 is done 4
the feature with machining time 23.000000 is done 5
the feature with machining time 46.000000 is done 6
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Fig 5.1

Slno	Depth (mm)	Diameter (mm)	Tool Diameter (mm)	Tool Length(mm)	Machining time(min)
Hole 1	5	5	5	6.5	0.41667
Hole 2	6	6	6	7.8	0.500
Pocket 1	5	25	20	6.5	23.50
Pocket 2	5	30	20	6.5	46.400005

Table 1

Sl no	Length (mm)	Width (mm)	Height (mm)	Tool Diameter (mm)	Tool Length (mm)	Machining time(min)
Slot 1	15	25	35	20	45.5	17.50
Slot 2	10	20	30	20	39	15.00

Table 2

- The above algorithm can easily produce process planning parameters and give very fast results for generative process planning.
- Conventional Process Planning requires a lot of manual effort when the number features are high and in batch production plants where the variety of pars is more this program can considerable decrease the human effort required for process planning.
- Using Firefly Algorithm the optimal sequencing of operations based on machining time as the constraint is achieved.
- Typical variables present in a process planning sheet are present in the output of code which is based on the standards available.
- Large variables can be easily stored and processed without the need for human intervention and thus reduces Manufacturing Lead Time (MLT) and also helps increase overall efficiency of the Production system.

4. CONCLUSION

In an ever changing world which is leaping toward automation the need for advanced tools to keep up with the pace of ever-changing technology increases as we move forward. Process planning has been a vital step in a manufacturing process and creating an algorithm for automation is a step toward the goal of engineering , which is to save time and effort and thus to increase the efficiency of day to day processes or to completely eliminate the trivial steps of any process. Firefly algorithm is a efficient optimisation technique which helps reduce complex problems into simple equations. The aim of the project was to use firefly algorithm to study the steps involves in process planning and to optimise the sequencing and the machining times calculated compared to the conventional methods. In batch production plants where the variety of parts is usually high implementation of this algorithm can reduce human efforts spent in planning. More Research is necessary and further optimisation is possible taking into consideration all the available variable to get a better picture of the technique i.e. Firefly algorithm as a optimisation tool

This is a small step toward progress and toward automation in a dynamic world where the only constant is human desire to improve efficiency and this project hopefully opens new insights into the topic and helps propel the world forward.

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