OPTIMIZATION OF ERROR COMPENSATION FOR CONTACT TYPE RONALD MDX-20 SCANNER IN REVERSE ENGINEERING

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Abstract*-The current scenario is product development process adopts the concept of concurrent engineering and uses the technologies CAD, CAE, rapid prototyping and reverse engineering. Reverse engineering is used when the original product design document has been lost or never existed, unable to create the complex shapes accurately. It also used to edit and tailor base model geometry for improved functionality or new application. Reverse engineering process involves four stages viz. scanning the object using the reverse engineering scanner to collect the information from the reference object, then the noises present in the point cloud obtained from the scanning are removed, after the removal of noisy point cloud cad model is produced, at last reverse engineering model is manufactured using CNC machine. The accuracy (or) obtaining the correct dimension depends on procedures adopted in all four steps of reverse engineering. There are two types of scanning process available in reverse engineering: one is contact type and another is non-contact type. The contact type scanner has some advantages compared to non-contact type scanner.It can able to scan shiny and transparent material, less able to measure deep slots, when compared to non-contact type scanner. It also has some limitations like Slow data collection, Less accuracy compared to noncontact type scanner. This paper presents the methodology to predict the error under various scanning conditions of contact type scanner. MDX-20 contact type scanner which is a low cost and low accuracy scanner has been used for experimentation and error compensation relationship is developed in-terms of scanning parameters of pitch on x-axis, & pitch on y-axis import software's. In this paper the reference object with features like (hole, fillet, chamfer, cylinder, square gauge, triangular pocket, square pocket) scanned at first with different parameter setting to identifies the error under each setting associates with selected modeling software's. Then a multi-regression model is formed for each feature to predict and compensate the error at CAD modeling stage. This will facilitates to use this low cost contact type scanner as high accurate scanner as compared to latest high cost scanner.

***IndexTerms*: Reverse Engineering, Scanning, Error compensation, Features**

I.INTRODUCTION

Reverse engineering process involves four stages viz. scanning, point processing, CAD model development, and CNC machine. In which scanning is one of the important and first stages in reverse engineering process to develop the part accurately. There are two types of scanning process available in reverse engineering: one is contact type and another is non-contact type. Roland MDX-20 scanner is a contact type scanner with lower accuracy and this will results in low accurate part production. The error during scanning stage is more compared to the other stages, due to scanning speed, complexity in object shape etc,. The elimination or minimization of error during scanning stage would lead to more accurate final part. On this consideration this thesis focuses on multiple regression based methodology to predict the error in terms of influencing scanning parameters. From this methodology error in the scanned model is minimized by error compensation.

Reverse Engineering is the duplication of existing parts by capturing the components physical dimensions, features and material properties. It is a process of obtaining a geometric CAD model from scanning the existing products. CAD is a design of ideas through computer modelling and then fabricates those models into real world objects. CARE flows in the reverse direction. CARE creates a CAD model of an object from a real world object. We illustrate the difference of CAD & CARE in Figure 1. In CAD, the computer 3D model of disc brake used to produce the real world object (disc brake). In CARE, the 3D model of disc brake generated from existing real world object through scanner.

