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Reverse Engineering Representation Using an Image Processing Modification

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Abstract

In the reverse engineering approach, a massive amount of point data is gathered together during data acquisition and this leads to larger file sizes and longer information data handling time. In addition, fitting of surfaces of these data point is time-consuming and demands particular skills. In the present work a method for getting the control points of any profile has been presented. Where, many process for an image modification was explained using Solid Work program, and a parametric equation of the profile that proposed has been derived using Bezier technique with the control points that adopted. Finally, the proposed profile was machined using 3-aixs CNC milling machine and a compression in dimensions process has been occurred between the proposed and original part so as to demonstrate the verification of the proposed method.

Keywords: *Bezier, reverse engineering, tool path generation.*

1. Introduction

The progression of a new product is a repeated process, which includes: design of product, product prototyping for experimental assessment and adjustment of design, where computer aided design (CAD) is commonly connected with interactive computer graphics, and the designer can conceptualize the object to designed very easily on the graphics screen and take into account alternative designs or modify a particular design more quickly to meet the needed design requirements or changes of design.

In previous works when the researchers make them design of any profile using MATLAB program they save the extension of the design file as m-file or dxf-file. And then open it in CAM program to get the simulation of machining operation and get G-code. This method can be succeeding for simple surface, but it's useless if complex profile was designed and translated using this basic method. While other researchers write the control points of any complex surface in CAM program manually, and this primitive method also may be taking a long time. Where from MATLAB program it can be made a program to get G-code directly, and this method can be done for 2-axis, 3-axis at the maximum, while it's difficult to adapt this method to obtain G-code for machining in multi-axis because this need hard work and may be the results that got not compatible with CNC machine control system [1]. Malgozata Ponitowska [2], investigated a method for representing a visual analysis of deviation in 2D graphs in measurements of free-form surface performed by use numerically control CMMs on the basis of a CAD models, the measurement is aim at evaluate the form deviation and thus the greatest deviation of the actual surfaces from the CAD models. Abil Kuş et al [3], reviewed the processes of digitizing a parts and creating a CAD model from 3D scan data use 3D optical scan technology. They illustrated two scanning experiments of automotive application, the first one examines the process from scan to re-manufacturing the damag sheet metal cutting die, using a 3D scan techniques and the second one compare the scanned points clouds data to 3D CAD data for inspection purpose. Wissam and et al [4], use CMM to measuring external profile of objects with external porosity space. In this processes the center of a CMM probing stylus would be compensate to avoid porosity spaces located above external surfaces area along surfaces normal directions. The proposed method is able to avoid porosity space in CMM measurement regardless of the availability of CAD model. And they present a processed of measure geometrical features of a physical object to convert the measured points cloud into a 3-D models. Dongdong Zhang et al [5], presented an approaching for generating curvature-adaptive finish tool path with bound error directly from massive points data in three-axis computer numerical control (CNC) milling. It enable the generation of curvature-adaptive tool path from massive points data that is critical for balancing the trade-off between machining accuracy and speed. To ensure the path accuracy and robust for arbitrary surface where there might be a sudden curvature change. It overcomes potential excessive locality of curvature-adaptive path by examine the neighboring point curvature within a self-updating search bound. their result affirm that the combination of curvature-adaptive paths generation and the guidance field algorithm produce high-quality numerical control (NC) path from a variety of points cloud data with bound error.

In the present research a new method for getting the control points of any profile will be presented. Where, many process for an image modification will be explained using Solid Work program, and then a parametric equation of the profile that will proposed will be derived using Bezier technique with the control points that adopted.

2. Construction of Proposed Method

Actually, the structure of the proposed method in the present research must be divide into four divisions, the first one relate with CAD program (Solid Work), which is deals with the control points that will be detected from an image of the proposed part. Second division relates with derived the parametric equation that describe the profile of the proposed part. Third division represents the CAM field to machine the proposed part. Finally, a comparison process will be occurred to check the verifying of the proposed method.

