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A Comparison Study of 3D Scanners for Diagnosing Deviations in Their Outputs Using Reverse Engineering Technique

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Abstract:*These days in the field of engineering several types of 3-D scanners such as laser or optical 3D scanners are used for object digitalization .In this work comparing two types of 3-D non- contact type scanners that is* ***V5 perceptron 3D laser scanner*** *and* ***3D SYSTEMS CAPTURE SCANNER(****fast blue light 3D scanning technology****).****The physical object is scanned individually for obtaining point cloud data of a existing freeform surface through these two scanners .The obtained data through scanning is then generated into ASCII(.asc file)file format type.So eventually both scanned files are evaluated through concerned reverse engineering software with necessary modules.In this standard deviation, Deviation status and deviation distribution are evaluated by comparing the reverse engineering model with the original CAD model over the free form surface.*
Keywords: *3D scanners, point data, free form surface,non-contact scanners, scanning comparison*

I. Introduction

The device which converts 3 dimensional physical data into digital data is known as 3D scanners. During this scanning process these scanners collects the data or information of shape and dimension of physical object. So the points which are made up through scanning is called as point cloud data such that each individual scanned point has a particular position in the 3 dimensional space in the coordinate system.

In similar way reverse engineering can be stated as duplication of already existing part by collecting the data or information such as shape and dimension of the object. This process is generally referred as reverse process to the conventional engineering process

There will be a certain sequence followed in the process of reverse engineering such as[9]

DATA CAPTURE → PRE PROCESSING → SEGMENTATION & SURFACE FITTING → CAD MODELCREATION

These 3D scanners can be divided into two types based on their physical parameter they are:[3]

I. Contact type: In this scanner should be in physical contact with the object.
II. Non –contact type: In this there is no physical contact between the scanners and object .they can scan the data without any mechanical contact with the object[1]

Based on scanning acquisition 3D scanners can be further divided into[3]

- Optical scanning method: In this object is scanned through several angles based on photographic principle and all the scans are subsequently accumulated to form a single digitized 3D image
- Laser scanning method: This works on the principle of laser triangulation.in this data is obtained to light reflection method based on its time period[1]
- Ultrasonic scanning method: In this method ultrasonic waves are subjected to the object through certain angles
- Mechanical type: This can be done through measuring arms and CMM machines in this entire information of the surface is not obtained but through selection of points locality of points can be obtained
- Destructive type: In this scanner breaks the object in order to get the interior and exterior data of the object.

Based on their varied ranges scanners can be classified as:

- SHORT RANGE 3D SCANNER[8]:- Short Range 3D scanners generally utilize a Laser triangulation or Structured Light technology. In this they generally use white LED light or blue light phenomena during data acquisition. This type of short range 3D scanner has its own benefits such as
  - Less sensitive to changing light conditions and ambient light
  - Able to scan tough surfaces, such as dark and shiny surface finishes
  - This are very much portable
  - It is available at low cost
  - Eye safe for 3D scanning of humans and animals

- MEDIUM AND LONG RANGE SCANNER[8]:- Long range 3D scanners come in two major formats - Pulse based and phase shift – both of which are well suited for large objects such as buildings, structures, aircraft, and military vehicles. Phase shift 3D scanners also work well for medium range scan needs such as automobiles, large pumps and industrial equipment. These scanners capture millions of points by rotating 360 degrees while spinning a mirror the redirects the laser outward towards the object or areas to be 3D scanned. Some of its benefits are
  - 3D scan million of data points in a single scan
  - It can scan upto area 1000 meters
  - Good accuracy and resolution based on object size
  - Non- contact type and keeps the object safe

II. Scanners

2.1 V5 PERCEPTRON 3D LASER SCANNER:

This scanner uses twin camera technology such that we can see two sides of an object at one instance this scanner produces high quality data acquisition and high dynamic range for scanning with high resolution of points along the laser line over the object.[5]

This V5 sensor has the ability to scan data on dark and reflective surfaces and projects an accurate trapezoidal representation of the field, this enables the user to become familiar with good scanning practices and minimizing overlapping data. This is suitable for various industries and applications, from the factorfloor to inspection rooms and laboratories.