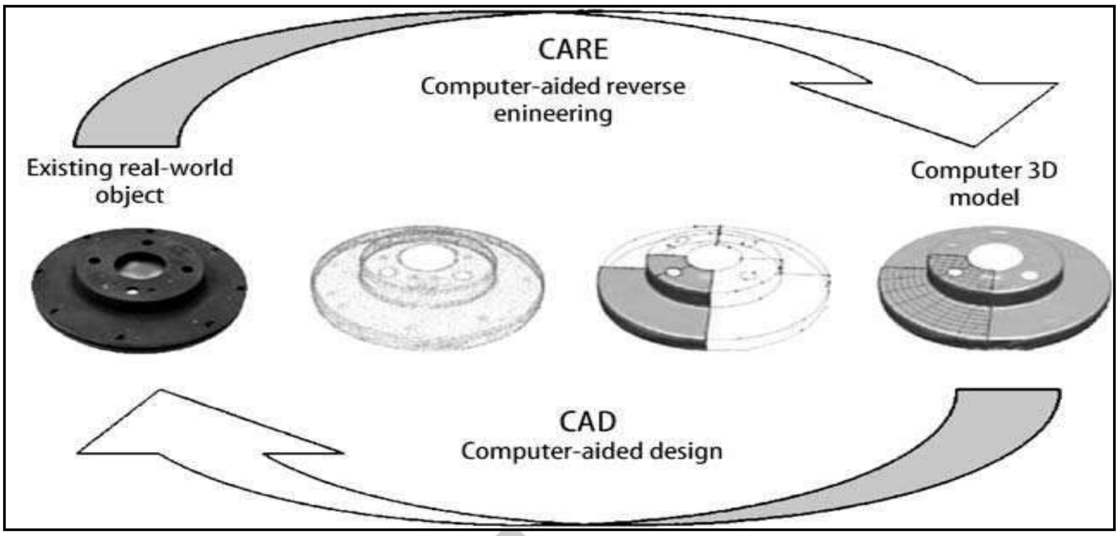


Figure 1.1. The difference between CAD & CARE

Computer Aided Reverse Engineering has the following processes:

1. Scanning:

To capture the information that describes all geometric features of a part such as steps, slots, pockets and holes. 3d laser scanner to scan the part geometry, producing clouds of points which define the surface geometry. The output of scanning process is point cloud data sets in the most convenient format.

2.Point processing:

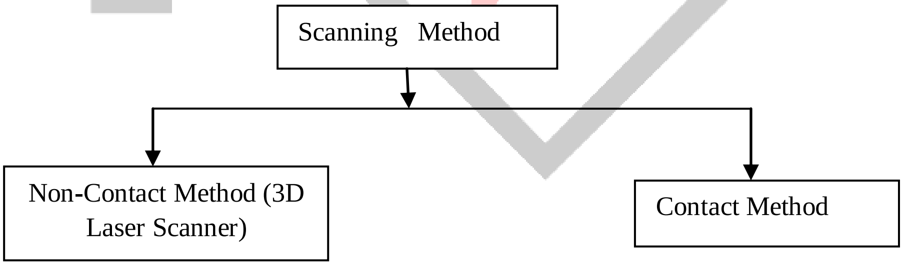
It involves importing the point cloud data, reducing the noise in data collected, and reducing the number of points. It also allows us to merge multiple scan data sets. The output of the point processing is a clean and merged point cloud data set in the most convenient format.

3.Geometric modeling:

It generate the surface data from point cloud data set. It produces the complete solid model for scanned object. The output of this process is geometric model in one of the standard file formats such as IGES, STL, DXF, etc.,

4.Manufacturing:

In this process, the ISO G code generated from the geometric model for producing the product in shortest time using CNC machines.



There are two scanning methods available in reverse engineering, contact and non-contact scanning. In non-contact scanning method, the cross sectional images & point clouds that represent the geometry of an object are captured by projecting energy sources (light, sound or magnetic fields) on the object. Then, the geometric data for an object are calculated by using triangulation, time of flight, wave interference information and image processing algorithms. Finally, the CAD model is generated from the available data. The object is produced by using CNC machine.

Contact 3D scanners explore (probe) physical objects while in contact with, or holding on to, a precision plane surface, ground and polished to a specific maximum of surface roughness. When the object to be scanned is not flat or cannot be stabilized on a plane surface, it has to be supported and held in place using a fixture. The scanner mechanism may either be a carriage system with fixed arms tightly clasped in perpendicular with each axis sliding along a track, or an articulated rigid arm provided with high precision angular sensors.

II. LITERATURE REVIEW

2.1.1 Summary of literature based on scanning accuracy

So the list of parameters influenced in scanning accuracy stated in literatures for various scanning machines are, Probe diameter, Pitch of scan, Probe orientation, Area to be scan, Z-plane setting, Speed, Zero pre-setting, Proper installation of probe, Set reference point, Modeling software selection, The parameters influences on scanning are vary from scanner to scanner. But the parameters that control this Roland MDX-20 scanner are X-scan pitch, Y-scan pitch and the modeling software selection.