Reverse engineering is a significant manner in constructing a CAD model from an existing substantial part through part or product design [1]. If it is interested in doing reverse engineering of legacy products, then let me save your time and energy and explain about the best company can outsource reverse engineering of legacy products. Mechanical 3D Modeling can provide complete design support to help you recover design information for your obsolete parts with accuracy. From automotive parts, industrial equipment to entire plants, it has worked on reverse engineering projects of any scale and complexity. It’s experienced team and designers utilize Solid Works as well other CAD tools and has remained a valuable partner to many clients for successfully serving reverse engineering projects.

Almost all of the proposed solutions for RE are realized in two proceedings; In the first step, the physical portion is measured or digitized by a measuring instrument such as a coordinate measuring machine (CMM), and surface points are captured in 3D coordinates. While the second step, curves or surfaces be suitable for to the measured points. The absence of coordinate measuring machine, it has been depending on Solid work program in order to obtain the control points of the case study. The getting point has been saved in a way so they can be used in MATLAB program. Also it can trace the procedure in the flowchart as shown figure (1).

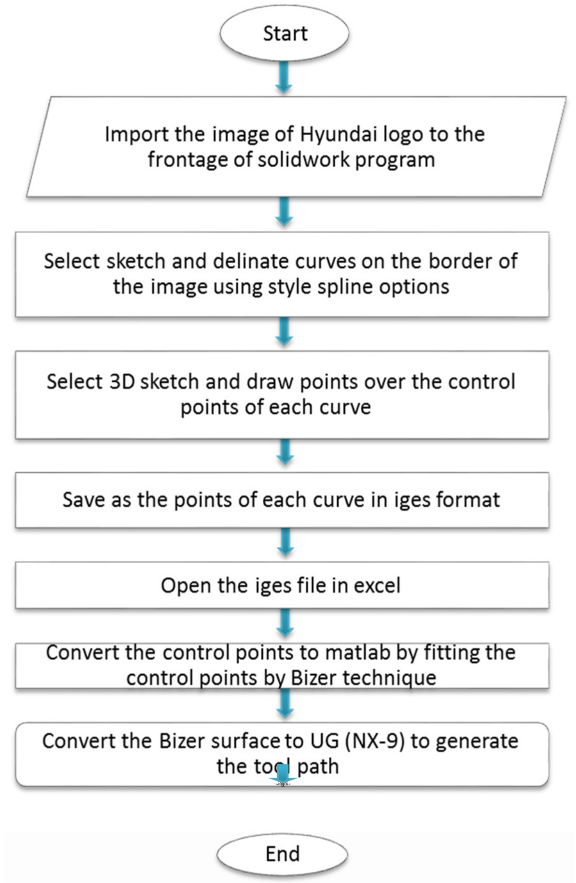

Fig. 1. The flowcharts demonstrate the procedure for recalling the control point using solid work program.

3. Surface Representation

In the present research Bezier surface was selected, which is a direct extension of a Bezier curve. The underlying principle in defining a Bezier surface is that to let a point trace out of Bezier curve and then let this curve sweep out a Bezier surface.

The simple extension for three dimensional free–form surfaces from 3-dimensional free-form curve is by incorporating another parameter (w) to the vector equation of the curve to obtain the surface equation [6]:

$$P(u,w)=[x(u,w),y(u,w),z(u,w)] \qquad \ldots (1)$$

Where: $0 \le u,w \le 1$ (u,w) are independent variables.

This equation is called bivaraite parametric equation since it includes two variable parameters in two various directions.

The use of higher degree causes small oscillations in curve and requires heavy computations. So in this research Bezier surface with order $n \times m = 9 \times 9$ was selected.

