Manufacturing Process and Cost Estimation through Process Detection by Applying Image Processing Technique

Chalakorn Chitsaart, Suchada Rianmora, Noppawat Vongpiyasatit

Abstract— In order to reduce the transportation time and cost for direct interface between customer and manufacturer, the image processing technique has been introduced in this research where designing part and defining manufacturing process can be performed quickly. A3D virtual model is directly generated from a series of multi-view images of an object, and it can be modified, analyzed, and improved the structure, or function for the further implementations, such as computer-aided manufacturing (CAM). To estimate and quote the production cost, the user-friendly platform has been developed in this research where the appropriate manufacturing parameters and process detections have been identified and planned by CAM simulation.

Keywords—Image processing technique, Feature detections, Surface registrations, Capturing multi-view images, Production costs, and Manufacturing processes.

I. INTRODUCTION

RECENTLY the image processing has been applied for extracting the geometric shapes and detecting features from 2D images [1]-[5]. For the regular channel of design process, the engineering drawing is firstly created for considering the geometric details of the part where the master part is available for measuring purpose. When the traditional measuring devices (e.g., vernier calipers, or micrometers) cannot perform on some complex details of the part's surface, the applications of reverse engineering (RE) process have been applied [3]-[5].

Various measurement methods, contact (e.g., Coordinate Measuring Machine-CMM), and non-contact (e.g., 3D laser scanner) methods, are introduced for data acquisition step of RE process. A CMM provides higher accuracy of the measuring data than a 3D laser scanner; however it is time-consuming process and cannot acquire soft surfaces [5].

To obtain a precise data and to prolong their use, maintenance activities (e.g., preventive and corrective maintenances) are required [6]. However, costs for purchasing and maintaining these advance devices are expensive where the special services and skilled operators are required.

Making profit and satisfying customer both are important for any manufactures to realize strategically [7]. The variety in shapes of products is the major difficulty in designing and approximating production cost. In practice, the production cost is estimated by the decision of manufacturer after designing process where the customer can negotiate for asking some discounts. The most important problem facing the customers today is interpreting their needs to be the engineering designs since it is quite difficult to explain the shapes, patterns, or the characteristics of the desire part through words or hand-drawing drafts [8], [9]. Currently, a digital camera, a mobile-imaging device, is widely used and introduced as fast, easy, cheap, and portable device to capture the characteristics of the object. Capturing images of the desire shapes from the existing part can assist the customer to easily explain the specific details of the new design [10-16]. These images can be quickly transferred to the manufacturer to design the part with less communication or discussion while satisfying the customer requirements. However, some feature details of the existing part are missed due to less captured views. In order to obtain a complete design, the appropriate guidelines for properly acquiring features by digital camera should be well provided.

Presented in this research is the alternative channel for the manufacturer for designing part based on the reverse engineering (RE) technique where the 3D virtual model can be constructed quickly from its physical part. Using the proposed technique can reduce cost and time for data acquisition activity where a digital camera is applied. The obtained data (i.e., a series of multi-view images) are constructed to be a 3D model which is used for identifying the manufacturing parameters in computer-aided manufacturing (CAM) application. With known cutting parameters, estimating production costs and quoting price for a part can be done immediately by applying the program developed in this research. The format of the reporting document is very simple (i.e., small file size); therefore, it can be transferred quickly to the customer for making decisions.

In order to accomplish the proposed technique, two main phases have been presented. The first phase is created for generating 3D model from the images taken from different views of the existing part as shown in Fig. 1. The obtained model is then used to simulate the manufacturing process and estimate cost in the second phase (Fig. 2).

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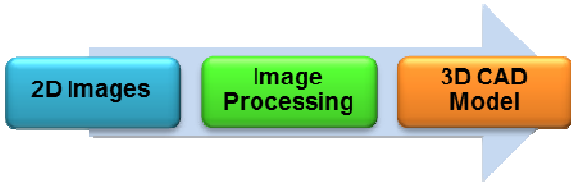
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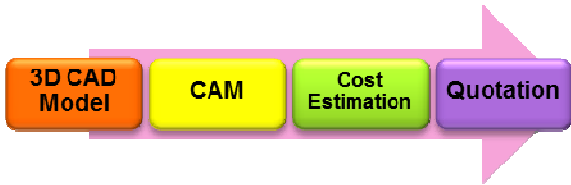Fig. 1 The first phase of the research: Generating 3D model

Fig. 2 The second phase of the research: Cost Estimation

II. RELATED WORKS

In order to accomplish the objective of this research where the manufacturing process and cost estimation can be determined by analyzing the surface details of the 3D virtual model which is quickly constructed from 2D images, data acquisition technique by digital camera and image registration are taken into accounted and discussed.