2.1.2 Summary of literature based on multiple regression analysis

The multiple regression analysis is used to find the surface topology on the accuracy of laser triangulation scanning,regression analysis are employed to analyze the effect of drilling parameters on the quality of drilled holes, Variation of the MRR wire cut EDM with machining parameters was mathematically modeled by using the regression analysis method,estimation of minimum cylindricity error values in CNC turning operation, Multiple regression analysis had been applied to develop a mathematical model for surface roughness prediction method in CNC end milling. So in this thesis the multiple regression analysis is used to predict the error in-terms of scanning parameters,

[1]**Reverse Engineering In Product Manufacturing An Overview, Kumar A.; Jain, P. K. &Pathak, P. M.** Reverse engineering plays vital role in the branch of the mechanical design and manufacturing based industry. This technique has been widely recognized as an important technique in the product design cycle. In regular computerized manufacturing environment, the operation order usually starts from the product design and ends with machine operation to convert raw material into final product. It is often essential to reproduce a CAD model of existing part using any digitization techniques, when original drawings or documentation are not available and used for analysis and modifications are required to construct a improved product design. In reverse engineering approach the important steps involved, are characterizations of geometric models and related surface representations, segmentation and surface fitting of simple and free-form shapes, and creating accurate CAD models. The chapter presents review on reverse engineering methodology and its application areas related to product design development. The product re-design and research with reverse engineering will largely reduce the production period and costs in product manufacturing industries.

[2]**Comparison of Data Capturing Techniques and Analysis of Part Model in Reverse Engineering, Mr. S.P. SathyaPrasanthDr.V.Dhanalakshmi**, Abstract —Reverse engineering enables the duplication of an existing part by capturing the component's physical dimensions, features, and material properties. Reverse engineering has four stages namely digitization, processing of the captured data, surface creation and Numerical Controlled codes generation and machining. Digitization or data capturing is the first step in reverse engineering. The two major types of data capturing techniques are contact and non-contact method. The time taken to recover surface details by the contact type method limits their application in some areas. To overcome this difficulty a simple method is used to capture the surface details of the part. In this work, the part model's image is captured using digital camera and is further processed using image processing to obtain the part model and the other reverse engineering stages is proceeded. In this work, a connecting rod used in 2wheeler is selected as the part model. To compare the machined part model, a contact type technique using Roland Mdx-15 Scanning and Milling Machine is used to capture the surface of the model. This surface data is further preceded and machined for comparison. The dimensions of the part model captured by the 3D contact method and 2D digital camera image processing method are inspected using co-ordinate measuring machine.

[3]**Machine Element Reconstruction Using Integrated Reverse Engineering And Rapid Prototyping Approach,Atul Kumar, P.K. Jain , P. M. Pathak,** The modern manufacturing industries are characterized by a wide spread use of remanufactured products. Thus there is a need of hour to fabricate an object by integrating the reverse engineering and rapid prototyping approach to facilitate the re-manufacturing process. This integrated approach might be reducing considerable product makeup time. Existing all integrated reverse engineering and rapid prototyping methodology are begin with the digitizing of an entire object surfaces. Reverse engineering technology enables to create CAD models of existing objects by capturing their surface data and rapid prototyping is another emerging technology that allows to promptly fabricating the physical prototype of a product using an adaptive manufacturing technique. In this research, a method that creates a direct link between reverse engineering and rapid prototype technologies to fabricate the physical model of scanned object has been proposed. Spur gear has been selected for the present work because of owing to its complex geometry and it is considered to be an imperative element in mechanical industries to transmit power between two parallel shafts. In the present work a spur gear is scanned to re-generate its CAD model. The scanned recreated model in STL format is fabricated by rapid prototyping approach using Object30-Pro machine. Finally, the original and fabricated models are use to compared for its critical geometrical dimensions and tolerances. The spur gear example gives an insight of how integrated approach can cater the requirements of industries especially the automotive sector.

[4]**Reverse Engineering of Parts with Optical Scanning and Additive Manufacturing,TomazIrgolic,JozeBalic**,This paper presents reverse engineering of car volume button. The purpose of article is to introduce reverse engineering procedure, what we need to do this kind of procedure and how we can remanufacture car's volume button. The purpose of reverse engineering is to manufacture another object based on a physic and existing object for which 3D CAD is not available. The first we need digital version of object. Because our car's volume button has free formed surfaces we decided to use 3D scanning technology to obtain the point cloud of existing object. With the help of point cloud we can developed 3D CAD model which will be used for manufacturing of button pair. We used for manufacturing of pair of buttons machine for selective laser sintering Formiga P 100. In the paper are also described costs of making of one pair of buttons and whole workspace.