By the mathematical derivation, the general equation to represent the Bezier surfaces of higher degrees can be shown as follow [6]:

$$P(u,w)= [U]\,[MB]\,[P]\,[MB]^{T}\,[W] \qquad \ldots (2)$$

$$[U] = [u^9\ \ u^8\ \ u^7\ \ u^6\ \ u^5\ \ u^4\ \ u^3\ \ u^2\ \ u\ \ 1]$$

$$[W]= [W^9\ \ W^8\ \ W^7\ \ W^6\ \ W^5\ \ W^4\ \ W^3\ \ W^2\ \ W\ \ 1]^T$$

$$M_B=\begin{bmatrix} -1 & 9 & -36 & 84 & -126 & 126 & -84 & 36 & -9 & 1 \\ 9 & -72 & 252 & -504 & 630 & -504 & 252 & -72 & 9 & 0 \\ -36 & 252 & -756 & 1260 & -1260 & 756 & -252 & 36 & 0 & 0 \\ 84 & -504 & 1260 & -1680 & 1260 & -504 & 84 & 0 & 0 & 0 \\ -126 & 630 & -1260 & 1260 & -630 & 126 & 0 & 0 & 0 & 0 \\ 126 & -504 & 756 & -504 & 126 & 0 & 0 & 0 & 0 & 0 \\ -84 & 252 & -252 & 84 & 0 & 0 & 0 & 0 & 0 & 0 \\ 36 & -72 & 36 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -9 & 9 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

So, according to these equations above and by select a several control points across x, y and z –axis using MATLAB program, it can be obtain the surface as show figure (2):

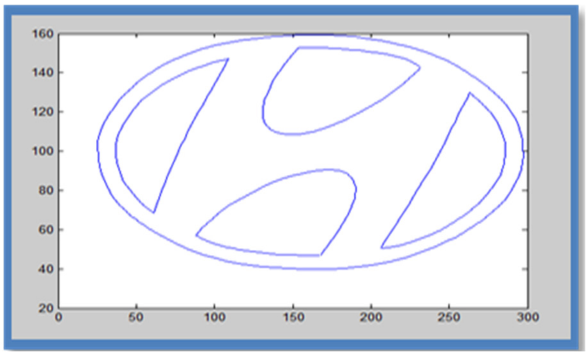

Fig. 2. Represent the higher degree Beziers's Surface in graphical mode.

From the all above, it must be notice that the M-program that was built to obtain the surface in figure (2) should be saved in (dat) extension so as to can open it in UGS program as shown figure (3) to take tool path as shown in figure (4).

Fig. 3. Model generation using UG-NX program.

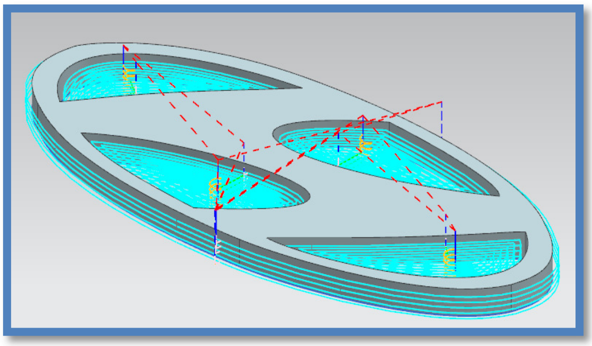

Fig. 4. Tool path using UG-NX program.

4. Continuity of the Present Work

To confirm the continuity for suggested work which divide in two zones of the curve based on the Bezier curve (B = 7) the kinds for continuity C^0, C^1 and C^2 will be achieve for the first segment of the Bezier curve by blended the region. To confirm the continuity in Bezier, the continuity would utilize to whole the region of the curve so the Z - axis would constant in value for whole curve of the work like in figure (bellow).

$$B(u) = [u^6 \quad u^5 \quad u^4 \quad u^3 \quad u^2 \quad u \quad 1]$$
$$B'(u) = [6u^5 \quad 5u^4 \quad 4u^3 \quad 3u^2 \quad 2u \quad 1 \quad 0]$$
$$B'(1) = [1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 0]$$
$$B''(u) = [30u^4 \quad 20u^3 \quad 12u^2 \quad 6u \quad 2 \quad 0 \quad 0]$$
$$B''(1) = [30 \quad 20 \quad 12 \quad 6 \quad 2 \quad 0 \quad 0]$$

By substitute u=1 in equation for the first curve and made this equal to equation of the next curve at (u = 0) like equation below.