Specifications of v5 perceptron 3D laser scanner

Scan Rate	458,000 points/second
Point to point Distance	12 microns
Laser Bandwidth	140mm
Accuracy	24 microns 2 sigma

Figure 1:v5 perceptron 3D laser scanner

2.2 .3D SYSTEMS CAPTURE SCANNER:

The 3D system capture scanners provide accurate and fast blue light 3d scanning technology. These scanners are generally portable and can be handled easily. The main advantage of this scanner is it is easy to access multiple scanner configuration .lost data of 3D CAD model for highly complex and broken parts of the model can be easily recreated[6] .

Specifications of 3D systems capture scanner:

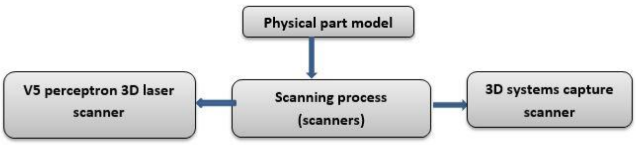
Data capture rate	985,000 points/scan(0.3 sec per scan)
Accuracy	0.060mm
Depth of field	180mm
Resolution	0.110mm at 300mm 0.130mm at 480mm

Figure 2:3D systems capture 3D scanner

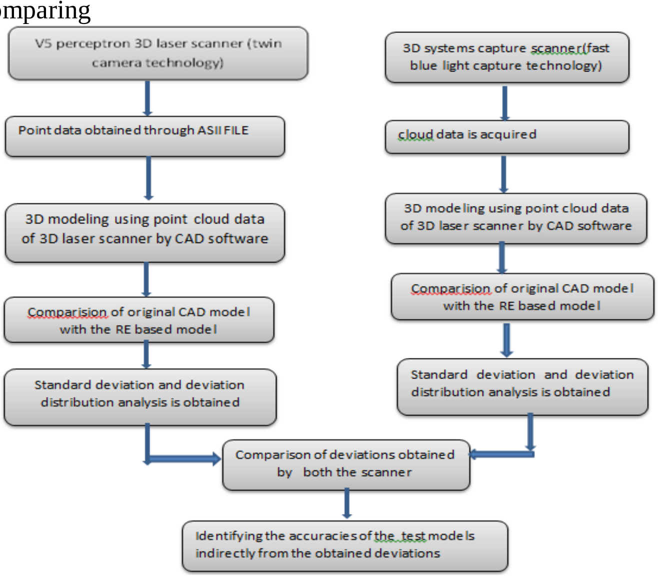
III. Methodology:

The steps involved in the data acquiring and comparing of efficiency of scanner based on their deviations with reference to the original CAD model to RE model are as follows:

Figure 3:physical free form surface model



3.1 Data acquiring and comparing



IV. Experimental Work

In this article of reverse engineering the point data of physical freeform surface is acquired by using two non-contact type scanner which is V5 perceptron 3D laser scan based on twin camera technology and the other scanner is 3D systems capture scanner based on capture technology trough different angles with fast blue light falls on the freeform surface of physical model.

A component is selected for the testing in such a way that it satisfies scanning criteria which has a complex freeform shape for scanning in order to know accuracy. Number of data points varies with each and every individual scanners in this case V5 laser perceptron 3D scanner has obtained 134653 data points, whereas for 3D systems capture 3D scanner has 199840 data point for the free form surface of the physical object. After certain multiple scans w.r.t angles the obtained data points are converted into ASII (.asc) file format based on the convenience required for CAD software package .this all collective data's of point cloud are imported into GEOMAGIC software . In this software we reconstruct the 3D free form surface this eventually gives us the RE based model[4] . then this RE based model and original CAD model is compared to obtain deviation .before the final deviations are obtained certain process should be followed in comparison of CAD model and RE model such as noise reduction, sampling ,meshwrapping defect, surface smoothing, model simplification, holes filling on model Then next step in the process will be locating the model in the co-ordinate system with reference to the x, y, z plane. This can be done by both the test and reference object such that test object should be reoriented in such a way that three planes should match the reference objects.