Imaging data by digital camera is applied as non-scanning technique for shortly extracting the entire geometric information of the existing part with a few snapshots. This technique allows a wider range of parameters (e.g., camera parameters) to improve the quality of the captured images where the low intensity, low contrast, dark lighting, and image distortion can be avoided during processing [9], [15].

Since the images are defined over two dimensions, to analyze the details of the object's features, multi-dimensional imaging system has been applied for obtaining 3D virtual model. To combine the multi-view images to be in 3D form, a registration process is required where the common positions should be presented on each view [10]-[12].

The registration process, in general, starts with finding the coordinated point or common points in the images. To simplify the captured details, edge detection algorithm is asked for extracting the area of interest in the virtual circles method where the outliers in image correspondences and view transformations can be well detected and defined [10]. Using this technique can reduce time for merging images from different views where the common positions can be automatically found and then transformed to be in the same plane. This technique is not available for low intensity and dark lighting images. In order to obtain clean and clear 3D model, the camera parameters (e.g., shutter speed, aperture size, and ISO) should be well controlled.

III. CONVERTING 2D IMAGES TO 3D VIRTUAL MODEL

Obtaining object information by digital camera has become an interesting technique for fast and easy acquisition process. The steps required for constructing 3D model from the images

are presented in Fig. 3. According to the regular path of RE technique, in data acquisition step, three activities are required: capturing images from different views, registering surfaces from 2D images, and modifying 3D surfaces.
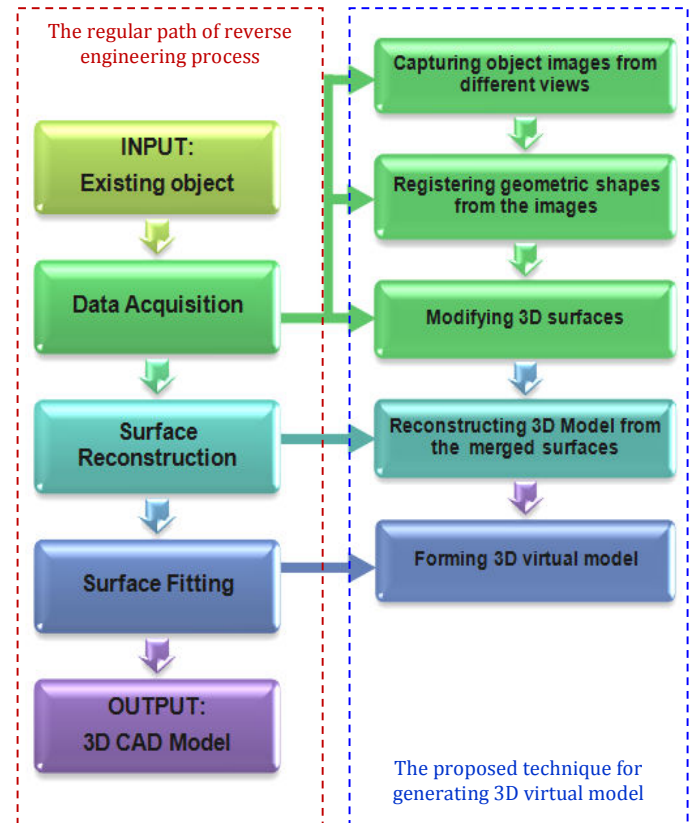

Fig. 3 The steps of 3D model reconstruction

To generate a 3D model of a physical object, firstly, different views (at least 20 views) are captures where the angle between two consecutive images is varied from 10 to 15 degrees as shown in Fig. 4. After combining all images via the registration function, the unwanted areas (around the bottom of the object) can be directly eliminated as shown in Fig. 5.