B (u= one)1 first curve = B (u = zero) 2 next curve to take C^0 as shown in figure (5).

Where B20=B16 for (x, y, z) … (3)

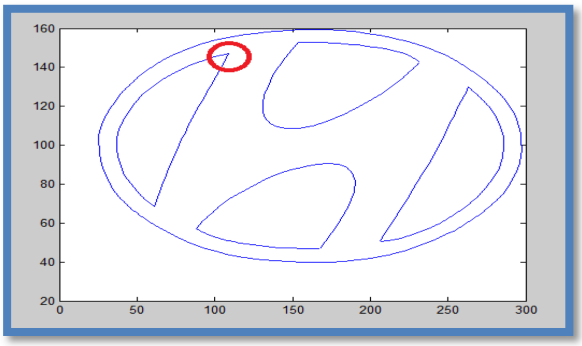

Fig. 5. Continuity example for curves of C^0 Bezier curve.

To confirm C^1 The equation of the first and next curves should derivative, then substituting (u = one) in first derivative of equation and substituting (u = zero) in derivative of equation for next curve to find B21 for the next curve as equation below.

B' (u = one) first curve = B' (u = zero) next curve as shown in figure (6).

Then B21 =2*B16-B15 for (x, y, z) ... (4)

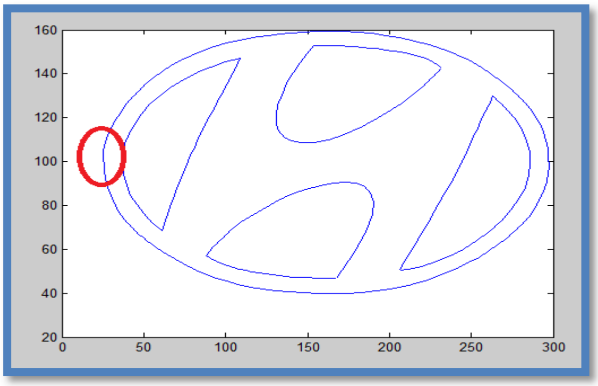

Fig. 6. Continuity for curves of C^1 Bezier curve.

And to take C^2 the equation of the first and next curves must be second derivative, then substituting (u = one) in second derivative of equation for first curve and substituting (u = zero) in second derivative of equation for next curve to take B22 for the next curve as equation below.

B'' (u=one) first curve = B'' (u = zero) next curve as shown in figure (7).

B22= B14-4*B15+4*B16 for (x, y, z) ... (5)

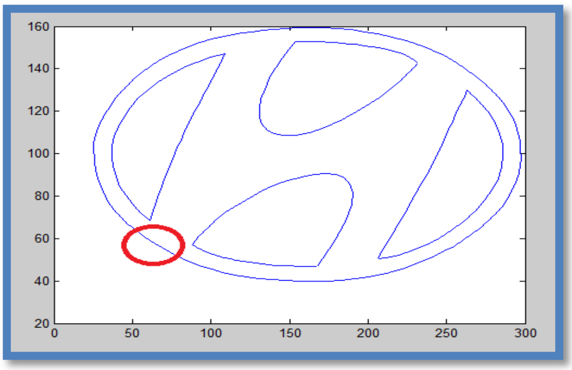

Fig. 7. Continuity example through two curves of C^2 Bezier techniques.

Fig. 8. Final shape of the proposed case study.

5. Experimental Work

The experimental work for the proposed case study had been achieved using 3-axis CNC milling machine, where figure (8) explained the final machined case study.