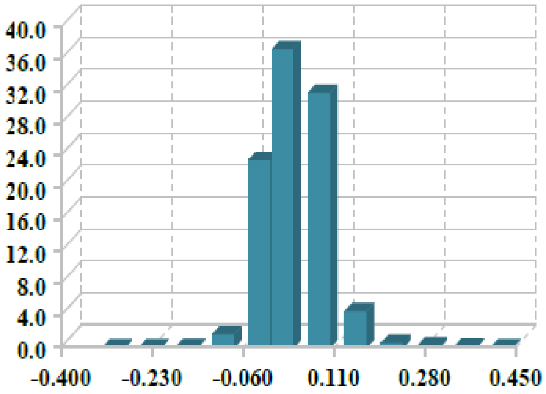
For final deviations of the models can be understand through the color coded mapping of difference between the selected objects. from this we get both the standard deviations and average deviations values through reference points .At last the outputs/deviations are compared between the both v5 perceptron and capture scanner and we conclude the better scanning performance.

V. Results AND DISCUSSION:

We need to consider the deviations in the shape, dimensions and orientation deviations as evaluating characteristics .By keeping tolerance as 0.5mm we should compare the RE model with CAD model for individual scanners

Comparison of deviation distribution

V5 PERCEPTRON 3D SCANNER				3D SYSTEMS CAPTURE 3D SCANNER			
>=Min	<Max	# Points	%	>=Min	<Max	# Points	%
-0.4313	-0.3630	0	0.0000	-0.500	-0.4282	303	0.1516
-0.3630	-0.2947	22	0.0163	-0.4282	-0.3496	956	0.4784
-0.2947	-0.2264	18	0.0134	-0.3496	-0.2744	2444	1.2230
-0.2264	-0.1581	86	0.0639	-0.2744	-0.1993	5440	2.7222
-0.1581	-0.0899	2234	1.6591	-0.1993	-0.1241	10072	5.0400
-0.0899	-0.0216	31580	23.4529	-0.1241	-0.0489	17202	8.6079
-0.0216	0.0216	50200	37.2810	-0.0489	0.0489	54347	27.1953
0.0216	0.0899	42896	31.8567	0.0489	0.1241	52400	26.2210
0.0899	0.1581	6149	4.5666	0.1241	0.1993	38956	19.4963
0.1581	0.2264	825	0.6127	0.1993	0.2744	13834	6.9225
0.2264	0.2947	415	0.3082	0.2744	0.3496	2168	1.084
0.2947	0.3630	187	0.1389	0.3496	0.4284	1039	0.5199
0.3630	0.4313	40	0.0297	0.4284	0.500	679	0.3398
Out of Upper Critical			1	Out of upper critical		0	
Out of Lower Critical			0	Out of lower critcal		0	



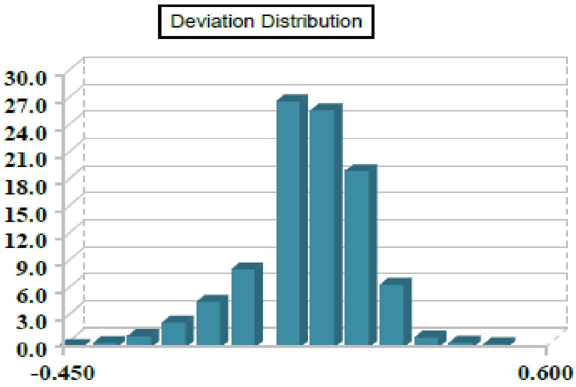


Figure 4: v5 perceptron deviation distribution**Figure 5:** capture scanner deviation distribution