[5]**Application of Reverse Engineering Techniques in Mechanics System Services,MichalDúbravčík. ŠtefanKender,**In today's industry and production systems it's important to do mechanics or measurements systems services regularly. In case of damages it is required to eliminate these in shortest time period, to avoid time losses and obviously also financial losses. In case of

destructive failure of devices, or their parts it is required to change them for new one. However, nowadays we know various types of techniques which are available for substitution of damaged parts in very short time period. One section of these techniques is reverse engineering. Especially techniques like 3D scanning and rapid prototyping. Submitted article analyse reverse engineering techniques utilizable for mechanics or measurements system services.

[6]**Method for Automated Structuring of Product Data and its Applications, SebastianAdolphy.Hendrik Grosser.** Product structures represent the data backbone for through-life management of complex systems. Product Lifecycle Management (PLM) Systems are used to maintain product structures and track product changes. However, in maintenance, repair and overhaul (MRO) product composition often is unknown when MRO service providers are not the original manufacturers. Thus, MRO processes start with an exhaustive product diagnosis to identify elements to be maintained or replaced. Existing 3D scanning and data post processing methods have to be improved to acquire structured product data. This paper presents a method for automated derivation of product structures from 3D assembly models.

III.PROBLEM DESCRIPTION

The main aim of this thesis is to enhance capability of Roland MDX-20 scanner by improving its accuracy. This accuracy mainly depends on scanning parameters pitch on x-axis, pitch on y-axis, features and also the modeling software. If the relationship between scanning errors and various parameter setting could be established, then the error are estimated and compensated during CAD model building process.

This will reduce scanning error and hence improved product accuracy. On the above considerations the problem is coined as development of future based multiple regression model to predict error, which is defined as difference between reference model dimension (a_r), and mean of CAD model dimension after scanning (a_s) and thereby compensating it in CAD model obtained from scanning to get more accurate model.

$$\text{Error} = [a_r - a_s] = \mathbf{fn}\,(P_x, P_y, S) = \beta_0 + \beta_1 (P_x) + \beta_2 (P_y)$$

Where, P_x = Pitch on X-axis
P_y = Pitch on Y-axis
S = Selection of modeling software
β_0 = regression constant
β_1, β_2 = regression coefficient