6. Comparison Operation

Table (1) demonstrates the compression and difference values in dimension between proposed and original part. Where experimental point has been taken from image data while the CAD point has been taken from MATLAB.

Table 1,
The compression and difference values in dimensions between the proposed and original part.

No.	CAD-POINTS	EXPERMENTAL POINTS	DEVATION FOR X-AXIS	CAD-POINTS	EXPERMENTAL POINTS	DEVATION FOR Y-AXIS
1	153.738	153.7	0.000388	152.938	152.098	0.008409
2	156.693	157	-0.00306	152.918	152.098	0.008205
3	159.834	159.58	0.002543	152.889	152.82	0.000696
4	163.183	163.002	0.001816	152.844	152.82	0.00024
5	166.756	166.987	-0.00231	152.773	152.77	3.71E-05
6	170.557	170.503	0.000548	152.670	151.002	0.016688
7	174.585	174.05	0.005354	152.527	151.002	0.015256
8	178.827	178.002	0.00825	152.336	151.0036	0.013332
9	183.262	183.0098	0.002523	152.091	152.008	0.00083
10	187.861	188.002	-0.00141	151.783	152.03	-0.00247
11	192.585	193.0005	-0.00415	151.406	152.04	-0.00633
12	197.389	197.889	-0.005	150.954	150.999	-0.00044
13	202.215	203.5	-0.01285	150.420	151.0008	-0.0058
14	206.999	206.08	0.009193	149.798	149.777	0.000217
15	211.668	211	0.006681	149.082	149.005	0.000776
16	216.139	216.058	0.000812	148.266	148.999	-0.00732
17	220.321	222	-0.01678	147.345	148	-0.00655
18	224.115	224.105	0.000103	146.312	146	0.003124
19	227.411	227.41	1.83E-05	145.163	145	0.001636
20	230.093	232.015	-0.01921	143.893	143.025	0.008686
21	232.034	233.06	-0.01025	142.497	142.44	0.000576
22	153.738	153.548	0.001908	152.938	152.99	-0.00051
23	149.781	148.352	0.014294	149.329	149.33	-3.2E-06
24	145.482	144.268	0.012143	145.068	145.0325	0.000358
25	141.225	140.368	0.008573	140.377	141	-0.00623

7. Discussion

1. Implementing error analysis tools to interpret error into meaningful information and give the designer feedback on how well the new surface matches the existing one, by using statistical analysis like average of error, standard deviation, error percentage. Also,

implementing visual analysis on error to show distribution of error. The compression and difference values in dimensions between the proposed and original part as shown in figure (9 and 10).

2. Machining the reconstructed surfaces using vertical CNC milling machine and inspect these machined surfaces using image processing to deduce the machining deviation compared with CAD surface model.

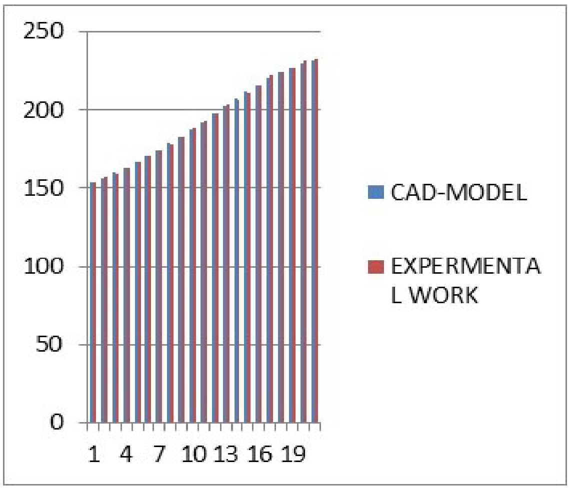

Fig. 9. The compression and difference values in dimensions between the proposed and original part for X-axis.

