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Feature Based Time Estimation: A Review

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Abstract

Productivity improvement is the need of current market and manufacturing sector globally and machining time plays a very important role in reducing cost and time. In this review paper author aims to study the various factors affecting the NC machining time estimation and also tries to study the available methods used for estimating it. Hence a new prototype feature based model has been developed for NC machine time estimation. This model is then compared with the existing commercial software and other time estimation methods. The experimental data indicate that the proposed feature based model is reliable, practical and feasible.

Keywords: *NC machining time estimation, productivity, feature based model, prototype model*

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INTRODUCTION

The demand of the global market is high quality products with lower costs which can be achieved through appropriate planning and scheduling. Machining time has a vital impact on the production planning and scheduling. It is an important factor in deciding the cost estimation and hence has a direct impact on the productivity of any industry [1]. Much of the information needed in the life cycle of a product, particularly its design and manufacturing process, evolves around the geometric shape of the product. Historically this led to the interest on geometric and the current generation of CAD systems based on geometric modelling techniques that provide useful functionality for geometry drafting, detailing, visualisation and analysis [2].

According to Shah, a feature represents the engineering meaning or significance of the geometry of a part or assembly [3]. Features can be thought of as building blocks for the product. Also Features are generic shapes useful in some computer aided application, such as geometry construction, process planning, and design for X. It also includes manufacturing features containing information related to geometry and topology of the product.

NC machining time estimation is a critical factor considered for manufacturing process planning and scheduling. Based on this time estimation process engineers can design and develop optimum design of products to reduce the manufacturing cycle time and hence reduce manufacturing costs.

Following are the various existing methods of NC machining time estimation explained by various authors:

The authors Yang and Lin described that the machining time can be completely estimated from the amount of material removed and can hence be roughly estimated [4]. The authors Shehab and Abdalla proposed a similar approach to estimate time from material removal rate and roughness of each feature [5]. Jung *et al*. explained a model to estimate time based on material removal rates and manufacturing features [6]. Hbaieb *et al*. developed an algorithm to calculate machining time using material removal rates [7].

The time estimation method based on NC Program considers NC machine feed rates and tool path length. However this method is not accurate because it does not consider machine characteristics yet this method has been widely used in most of the commercial software used for the same purpose such as NX CAM, MASTERCAM.

The authors Jung and Park described an algorithm to calculate five axis machining time based on manufacturing characteristics [8]. Heo *et al*. proposed a machining time estimation model based on the factors such as NC tool path blocks, feed rate, and acceleration and deceleration constants [9].

Siller *et al*. presented a mechanistic approach in high speed milling of sculptured surfaces [10]. Coelho *et al*. proposed a practical approach for time estimation of milling free form geometries [11]. Jahan *et al.* developed a multi valued fuzzy set to estimate time in a flat plate processing [12]. Zhu *et al.* proposed an ANN model for developing machining time through a hybrid method [13].

Hence, it can be stated that the methods suggested by various authors considers the following three factors for machining time estimation: Material removal rates, NC program, and Machine characteristics. The existing methods suggested above cannot achieve the timeliness, accuracy and efficiency of time estimation.

METHODOLOGY

The proposed feature based time estimation method considers the following factors (Figure 1):

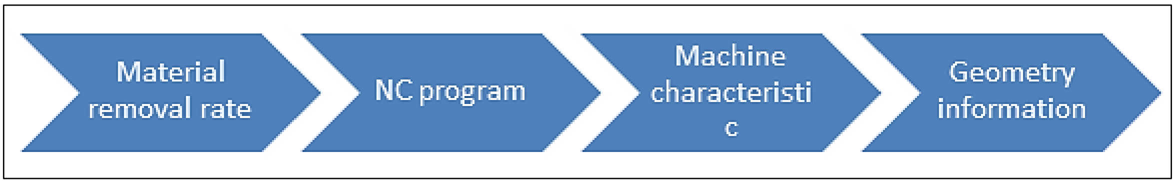

Fig. 1: Feature Based Time Estimation Method.

The most important and initial point for NC machine time estimation is the speed of the machine. This initial factor also depends on a number of factors. Among these factors control speed set in the NC program is the first factor. The other factors also include machine characteristics like velocity, acceleration and velocity alteration rules. NC part programing is method of interpolation.

Different methods result in different speed changes. These cutting conditions affect the cutting force and hence the required cutting power can be obtained from the cutting force and the cutting speed.

Cutting conditions, techniques of interpolation and machine conditions affect the NC machine time estimation. Process planning of the tool path is dependent on the machining features. Different machining features have different tool path planning. Required cutting power is based on cutting tools, cutting speed, cutting depth and width. All the above factors are connected to the manufacturing features and it is quite effective and efficient to estimate time based on them [14–16]. Figure 2 shows the relation between features and machining time.