IV. PROPOSED METHODOLOGY

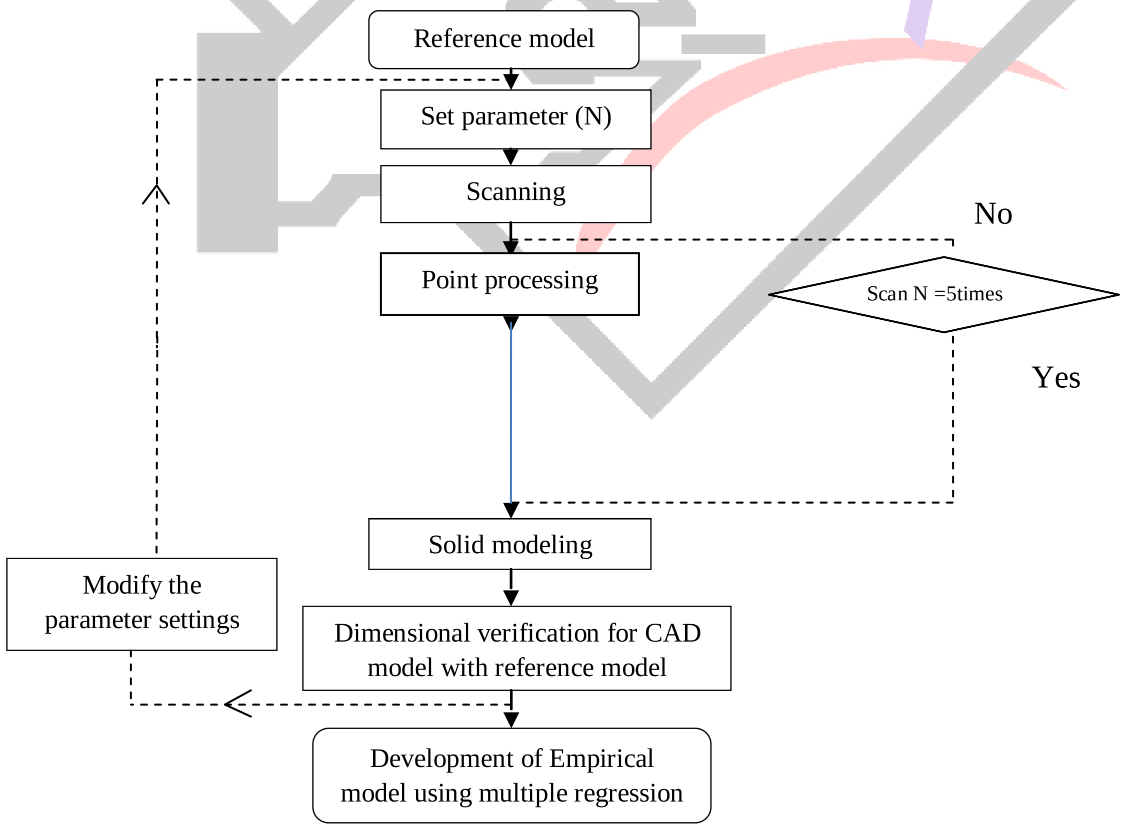


Figure 4.1 Proposed Methodology

4.1.1 Scanning

The first step is to scan the reference model (shown in fig 4.2) with various features. The reference object is scanned for eight different parameter settings (shown in table 4.1). Each feature in the object is scanned 5 times to maintain the consistency in outcome, which described by standard deviation .

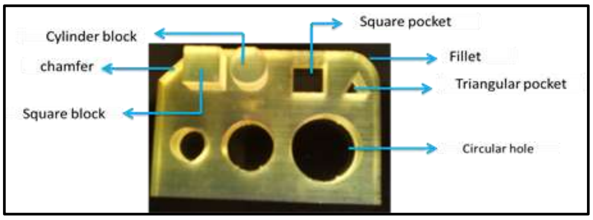


Figure 4.2 Reference model

Table 4.1 Different parameter setting

Parameter setting	**X-scan pitch**	**0.5**	**1.0**	**0.5**	**1.0**	**1.0**	**1.5**	**1.5**	**2.0**
	Y-scan pitch	0.5	0.5	1.0	1.0	1.5	1.0	1.5	2.0

4.1.2 CAD model

After point processing, IGES file format is imported into respective CAD software CATIA and GEOMAGIC. Then solid model is created from the point cloud obtained from scanning process by fitting the suitable curve (shown in figure 4.3).

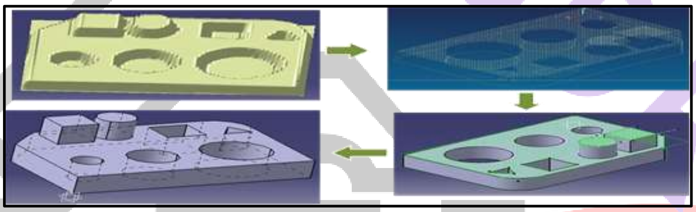


Figure 4.3 Conversion scanned object to CAD model

4.1.3 Dimensional verification

The dimensions are extracted from the CAD model created using CATIA and GEOMAGIC software. These dimensions are compared with reference model to find the dimensional deviation. Dimensional error are listed in the table (4.1)

4.1.4 Development of Multiple Regression

Finally an empirical relationship is established using the multiple regression equation for each feature with associated modeling software.

V. EXPERMENTATION

Some sample experimental results are compared with original dimension for error analysis in two different modeling software platforms (shown in table 5. 1)

Table 5.1 Experimental result

Chamfer angle 45 degree								
X-pitch in mm	Y-pitch in mm	CATIA dimension degree	GEOMA-GIC dimension in degree	CATIA Error in degree	GEOMA-GIC Error In degree	Scan time in sec	CATIA dimension SD	GEOMA-GIC dimension SD
0.5	0.5	45	44.997	0	0.003	300	0	0.0031
1	1	44.948	44.943	0.052	0.057	179	0.0025	0.0033
1.5	1.5	44.868	44.86	0.132	0.140	138	0.0067	0.0047
2	2	44.765	44.755	0.235	0.245	125	0.0067	0.0089
Cylinder dia 10mm								
0.5	0.5	9.961	9.957	0.039	0.043	540	0.0019	0.0026