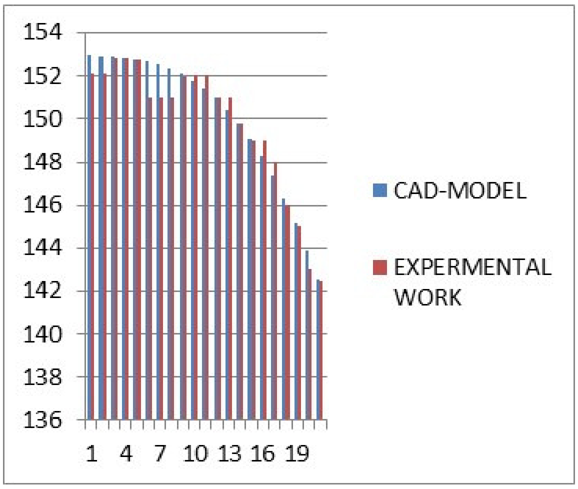

Fig. 10. The compression and difference values in dimensions between the proposed and original part for Y-axis.

8. Conclusions

The novel procedure focuses on contraction the point data. The adopted operation for detecting the control points newly has become practical in terms of speed and accuracy, where a great number of point data is being created in the data procuration phase of reverse engineering. Hence, it can be conclude from the compression and difference values in dimensions between the proposed and original part, the success and accuracy of the adopted method based on the deviation in reading that shown in table (1). Finally, this method can be used in reverse engineering depending on the images that taken for the part which wanted to design and manufacture it based on the facilities in the CAD/CAM programs.

9. References

[1] B. L. Curless," New Methods for Surface Reconstruction from Range Images", Department of Electrical Engineering, Stanford University, June, 1997.

[2] M. Poniatowska," Deviation Model Based Method of Planning Accuracy Inspection of Free-Form Surfaces Using C.M.M", Division of Production Engineering, Faculty of Mechanical Engineering, Bialystok University of Technology, 2012.

[3] A. Kus, "Implementation of 3D Optical Scanning Technology for Automotive Applications" Sensors 2009, 9, Uludağ University, 2009.

[4] W. Kadhim, M. Mohammed., "Constricting Multi-Patches B-spline Surfaces" Eng. & Tech. Journal, University of Technology, Vol. 31, Part (A), No. 1, 2015.

[5] D. Zhang, P. Yang and X. Qian, "Adaptive NC Path Generation from Massive Point Data with Bounded Error", Department of Mechanical, Materials and Aerospace Engineering, Illinois Institute of Technology, Journal of Manufacturing Science and Engineering, Vol. 131 / 011001-1, February 2009.

[6] M. Tawfiq, A. abdusamii, S. Kadhim, Ahmed, "enhancement tool path generation using ANN", Eng. & Tech. Journal, University of Technology, Vol. 31, Part (A), No. 1, 2016.

تمثيل الهندسة العكسية عن طريق استخدام المعالجات الصورية

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الخلاصة

في نهج الهندسة العكسية، يتم جمع كمية هائلة من البيانات معا وذلك أثناء الحصول على البيانات وهذا يؤدي إلى أحجام ملف أكبر ووقت أطول لمعالجة البيانات. فظلا عن ذلك، تركيب الأسطح من هذه البيانات التي تستغرق وقتا طويلا وتتطلب مهارات معينة. في هذا العمل تم تقديم طريقة جديدة للحصول على نقاط السيطرة في أي ملف. حيث تم شرح العديد من العمليات لتعديل الصورة باستخدام برنامج (solid work)، ومعادلة بارامترية من الملف المقترح تم اشتقاقها باستخدام تقنية بيزير مع نقاط التحكم التي اعتمدت. وأخيرا، تم تشغيل الشكل المقترح باستخدام ماكنة تفريز مبرمجة وتم إجراء عملية مقارنة في الأبعاد بين الجزء المقترح والأصلي من أجل إثبات التحقق من الطريقة المقترحة.