Integrating all the above factors for machining time estimation; is a very tedious and tough task. But, a recent research on STEP based NC program has been done which includes machine characteristics and geometry information. However, this method has a limitation as it requires a special interpreter, a special platform and a NC control system.

This paper proposes a feature based time estimation model. With machining features as the carrier of machining knowledge, the proposed model includes geometry information, machine input data and information related to NC program, as shown in Figure 3.

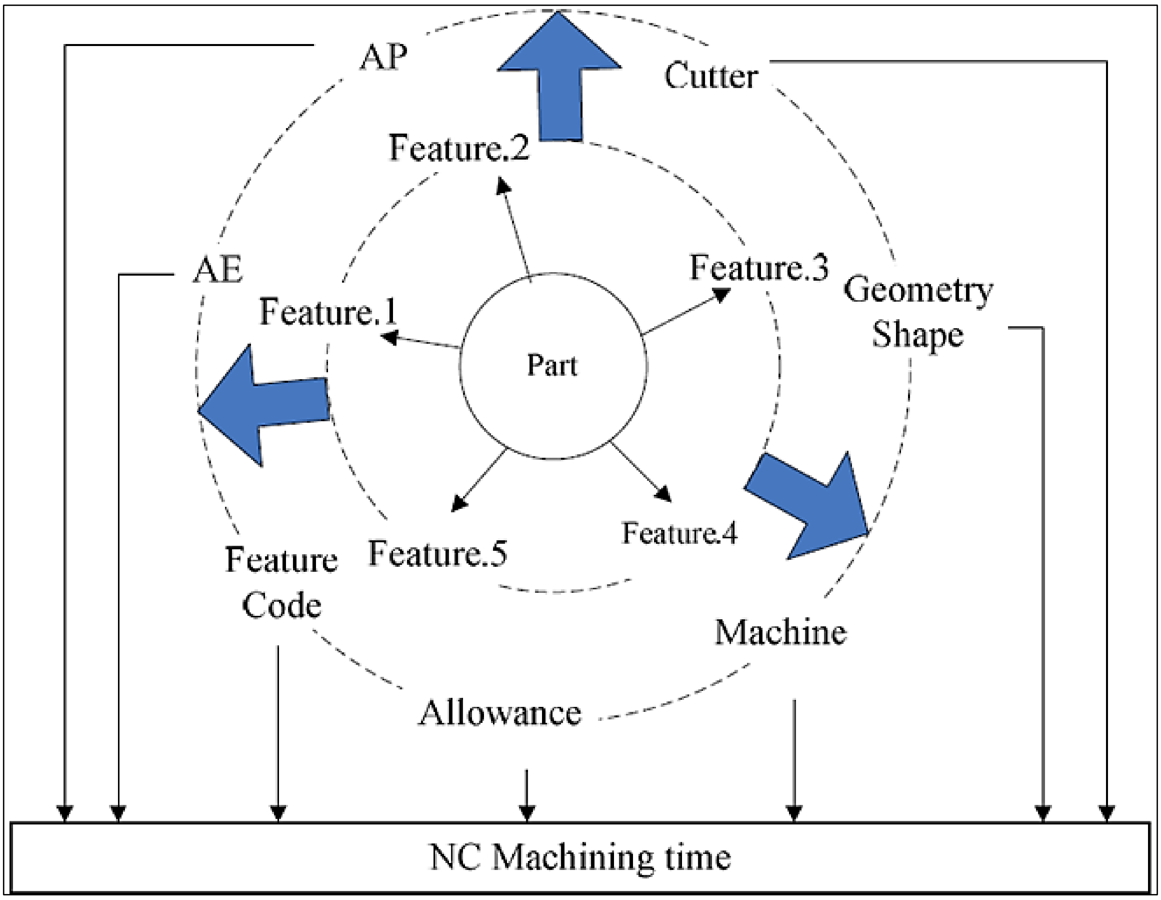

Fig. 2: Relationship Between Features and Machining Time.

