PRODUCTION TIME ESTIMATION AS PART OF THE COLLABORATIVE VIRTUAL MANUFACTURING

P. Cosic¹, D. Milcic², I. Kovacic¹

¹University of Zagreb, FSB, Department of Industrial Engineering,
Ivana Lucica 5, 10000 Zagreb, Croatia
²University of Zagreb, Faculty of Graphic Arts, Getaldiceva 2, 10000 Zagreb, Croatia

ABSTRACT

Very frequently as decision makers we have to develop decision support for possible answers/requests on some important requests for offers, generated for individual or batch production, for example: great number of requested offers for production of products at once, small batches with very rarely repetition, frequently changes of priorities during production, short deadlines of deadline of delivery, market demands for approaching prices of the individual or batch production near the prices of mass production etc. Purpose of this research was establishing possible connections between drawing/3D features and necessary production times/costs.

Keywords: Virtual Manufacturing, Production time estimations

1. INTRODUCTION

Very frequently we must answer on some important requests for offers, generated for individual or batch production, for example: great number of requested offers for production of products at once, small batches with very rarely repetition, frequently changes of priorities during production, short deadlines of deadline of delivery, market demands for approaching prices of the individual or batch production near the prices of mass production etc. During product development we are often faced with evaluation of the best suppliers. Purpose of this research was establishing possible connections between drawing features (2D, 3D) and necessary production times for manufacturing products. Research of the connection between production time and features of products give us as result technological knowledge base and regression equations.
2. SEQUENCING OF OPERATIONS AND ESTIMATION OF PRODUCTION TIMES

The operations defined in process planning have to be put in certain order according to precedence relationships based on technical or economical constraints. Operations sequencing depends on many influences like: nature of the material, general shape of the part, required level of accuracy, blank size, number of parts in the batch, possible choice of machine tools, etc.

The expected difficulties in the process of solving operations sequencing can be: pattern recognition, selection of datum, connection between machining surfaces and type of operations, machining tools, tools, positioning and holding of workpiece etc.

Few approaches in sequence operations and production time’s estimation can be mentioned.

First approach named Matrix method [1] can be described as operations defined by putting in certain order according to precedence relationship based on technical or economical constraints.

Shape complexity approach as the second possible approach for production time’s estimation is defined through entropy as a measure of sample randomness [2]. The entropy is expressed as $H=-\sum p_i \log_2 p_i$, where $p_i$ is the probability of a certain outcome (angle change along contour in this case). The ultimate goal is to calculate the shape entropy as a measure of shape complexity.

Third approach named Variants of process planning [3, 4] can be explain as production time’s estimation. For example, estimation of production times & costs by web application for different variants of product production were developed. Selected variant of product production is result of product shape, way of tightening), roughness surface and kind of machine tools.

Fourth approach named Operation sequencing [5] can be explain as development of original web application by Microsoft .net technology and Flash (temporary site http://www.igorm.net/studadmin/). Fundamental idea for sequencing operations is shape recognition, determination between dimensional & geometrical tolerance with requested process roughness, calculation tolerance and cutting addition and final sequence operation. Web site for this application would be at http://ptp.fsb.hr.

Fifth approach named Basic technological operations [5, 6] can be explain as development of the original knowledge base of fundamental, the most frequently operations.
What can we put as the characteristics for the previous first four approaches for possible estimation production times? First, problems with the insufficient generalization level of the used procedure, too complicated calculation, insufficient level of automation of solutions generating in IT application, etc. In this paper would be discussed fifth approach by more details in two variants.

3. WAYS OF ASSUMPTION DATA FROM "CLASSICAL" 2D DRAWING AND 3D MODEL

So, as the first phase have to be establish technological knowledge base, features of drawing (independent variables) and possible dependent variables for production times estimation (Fig. 1), size and criteria for sample homogenization (principles of group technology) for analysis of variance and regression analysis.

For establishing potential high quality relationship between features of drawing and production time we have to execute two actions. One action can be explain as exploring measures for reduction number of independent variables for regression analysis. Method of analysis of variance (ANOVA procedure) and stepwise multiple linear regression were very
helpful in process reduction of number of independent variables. The other action was process of sample homogenization for example, elimination of too big or small value of members of sample, etc. As result of development we have developed some multiple stepwise linear regression equations. As the result of previous research, sample homogenization, classifier selection and multiple stepwise linear regression we obtained: (Fig. 2):

7 independent selected variables, basic sample of 320 parts, constraints for data parts, 8 regression equations, percentage of explained effects, relative error (7%-30%), etc. Of course, desired level of generalization in regression analysis would be important indicator for the quality of regression equation. Adequate method for process of homogenization of sample was one of methods of group technology. Logical operators during query process in database Access were very helpful in process of homogenization of sample of products.

As the second phase in research was investigated possibility for easy automatic, directly receiving 3D features of axial symetric product to regression model. Defined request is resulted with development process of receiving parameters from 3D models with low level of subjectivity, very fast and reliable process via CAD report to regression model. As the first step some dimensions are considered as parameters (outside product diameter, inside diameter, product length, product width and product thickness). For development IT
application (PhP) are used Pro/ENGINEER (Wildfire3.0), Mozilla Firefox, Ultra Edit 32, WAMP5 (server runs PhP code) and Excel 2003 & MatLABR 2006a software. The first version of application is based on report receiving in html format and last version of report was in txt format. As the second step of our research, application is developed for recognition the important parts of source code and receiving parameters from CAD application (Pro/E) to output table report.