Fig. 4 Capturing object with different views

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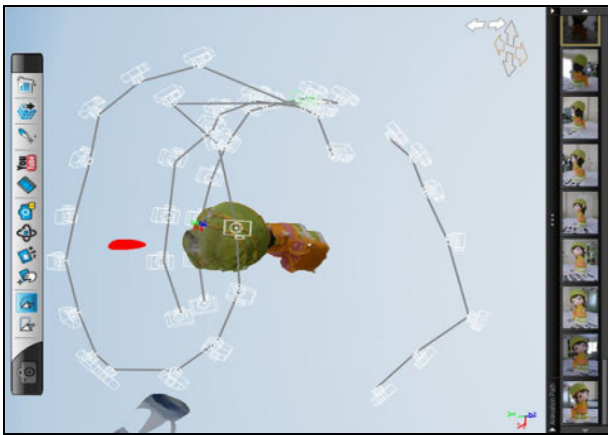Vol:7, No:10, 2013

Fig. 5 Eliminating noises around the bottom regions of the model

With the same concept of capturing multi-view images illustrated in Figs. 4 and 5, the sample part shown in Fig. 6 is applied for demonstrating the proposed technique. After adjusting the appropriate camera parameters, this sample was captured in 41 views as shown in Fig. 7.

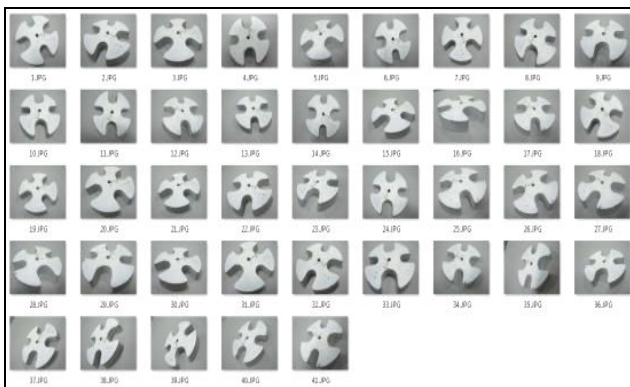Fig. 6 The sample part used for demonstrating the proposed technique

Fig. 7 41 views of the captured images

All 41 images are transferred to the registration process which is available in AutoDesk application in which the combination and registration processes are applied on the captured images to get the triangular facets. These facets can represent the geometric shapes of the object. In the process,

between the two consecutive images, the common areas or the reference points are firstly identified.

Once the similar portions from these two images are aligned, the registration technique is then asked for merging the images and the overlapped regions are presented. These activities are repeated until all views of the captured images are combined as shown in Fig. 8 and 9.

The dimensions of the polygon phase can be approximated automatically to be 8cm x 6.44cm x 1.114cm (Width x Depth x Height).
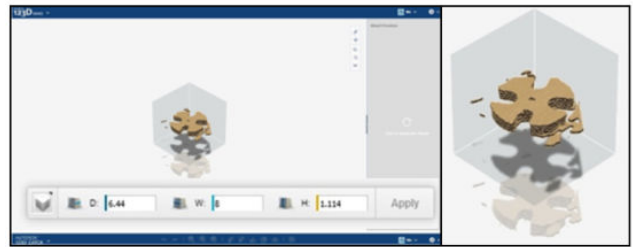

Fig. 8 Surface registration process

Fig. 9 The completion of surface registration process

After registering all images at the common points, the polygon model (i.e., triangular facets) is quickly constructed as shown in Fig. 10. Some small portions of the unwanted areas are eliminated (Fig. 11). The 3D CAD model is created after modifying and editing the polygon phases. For supporting the functional test in the design stage, the obtained 3D CAD model can be used directly to fabricate a prototype in the subsequence process.

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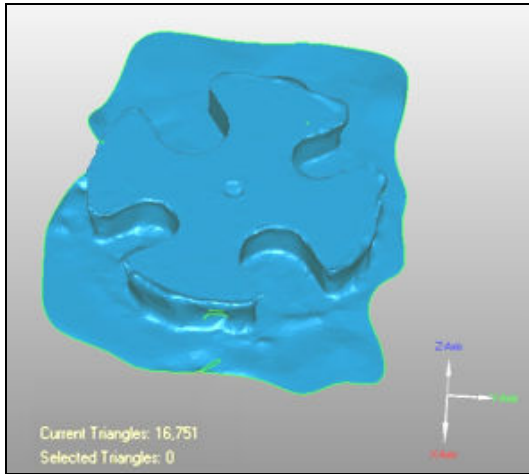Vol:7, No:10, 2013