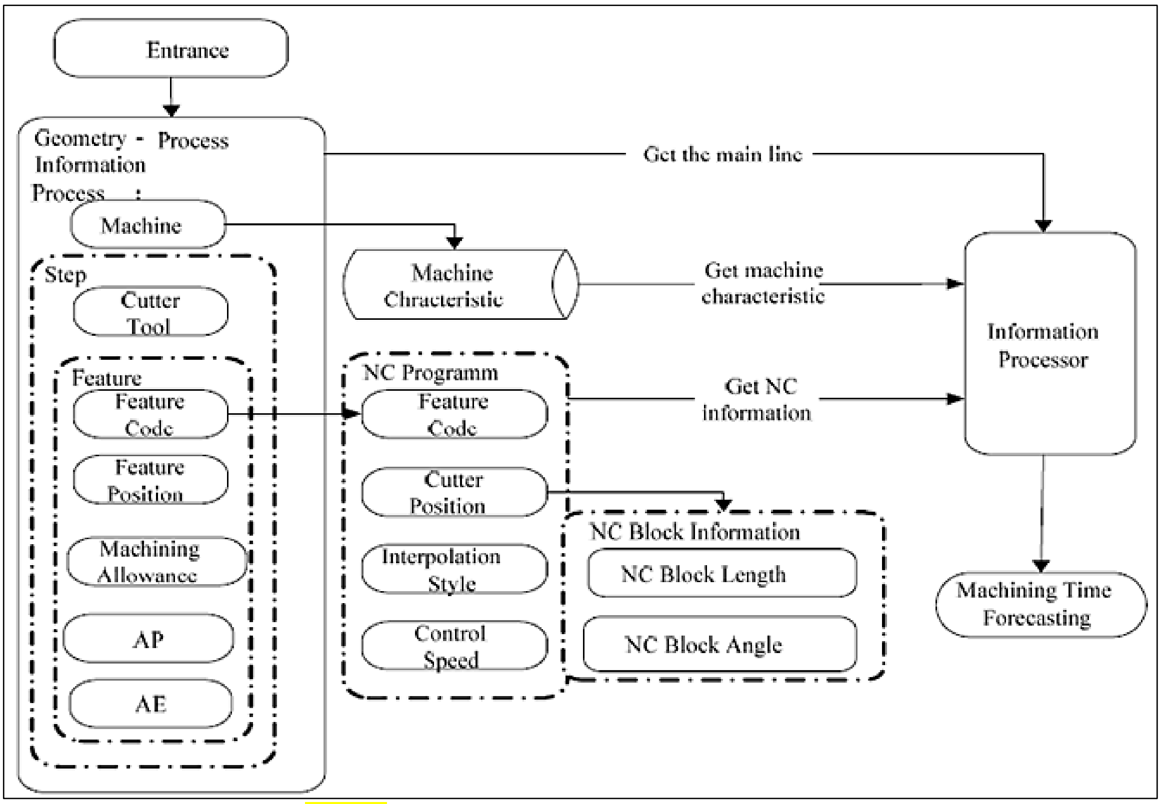

Fig. 3: Feature Based Time Estimation Model.

The suggested model consists of three modules: Data preparation module, Data module and Data calculation module. The data preparation level prepares the data for machining information, geometry process information and cutting parameters decision. At this level the NC program is calculated based on the feature based auto programming.
The data module consists of the geometry information, machine characteristics and NC programing based on the data prepared in the previous module.

The data calculation module calculates the required time for machining from the previous modules. The machining time of each step of the process encompasses the total machining time.
$T_{machining}=\sum T_{STEP}$

Where; $T_{machining}$ shows the machining time estimate and T_{STEP} shows the machining time estimate for the STEP.

$T_{STEP}=\sum T_{mf}$

Where; T_{mf} shows the machining time estimate for the machining featurein each STEP. The path movement of the tool for the entire machining feature includes rapid locating, approaching and retreating, and cutting. Hence the machining time can be expressed as:
$T_{mf}=t_r+t_{ar}+t_m$

Where; t_r shows rapid locating time, t_{ar} shows approach and retreating time and t_m shows the machining time for the feature.

Geometry Process Information
A knowledge based library contains the geometry process information which comprises of machine characteristics, machining steps and manufacturing features as shown in Figure 4.