As result we have got clearly defined table of possible independent variables (number of features, finding out and counting dimensions with tolerances, counting of total number of dimensions, receiving additional parameters (mass, volume, superficial area). So, with these additional new independent variables we can: compare precision and reliability of ‘classical’ and ‘automatic’ estimation of production times, estimate competitiveness different competitors and suppliers and develop some aspects of decision support for management through use tools of optimization (genetic algorithm). With these ‘tools’, we can use some aspects of competitive intelligence and please some requests of virtual manufacturing.

4. DESIGN OF 3D MODEL OF PRODUCT

During modelling process is necessary to use some rules for mathematical definition of geometrical model rigid body, for example: rigidity, homogenous three-dimensional, finality, closed condition of basic transformations and some Boolean operations, finality of description, definiteness of superficial area.

For easily data transfer (variables) from 3D model, it is desirable to define unambiguously characteristic dimensions of the model of product. The most simple manner is assigning for the important dimension lines (naming of important dimension lines).

These names would be variable names for later data sharing: outside diameter of product, inside diameter of product, breadth of product, thickness of product and product length. Some of them was very complicated to detect in report generated from application. It was necessary to develop algorithm which has to anticipate many various product shapes. Mentioned dimension lines are named for avoidance potential errors in application.

After all of mentioned condition of model stability are satisfied (mathematical definition of geometrical model rigid body) it is necessary to define all characteristics of surfaces, shape and position tolerance from technical drawing. In the other case it can be occur that the
estimated production time would considerable differ from time which we can get with all model characteristics. Defined characteristics after finished modelling are:

- tolerance of dimension lines
- roughness of surface
- tolerance field
- tolerance of position and shape.

5. ADVANTAGES AND DISADVANTAGES OF THE AUTOMATIC FEATURES ASSUMPTION

"Migration" from classical technical drawing to 3D model of product for automatic features assumption has important advantages: automatic features assumption and use in the other applications, it's good manner to avoid subjective features from drawing which generally depend of designer (scale, number of views, number of dimension lines, etc) elimination of possibility for loss or wrong assumption of features (elimination of operator influence) possibility for adoption additional variables which are not observable from 2D drawing better perception for real product appearance, dimensions observability for geometrical undefined models. Some of the most important disadvantages "migration" from classical technical drawing to 3D model of product for automatic features assumption are:

- owned 3D CAD application and necessary skills for use it,
- making of 3D model in the case that it's not realised from customer,
- keeping to necessary rules for mathematical definition of geometrical model,
- wrong layout defined dimension lines, tolerances and surface features
- impossibility of assumption surface quality , tolerance of shape and position, radial and axial chucking.

6. DEVELOPMENT OF THE WEB APPLICATION FOR AUTOMATIC ASSUMPTION FROM CAD SOFTWARE

In CAD application Pro/Engineer exists possibility for adjusting format writing of reports. html format is better for for presentation generated data (letter size, font style, letter colors. Report in txt format has more easy source code (one color, size and font style). Therefore, code application is more simple for writing and modification. From reports generated in txt code it's more easy for data assumption.
7. RUNNING OF APPLICATION FOR ASSUMPTION FROM CAD SOFTWARE

As example of multiple linear regression, after classifiers actions and stepwise multiple regression was selected group of rotational parts with 9 parts in a sample for 2D paper drawing. Observed multiple linear regression for 4 independent variables \( Y = f (X_{16}, X_{21}, X_{31}, X_{44}) \) (1) has index of determination \( R^2 = 0.998651 \) and regression equation:

\[
Y = 757.472 + 2.52562X_{16} - 0.333048X_{21} - 62.3869X_{31} + 0.300431X_{44} \tag{1}
\]

\( 0 < X_{16} < 3 \) – number of descriptions
\( 10 < X_{21} < 36 \) – number of usual dimension lines
\( 11.21 < X_{31} < 11.71 \) – mass strength of material
\( 43.18 < X_{44} < 290.45 \) – volume of material
\( 45.00 < Y < 111.00 \) – production time.

Observed multiple linear regression for 6 independent variables, for the same sample and 3D model is \( Y = f (K_t, K_s, fea, m, V, P) \) (2) has index of determination \( R^2 = 0.9918 \) and regression equation:

\[
Y = 28.77308 + 8.277896K_t - 0.16359K_s - 1.46341fea - 50.8704m + 0.000324V + 0.002462P \tag{2}
\]

\( 2.00 < K_t < 8.00 \) – toleranced dimension line of the part
\( 9.00 < K_s < 46.00 \) – all dimension line
\( 9.00 < fea < 25.00 \) – features of 3D
\( 0.174 < m < 0.584 \) – mass of the part
\( 4,063.80 < V < 74,724.50 \) – volume of the part
\( 6,660.70 < P < 28,131.30 \) – superficial area
\( 45.00 < Y < 111.00 \) – production time

error between predicted and calculated production times for each part (-5.64%; + 4.32%)

8. CONCLUSION

Automatic assumption from 3D model get objective observed variables with correct values of variables. Assumption from 3D model instead classical ‘manual’ assumption from 2D paper introduce new variables which are important in process of 3D modelling. In the near future further research would be oriented to different cost models, optimization through AI methods (genetic algorithm, fuzzy logic, etc.), structural analysis relationship between geometrical characteristics of the part and production times, making application for national
Croatian technological project and necessary steps for knowledge implementation in manufacturing.

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