Comparison of standard deviation

V5 PERCEPTRON 3D LASER SCANNER			3D SYSTEMS CAPTURE 3D SCANNER		
Distribution(+/-)	Points	Percentage%	Distribution(+/-)	Points	Percentage%
-6*std. Dev.	34	0.0253	-6*std. Dev.	0	0
-5*std. Dev.	14	0.0104	-5*std. Dev.	111	0.05
-4* std. Dev.	121	0.0899	-4*std. Dev.	1473	0.7
-3* std. Dev.	1630	1.2105	-3*std. Dev.	6719	3.36
-2* std. Dev.	14239	10.5746	-2*std. Dev.	19009	**9.5121**
-1* std. Dev.	58378	43.3544	-1*std. Dev.	63452	31.7514
1* std. Dev.	39310	29.1936	1*std. Dev.	80992	40.5284
2* std. Dev.	17771	13.1950	2*std. Dev.	25460	12.7402
3* std. Dev.	2013	1.4950	3*std. Dev.	2068	1.0348
4* std. Dev.	500	0.3713	4*std. Dev.	556	0.2782
5* std. Dev.	350	0.2599	5*std. Dev.	0	0
6* std. Dev.	293	0.2176	6*std. Dev.	0	0

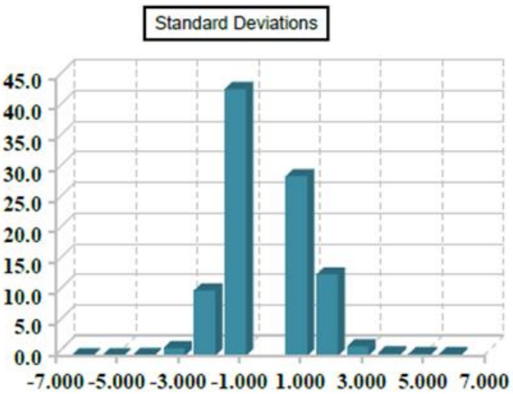


Fig 6: v5 perceptron std* dev

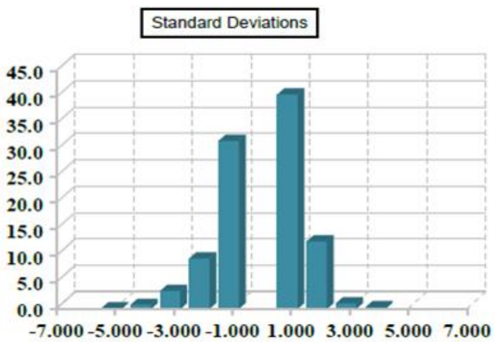


Fig 7: capture 3D scanner std* dev

LOCATION SET:

						PERCEPTRON		CAPTURE 3D	
Name	**Upper Tol**	**Lower Tol**	**Ref. X**	**Ref. Y**	**Ref. Z**	**Dev.**	**Status**	**Dev.**	**Status**
L1	0.1372	-0.1372	-137.18	11.9480	109.7459	-0.0676	PASS	-0.0674	PASS
L2	0.1372	-0.1372	-109.74	16.8592	137.1823	0.0142	PASS	0.0242	PASS
L3	0.1372	-0.1372	-109.74	19.6887	82.3094	0.0234	PASS	0.0843	PASS
L4	0.1372	-0.1372	-109.74	19.5591	27.4365	-0.0428	PASS	0.0111	PASS
L5	0.1372	-0.1372	-109.74	23.9935	54.8729	-0.0130	PASS	-0.0137	PASS
L6	0.1372	-0.1372	-109.74	21.3370	109.7459	-0.0004	PASS	0.1500	FAIL
L7	0.1372	-0.1372	-82.30	12.8355	54.8729	0.0593	PASS	0.1492	FAIL
L8	0.1372	-0.1372	-82.30	11.0261	82.3094	0.0580	PASS	0.1970	FAIL
L9	0.1372	-0.1372	-82.30	11.9429	27.4365	0.0810	PASS	0.1480	FAIL
L10	0.1372	-0.1372	-82.30	16.5788	109.7459	-0.0559	PASS	0.0321	PASS
L11	0.1372	-0.1372	-54.87	18.2871	27.4365	0.0559	PASS	0.0861	PASS
L12	0.1372	-0.1372	-54.87	12.5957	109.7459	0.0480	PASS	0.2018	FAIL
L13	0.1372	-0.1372	-54.87	21.6522	82.3094	-0.0105	PASS	0.0745	PASS
L14	0.1372	-0.1372	-54.87	15.8218	54.8729	0.0664	PASS	0.1756	FAIL