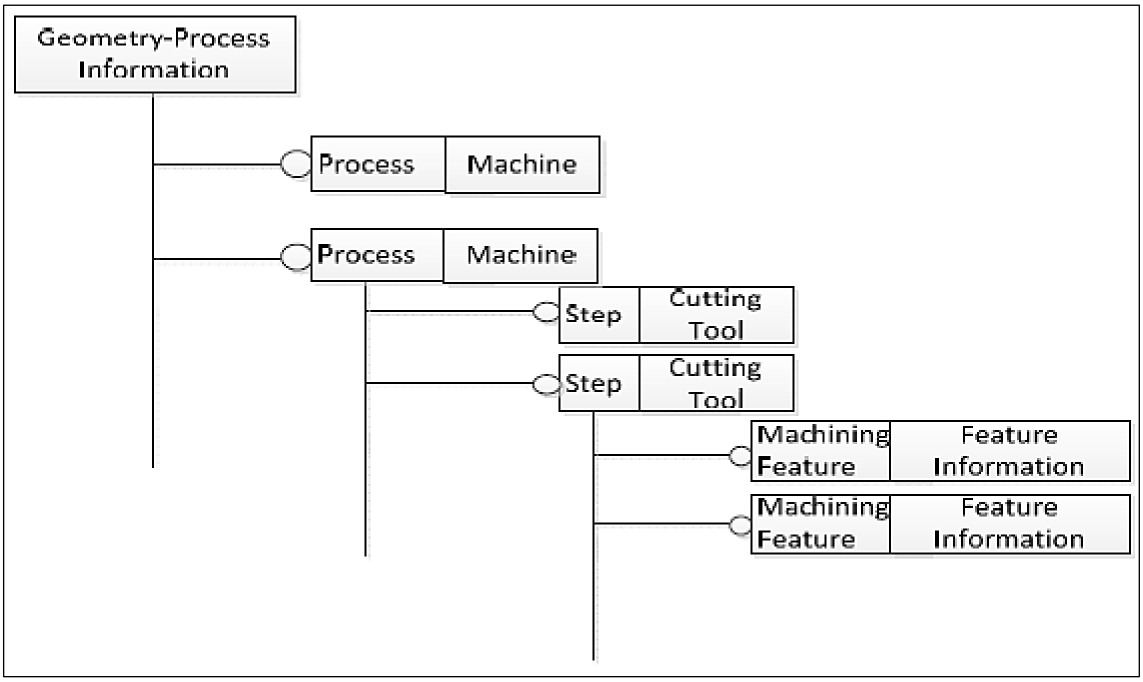

Fig. 4: Geometry Process Information.

The manufacturing features include the information related to feature codes, feature positions, machining allowance, cutting depth and cutting width.
$MF=(f_c, f_p, m_a, a_p, a_e)$

Where; MF shows manufacturing feature, f_c shows feature code, f_p shows feature position, m_a shows allowance, a_p shows cutting depth, a_e shows the cutting depth.

NC Program
The proposed method suggests a new way of establishing the data related to NC programs in the form of features. In this method the features are used as a unit. Corresponding to

each feature and feature code there is NC code. The syntax of the NC program is as follows:

NC=∪MFC

MFC=FC∪MC

Where; MFC shows the feature code for the corresponding feature, FC shows the machining feature code for the corresponding feature, MC represents NC code for the particular feature.

Machine Characteristics

In the proposed method, the machine characteristics are also stored in the knowledge based library including three constituents: machine library, CNC system library and speed control mode library.

Machine library={Machine_Name, Control_Sys, Para1, Para2…}

The CNC system library contains the information retardation control mode, turn control mode and other tool handling cases.

Control_Sys={Sys_name, Control_model, Situ1, Situ2….}

The speed control mode knowledge based library stores the information related to the speed control for each feature. It contains two function modes. The first function includes machine characteristics and the second function includes speed and displacement functions. The relationship among these data base libraries (knowledge based library) is as shown in the Figure 5.

Fig. 5: The Relationship Among Data Base Libraries.

Calculation of Cutting Speed and Cutting Power

There is quite complexity in setting machine speeds in the NC programs for each feature due to features such as corner radius. Cutting parameters are not optimized in most cases. As these parameters are not optimum, the acceleration and retardation of the machine will not be according to predefined sets. Based on the geometry information as stated above the speed alterations can be forecasted easily and hence the time can be predicted correctly and effortlessly. The cutting force and cutting speed can be used to obtain cutting power as follows:

P=fv

Where; p is the cutting power, f is the cutting force and v is the cutting speed.

Machining Time Calculation

The compromise is to be made between time estimation efficiency and precision. This can be achieved by considering various factors. The roughing and drilling operations being low speed operations, their estimated machining time is quite close to the actual time. The finishing operations are high speed operations and hence the influence of machine values is quite high for time estimation and therefore it should be considered. As discussed above the tool path of a particular feature is composed of rapid locating, approaching and retreating time and cutting. Rapid locating is easy to calculate. Approaching and retreating time is quite complex. Only machine characteristics, if considered, the calculated machining time will be inefficient. Each particular feature has its own tool path strategy which decides the approaching and retreating time. Hence the machining time can be calculated using the proposed method.

CONCLUSION

A prototype system for calculating machining time has been developed based on feature based techniques. The experimental results taken by various authors show that this method is accurate and efficient compared to the other commercially available software and other existing methods. We can also find that the proposed method is also feasible and applicable in industry.

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