Fig. 10 The polygon model from imaging registration process
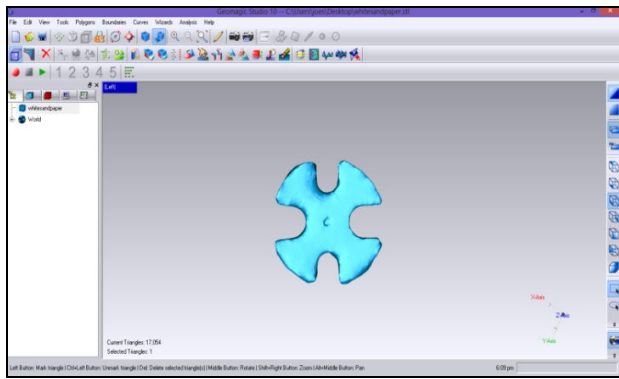

Fig. 11 The polygon model after modifying surfaces

The obtained 3D CAD model can be resized the scales by applying the commercial CAD software. It is then exported to CAM application to generate tool paths and estimate time for producing part where the manufacturing parameters are assigned according to the performance of the machine applied. The results obtained of this simulation, the value of cutting parameters, are used to calculate operation cost by the developed program in the subsequent process.

IV. COST CALCULATION

After obtaining the cutting parameters, the operation cost can be quickly calculated by the program which is developed in this research. Some of the manufacturing equations [9] which are applied in this study are shown in the demonstrating example.

Example: A face milling operation is being carried out on a 8-inch long, 6.44-inch wide, annealed mind-steel block at a feed *f* is 0.12 inch/tooth and a depth of cut *d* = 0.25 inch. The cutter diameter *D* is 0.5 inch with 4 straight teeth, rotate at *N* = 2000 rpm. Set up time is15 minutes for set up. Cycle time is 15 minutes. The number of products is 20 pieces. The productive hour cost is $200. If the discount rate is 8% determine the total estimate cost of the operation.
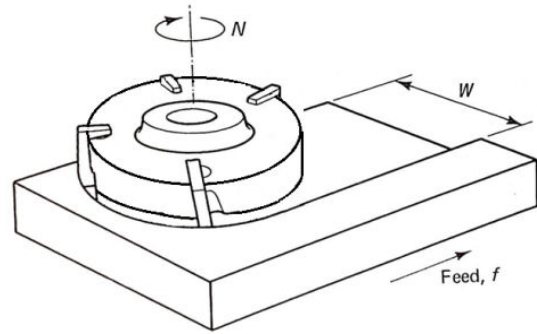

Fig. 12 Face milling operation

Feed rate (IPM):
$$f = f_t N n$$
f_t = *feet per tooth (recommended) = 0.12 IPT*
N = Spindle speed of tool material (RPM)
n = Number of teeth
$$\therefore \quad f_t = 0.12 = 960 \ IPM$$

Fig. 13 Feed rate approximation

Distance between the point of approach and the edge of the workpiece
$$(A) = \frac{D}{2} \ for \ W = \frac{D}{2} \ up \ to \ D$$
$$\therefore \quad A = \frac{0.5}{2} = 0.25 \ mm$$

Fig. 14 Distance between the point of approach and the edge of the work piece

Machining time
$$(T) = \frac{L+2A}{f}$$
Where L = cut length of the workpiece= 8 inch
$$\therefore \ Machining \ time \ (T) = \frac{(8+(2*0.25))}{960}$$
$$= 0.00885 \ min$$

Fig. 15 Machining time

Total cycle time = Cycle time + Machining time
$\therefore$Total cycle time: 15+0.0088541
$$= 15.00885 \ min$$

Fig. 16 Total cycle time

Lot hour =
(Setup Time(hours) + (TotalCycle Time / 60) * Quantity (pieces))
=0.25+ (15.00885 / 60)* 20
= 5.25295 piece/hour

Fig. 17 Lot hour

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Estimated cost =

(Lot Hour * Productive Hour Cost ($)) * 1.35

= (5.25295*200) * 1.35 = 1418.2595 $

Fig. 18 Estimated cost

Total Estimated Cost after discount=

Estimated Cost * ((100 −percent discount) / 100)

$$=1418.2595 * \frac{(100-8)}{100}$$

=$ 1304.833125

Fig. 19 Total Estimated Cost after discount

The user interface of this developed program is shown in Fig. 20. Illustrated Fig. 21 is the summary of the manufacturing operation is quoted.