1	1	9.895	9.89	0.105	0.11	273	0.0027	0.004
1.5	1.5	9.812	9.807	0.188	0.193	194	0.0043	0.0068
2	2	9.738	9.735	0.262	0.265	165	0.0053	0.0086

Square block side 10mm								
0.5	0.5	9.967	9.963	0.033	0.037	420	0.0015	0.0031
1.5	1	9.897	9.893	0.103	0.107	190	0.0037	0.0043
1.5	1.5	9.846	9.838	0.154	0.162	180	0.0043	0.0055
2	2	9.766	9.75	0.234	0.25	130	0.0048	0.0082
Triangle height 7mm								
0.5	0.5	6.898	6.891	0.102	0.109	243	0.0018	0.0036
1	1	6.785	6.772	0.215	0.228	137	0.0025	0.0049
1.5	1.5	6.593	6.579	0.407	0.421	99	0.0040	0.0063
2	2	6.477	6.405	0.523	0.595	93	0.0054	0.0079

Triangle base 7mm								
0.5	0.5	6.946	6.942	0.054	0.058	243	0.0019	0.0031
1	1	6.873	6.869	0.127	0.131	137	0.0027	0.0045
1.5	1.5	6.787	6.763	0.213	0.237	99	0.0047	0.0073
2	2	6.69	6.665	0.31	0.335	93	0.0051	0.0082
Fillet radius 8mm								
0.5	0.5	7.905	7.899	0.095	0.101	622	0.0018	0.0029
1	1	7.754	7.747	0.246	0.253	312	0.0042	0.0037
1.5	1.5	7.537	7.528	0.463	0.472	228	0.0058	0.0044
2	2	7.363	7.335	0.637	0.665	190	0.0067	0.007
Square pocket side 10mm								
0.5	0.5	9.95	9.948	0.05	0.052	354	0.0017	0.0031
1	1	9.86	9.857	0.14	0.143	200	0.0028	0.0045
1.5	1.5	9.815	9.812	0.185	0.188	142	0.0044	0.0069
2	2	9.717	9.713	0.283	0.287	124	0.0065	0.0093
Circular hole dia 20mm								
0.5	0.5	19.938	19.933	0.062	0.067	397	0.0018	0.0033
1	1	19.825	19.798	0.175	0.202	209	0.003	0.0043
1.5	1.5	19.613	19.606	0.387	0.394	152	0.0036	0.0065
2	2	19.487	19.448	0.513	0.552	132	0.0052	0.0072

5.1.1 Empirical model

The empirical model is developed using the multiple regression with help of Minitab statistical software. This empirical model is used to predict the error, which will be compensated at CAD modeling stage. The multiple regression equation is developed individually for each feature with respect to modeling software. The multiple regression for each features developed under two different modeling software are shown table 1.3.

Table 5.2 Multiple regression equation

FEATURE	Multiple regression equation for features developed by modeling software With input pox-pitch on x-axis; poy-pitch on y-axis and output in form of error	
	CATIA	GEOMAGIC
Chamfer	Error = - 0.106 + 0.066 p.o.x+ 0.094 p.o.y	Error = - 0.106 + 0.068 p.o.x+ 0.097 p.o.y
Cylinder	Error = - 0.053 + 0.065 p.o.x+ 0.089 p.o.y	Error = - 0.0485 + 0.064 p.o.x+ 0.089 p.o.y
Fillet	Error = - 0.114 + 0.136 p.o.x+ 0.235 p.o.y	Error = - 0.110 + 0.130 p.o.x+ 0.250 p.o.y
Square block	Error = - 0.0448 + 0.051 p.o.x + 0.083 p.o.y	Error = - 0.0470 + 0.054 p.o.x+ 0.087 p.o.y
Square pocket	Error = - 0.0010 + 0.051 p.o.x+ 0.085 p.o.y	Error = 0.0021 + 0.049 p.o.x+ 0.0866 p.o.y
Circular hole	Error = - 0.113 + 0.0893 p.o.x + 0.226 p.o.y	error = - 0.118 + 0.0979 p.o.x+ 0.235 p.o.y
Triangle base	Error = - 0.036 + 0.0661 p.o.x+ 0.101 p.o.y	error = - 0.045 + 0.0726 p.o.x + 0.111 p.o.y
Triangle height	Error = - 0.079 + 0.0990 p.o.x + 0.231 p.o.y	Error = - 0.0793 + 0.0990 p.o.x + 0.231 p.o.y

