DEVELOPMENT OF 3D MODEL FROM 2D IMAGE BY POINT CLOUD METHOD

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Abstract— Reverse engineering faces challenges when it comes to data extraction using indirect contact method. There are 3D scanners capable of extracting data from distance more than a few meters away without contacting the objects but yet limited to same space range only. Although synchronizing the 3D scanners from another place can enable long distance data extraction, synchronizing devices over long distance can lead to other issues such as lagging. Moreover, the uses of 3D scanners usually involve quite long consumption time regardless of same space range or long distance range application. To overcome these issues, this study introduces a 3D surface reconstruction system by including a webcam imaging technique to produce a 3D point cloud, which is the same as that produced by a 3D scanner, and thus, eliminate the use of a 3D scanner. Through webcam imaging, image data can be transferred over the Internet and can be shared instantly even in different locations. Hence, webcam imaging is an alternative to using a 3D scanner. This system will continuously generate 3D free-form surfaces to resemble the surface profile of physical objects. Acquiring data until the surface fitting process will take less time compared with using a combination of 3D scanner and CAD software. In addition, results produced from the webcam imaging technique are compared with conventional results from a 3D scanner.

Index Terms—Webcam, RGB data, HSI data, Image processing, Gear, Designing, point cloud

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1 INTRODUCTION

This research mainly focuses on converting captured images into a 3D point cloud to eliminate the use of a3D scanner, followed by the process of generating 3D surfaces from the 3D point cloud. This study explains and illustrates the process of converting 2D digital images into a 3Dsurface to enable reverse engineering without a 3D scanner, and thus, reduce the time required if a 3D scanner is unavailable or in the process of delivering the object to a desired location. This webcam imaging technique is classified as anon-contact method because it only uses 2D data from the digital image as input, and then produces a 3D point cloud model, which is later generated into a 3D surface

When performing reverse engineering in engineering designs, designers frequently use an existing object to recreate a 3D model. The first step in reverse engineering is generally 3Ddigitization, which can be described as the process of obtaining design data from the surface of an object, and then processing the data into a point cloud model. Digitization can be achieved through various techniques, which can be grouped into two types i.e. non-contact and contact techniques. The most common non-contact technique for performing reverse engineering is via a 3D scanner; other methods include the coordinate measurement technique that uses touch probes .A 3D scanner has one significant advantage over a non contact method that it is better in capturing irregular surfaces details. This process can take few days when the object and the scanner are located in different continents.

In the modern world where telecommunication technologies have advanced considerably, image data can be transferred globally through the Internet. Images are now instantly transferable even between different continents. Transferable data, with the aid of computer programming, will make performing reverse engineering in different places possible without physical transportation. In addition, it will reduce the time required to conduct reverse engineering indifferent locations because physical travel will no longer be necessary. Moreover, transportation cost is eliminated. To further reduce data acquisition and setup time, using a USB webcam on a computer can make data instantly available in the memory of the computer, and then, data can be processed directly from the memory. Hence, data acquisition will require less than a second to capture an object into an image

2 Literature Survey

In reverse engineering studies, numerous attempts have been conducted on using various techniques to obtain 3D models [1] and the objectives in obtaining 3D models also vary significantly. The outputs, namely, 3D models, are used for design and redesign processes, as well as for studies in various fields. Designers perform reverse engineering for various reasons, one of which is to recreate similar parts. Paulic et al. [2] performed reverse engineering to manufacture an identical automobile button in mirrored orientation; a 3D scanner was used in this work to obtain a 3D point cloud from the physical object. Designers also perform reverse engineering because an exact part is necessary to replace a worn or broken part. Dúbravčík and Kender [3] demonstrated reverse engineering applications on a damaged gear as an example using a 3D scanner and 3D software. Bagci [4] conducted case studies on three different objects using a contact technique, namely, a coordinate measuring machine (CMM), as the digitization

method. Recently, Al-Ahmari and Aalam [5] also used the same contact method, which required the 3D object to be on the set and a CMM to enable the digitization.

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2.1 OBJECTIVES:

➢ To study the information found in 2D digital images and to develop an extraction method for obtaining useful information from 2D digital images for conversion process into 3D point clouds.