L15	0.1372	-0.1372	-27.43	24.4948	54.8729	0.0094	PASS	0.0957	PASS
L16	0.1372	-0.1372	-27.43	20.8606	82.3094	0.011	PASS	0.1444	FAIL
L17	0.1372	-0.1372	-27.43	24.6770	27.4365	-0.0085	PASS	0.0521	PASS
L18	0.1372	-0.1372	-27.43	21.2284	109.7459	-0.0272	PASS	0.0413	PASS

In this all the 18 predefined points are compared giving out the deviation status as PASS or FAIL points. This table shows that the perceptron 3D scanner resulted with all PASS points which resembles that it has very minute variation in their deviation individually. While the 3D systems capture 3D have some failure points at location set i.e, L6,L7,L8,L9,L12,L14,L16 . This states that capture have very large deviations in their freeform surface point data in the process of comparing RE model with the original CAD mode
Pictorial representation of deviations:

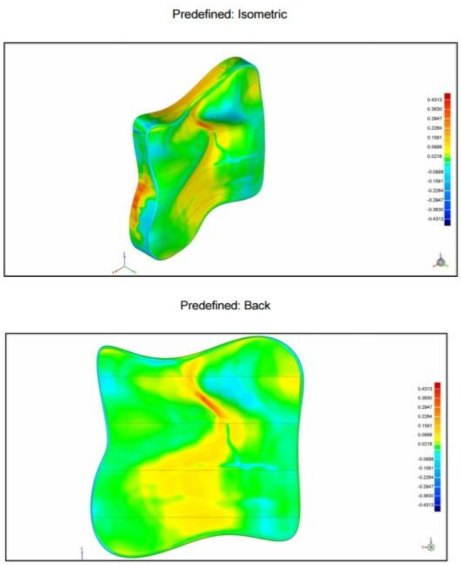


Figure 8:v5 perceptron

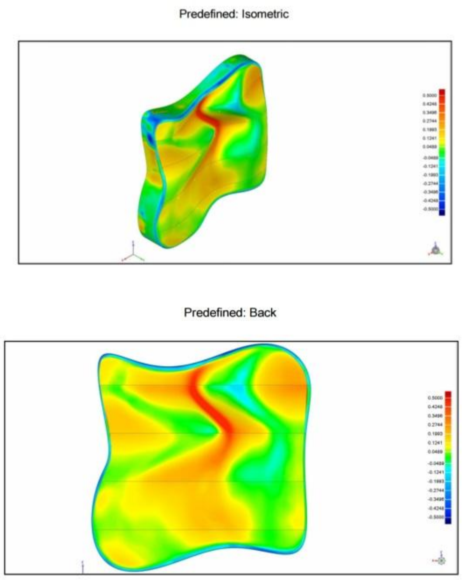


Figure 9:capture 3D scanner

VI. Conclusion

In this evaluation is done over the complex freeform surface with deep curved profiles are considered. The above comparative study of outputs illustrates that Laser scanner have great accuracy when compared to capture scanner i.e., V5 Perceptron (twin camera technology) scanner has better accuracies when compared with 3D systems capture 3Dscanner.

In this comparison V5 perceptron has very minimal variation, by having minimum percentage of points in the range of -0.060 to 0.110 in Deviation distribution ,58378 points in -1* standard dev. Distribution -39310 points in 1* standard. This values are far better when compared with the 3D system capture scannerwith the reference of all 18 location set (L1-L18). This concludes that V5 perceptron 3D scanner is fast and better at scanning the complex freeform surface than that of capture 3D scanner.All the deviation values are depicted in the table 1,2,3 shows the accuracies of both the scanner .which directly emphasizes that the value with lower deviation has high accuracies and better scanning performance. From the above experiment we can observe that v5 perceptron scanner better comparatively.

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