VI. CONCLUSION

The main purpose of this thesis is to provide an effective and accurate way to predict error produced during scanning process associated with influencing parameter. Feature based multiple regression models has developed to predict scanning error at various parameter setting. The Average, mean absolute percentage deviation is calculated considering all feature is 0.345%, shows that average prediction accuracy of feature based multiple regression model is 93.225%. That means the model developed is reliable to predict scanning error with accepting accuracy range. Thereby predicted errors are compensated during CAD model building process. This will facilitates to use this low cost contact type scanner as high accurate scanner as compared to latest high cost scanner.

REFERENCE

[1].Florin Popister, Daniela Popescu, Dan Hurgoiu, RaduRacasan, Applying Reverse Engineering to Manufacture the Molds for the Interior Decorations Industry Journal of Automation, Mobile Robotics & Intelligent Systems VOLUME 6 (2011), pp.61-64.
[2].ManzoorHussain M., SambasivaRao CH.and Prasad K. E., Reverse Engineering: Point cloud generation with CMM for part modeling and error analysis ARPN Journal of Engineering and Applied Sciences VOL. 3, NO. 4, (2008), pp. 37-40.
[3].Martı´nez.S , E.Cuesta , J.Barreiro , B.A´ lvarez , Methodology for comparison of laser digitizing versus contact systems in dimensional control Elsevier Ltd (2010), pp1238–1246.
[4].Sokovic M, Cedilnik M, Kopac J Use of 3D-scanning and reverse engineering by manufacturing of complex shapes 13th international scientific conference on AMME May 2005 pp.601-604.
[5].Suresh babu .T, Romy.D.Thumbanga Reverse Engineering, CAD\CAM & pattern less process applications in casting International journal of mechanics Issue 1, Volume 5, (2011), pp.40-47.
[6].Vishal Parashar, A.RehmanA, J.L.BhagoriaJ L, Y.M.PuriY M, Statistical and regression analysis of Material Removal Rate for wire cut Electro Discharge Machining of SS 304L using design of experiments, IJES Vol. 2(5), 2010, pp 1021-1028.
[7].Pal D.K., Ravi B., Bhargava L.S., “Computer-Aided Reverse Engineering for Rapid Replacement Parts: A Case Study Defence Science Journal”, Dessidoc, DRDO, New Delhi, in print. (2005).
[8].Gudimetal P and Gopinath C.V., “Finite Element Analysis of Reverse Engineered Internal Combustion Engine Piston”, AIJSTPME vol 2(4): pp 85-92. (2009).
[9] Gregory Lecrivain, Ian Kennedy and ArezkiSlaouti., “Evaluation and Optimization of Errors in the Reverse Engineering Process”, International Conference on Agile Manufacturing, Durham (UK). (2007).
[10] IoannisFudos., “CAD/CAM Methods for Reverse Engineering: A Case Study of Re-engineering Jewellery”, University of Ioannina, fudos@cs.uoi.gr. Computer-Aided Design & Applications, vol. 3, No. 6, pp 683-700. (2006).
[11] ManzoorHussain M., SambasivaRao CH. and Prasad K. E., “Reverse Engineering: Point Cloud Generation with CMM for Part Modelling and Error Analysis”, vol. 3, no. 4, August 2008 ISSN 1819-6608 Asian Research Publishing Network (ARPN)(2008).
[12] Qingjinpeng, Martin loftus., “Using image processing based on neural networks in Reverse engineering”, International Journal Of Machine Tools & Manufacture vol 41 625-640.(2001).
[13] You-Min Huanga and Hsiang-Yao Lamb., “Dynamic reverse compensation to increase the accuracy of the rapid prototyping system”., Journal of Materials Processing Technology vol 167–176. (2005).
[14] Yuzhu Lu, Shana Smith., “A Comprehensive Tool for Recovering 3D Models From 2D Photos with Wide Baselines”, International Conference Human Computer Interaction.(2005).
[15] Ted Shultz and Luis A. Rodriguez., “3D Reconstruction from Two 2D Images”, ECE 533 fall (2003).