➢ To study the structure of the after refined point clouds and develop a simple surface fitting approach to create 3D CAD surfaces from the after refined point clouds.
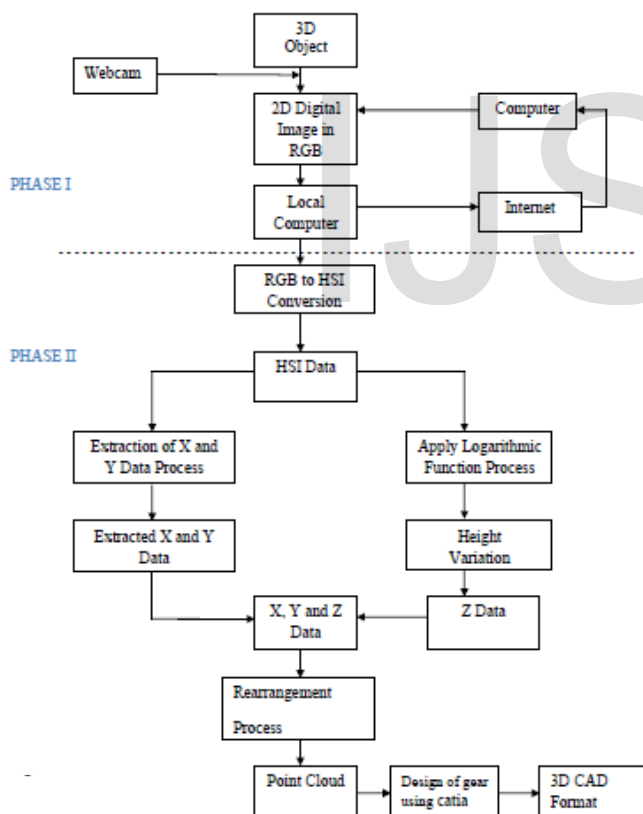
3   Methodology / System design

Fig.1 Experimental Setup

3.1 Experimental Setup:

The main equipment used in the setup of the proposed system is a webcam and a personal computer. Additional tools include wires, light source, webcam holder, and black background sheets.

3.2 Phases of work involved:

1. Digitalizing from the Surface of the Object

2. Converting a RGB Image into a HSI image

3. 2D Point Cloud from HSI data

4. 2D Point Cloud Digitization

3.3 Digitalizing from the surface of the object:

The intermediate output of is a 2D digital image, which can be processed into a point cloud either locally or remotely. The output of a 2D digital image has to be in RGB pixel form.2D transferable data via a webcam with a resolution of 640 × 480 pixels. The recommended maximum dimension of the physical object is 329mm addendum diameter and 271mm duodenum diameter because this setup is for single-surface detection. The webcam is positioned directly above the top view orientation of the object. To enable the system to run smoothly and produce a reliable result, the height between the camera and the furthest point of the object is fixed at 30 cm, and light from a source is shined in the same direction toward the object at the same distance as the webcam.

Fig.2 RGB image of Gear

The RGB image has data stored as integers from 0 to 255, which are transferable via a computer either through a local network or over the Internet. The "Red Green Blue" RGB refers to three hues of light that can be mixed to create different colors. Combining red, green, and blue light is the standard method of producing color images on screens, such as TVs, computer monitors, and smart phone screens.

CYAN
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The number of colors supported by RGB depends on how many possible values can be used for red, green, and blue. This is known as "color depth" and is measured in bits. The most common color depth is 24-bit color, also known as "true color." It supports eight bits for each of the three colors, or 24 bits total. This provides 28, or 256 possible values for red, green, and blue. 256 x 256 x 256 = 16,777,216 total possible colors in the "true color" palette.
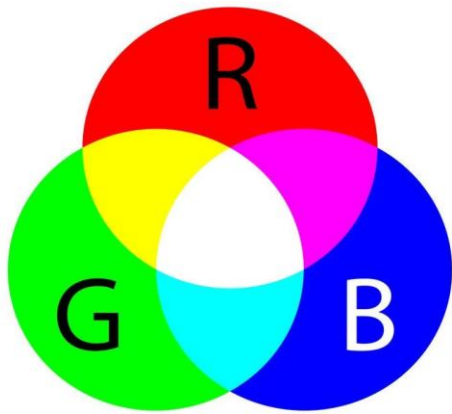

Fig.3 RGB color model

Highest number of 255 for the RED, GREEN, BLUE component of the RGB image which occurs in all white and the lowest number is 0, which occurs in all the black.

3.4 Converting a RGB image into HSI image:

The HSI model is described as a hexcone, with colors defined as angles in a 360° revolution. This revolution is an important factor for universal applications because of its characteristics. Any object with any colored surface, regardless of the type of color, will be detected and read as data double at a maximum value of 1, except for black, which has a value of 0. The graphical description of the RGB and HSI models is shown in Fig.4
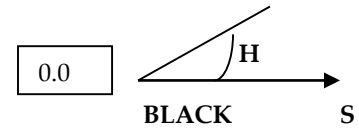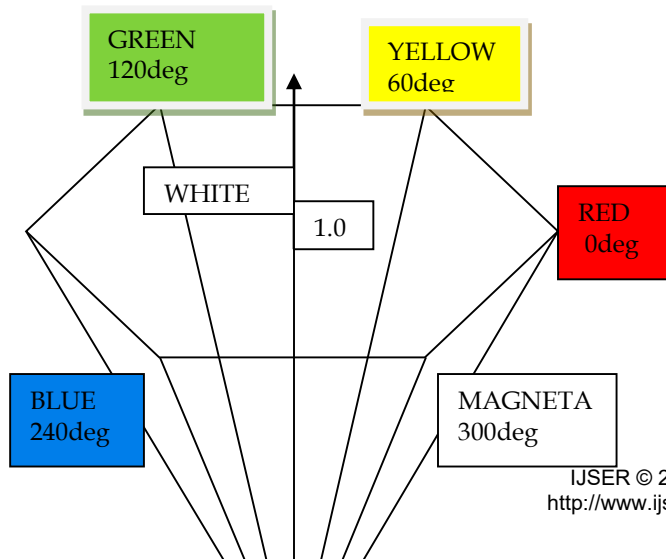

Fig.4 HSI color model

The conversion of RGB to HSI (Hue Saturation Intensity) is done through MATLAB software, after converting the image we get data's required to plot point cloud, the converted image from RGB to HSI is shown in Fig.5.