Fig. 20 Developed Program for calculating operation cost

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Summary of  - Milling Operation Face Milling

Tool diameter (in)           0.5
Depth of cut (in)            0.250
Cutting feed (IPR)           0.48
Spindle Speed (RPM)          2000
Number of teeth              4
Feed per tooth (IPT)         0.12
Feed rate (IPM)              960
Cut length (in)              8
Width of cut (in)            6.44
Cutting Speed (SFM)          3141.59265358979
Mean Cutting Speed (SFM)     1570.7963267949
Machining Time (min)         0.00885416666666667
Material-removal Rate        1545.6
Tool Life - Steel work       0.00390625
Tool Life - Non-steel work   0.0410062500000001
Workpiece                    Other - Specify number of teeth and feed per tooth
Tool material                Cemented Carbide
Setup time (Hrs)             0.25
Cycle time (min)             15
Total cycle time (min)       15.0088541666667
Quantity (Unit)              20
Productive hour cost         200
Lot hour                     5.25295138888889
Estimated cost               1418.296875
Discount (%)                 8
Total estimated cost         1304.833125
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Fig. 21 Summary of the manufacturing process

V. GENERATING A PHYSICAL PROTOTYPE

In order to inspect the geometric shape and test the function of the 3D CAD model obtained from the proposed technique, the layer manufacturing technique (i.e., rapid prototyping (RP)) is applied for generating the prototype where the 3D CAD model is sliced into several layers with uniform layer thickness [17]. In this research the fused deposition modeling-FDM technique has been applied. Firstly, the 3D CAD model is imported to the slicing program (as shown in Fig. 22) to generate a series of slicing layers. In this research, the thickness of one layer is 0.254mm. The height of the 3D model is around 11mm; therefore, the total number of the fabricated model is 43 layers. Illustrated in Figs. 23 and 24 are the FDM machine and the fabricated prototype, respectively.
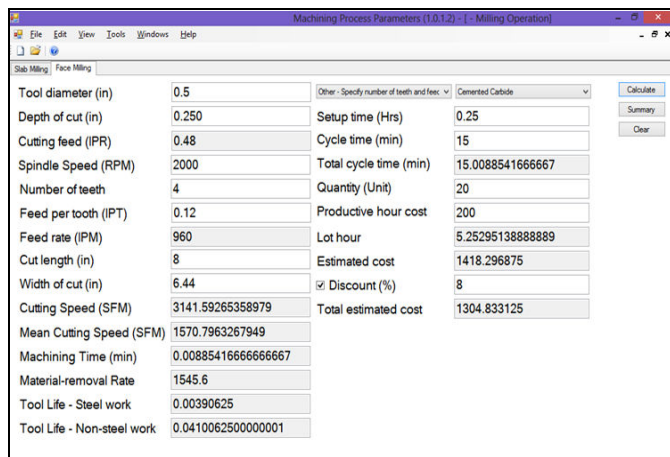

Fig. 22 Slicing program-RP process

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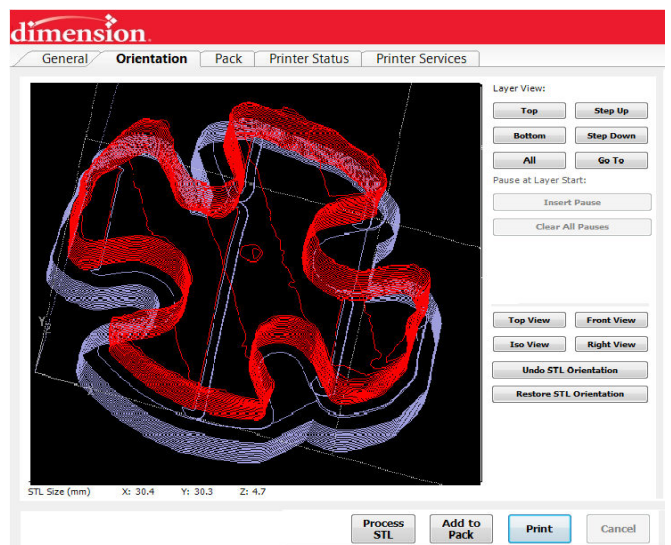International Journal of Industrial and Manufacturing Engineering
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Fig. 23 RP machine-FDM Process

Fig. 24 Fabricated prototype

VI. CONCLUSION

Applying the concept of image processing technique to generate 3D virtual model from 2D images can help manufacturer to design a product quickly where the telecommunication and transportation costs can be reduced. The difficulties of creating 3D model can be identified into three main parts: obtaining clear details of object's features from the images, merging multi-view images, and constructing 3D surfaces. Well adjusting light intensity, capturing images with a proper number of views (at least 20 views), and modifying polygon phases can reduce time and enhancing the obtained 3D virtual model. The obtained virtual model can be tested its function by rapid prototyping process.

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