3.5 MATLAB codes to convert RGB image to HSI image:

```
A=imread('peppers.png');

figure,imshow(A);title('RGB Image');

I=double(A)/255;

R=I(:,:,1);

G=I(:,:,2);

B=I(:,:,3);

numi=1/2*((R-G)+(R-B));

denom=((R-G).^2+((R-B).*(G-B))).^0.5;

H=acosd(numi./(denom+0.000001));

H(B>G)=360-H(B>G);

H=H/360;

S=1- (3./(sum(I,3)+0.000001)).*min(I,[],3);

I=sum(I,3)./3;HSI=zeros(size(A));

HSI(:,:,1)=H;

HSI(:,:,2)=S;

HSI(:,:,3)=I;

figure,imshow(HSI);title('HSI Image');
```
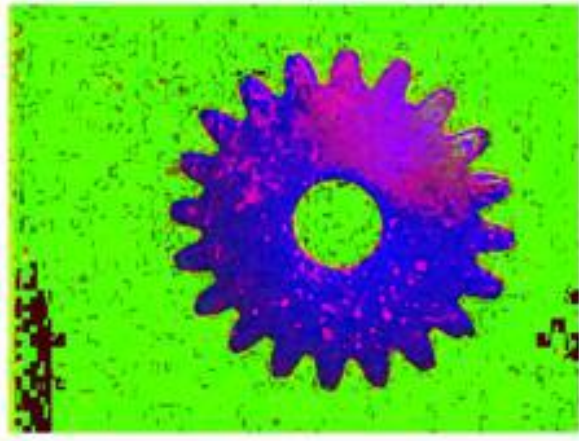
Fig.5 Hue Saturation Intensity image

3.6 2D Point Cloud from HSI data:

Point clouds are datasets that represent objects or space. These points represent the X, Y, and Z geometric coordinates of a single point on an underlying sampled surface. Point clouds are a means of collating a large number of single spatial measurements into a dataset that can then represent a whole. For point cloud mapping, the user only needs to provide the coordinates of the points on the source side and the coordinates of the points on the target side separately. The mapping algorithm is done among those points.

Here we are going to collect the X data and Y data of the image from the HSI image for plotting the point cloud in MATLAB. There is a direct coding in MATLAB for this conversion process.

The digitization process is carried out using MATLAB version 2014a. As explained earlier, running the digitization process code leads to a set of point clouds and their corresponding background. The purpose of a black background is to differentiate the height of each surface point of the object and the lowest point of the object. The Fig.6 shows the scattered point cloud image.

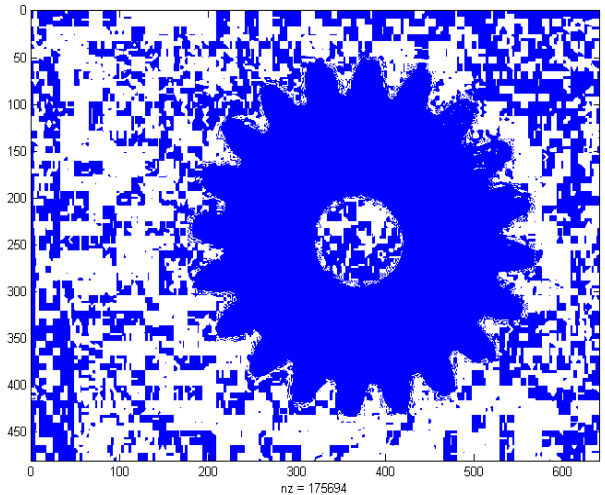### 3.7 MATLAB code for point cloud:

Scatter('x,y');

Spy('x,y');

Fig.6 2D Point cloud image

3.8 2D Point Cloud Digitization:

The 2D point cloud now needs to be converted into 3D model. So after running through the codes, the point cloud can be visualized in any CAD software when saved in xyz format.

The resulting point cloud is in 2D with the x, y coordinates. Now these point clouds are processed in designing software like SOLIDEDGE or CATIA and then will be converted to an solid model. We have used CATIA software to convert the point cloud into 3D solid model. The solid model is refined and trimmed for obtaining smooth surface.

Computer **A**ided **T**hree dimensional **I**nteractive **A**pplication it is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products.

CATIA can be used at different stages of the design - ideate, draw, test and iterate. The software comes with different workbenches ("modules") that allow CATIA to be used across varied industries – from parts design, surface design and assembly to sheet metal design. CATIA can also be used for CNC. The Fig.7 shows the image of a gear designed using point cloud in CATIA software.
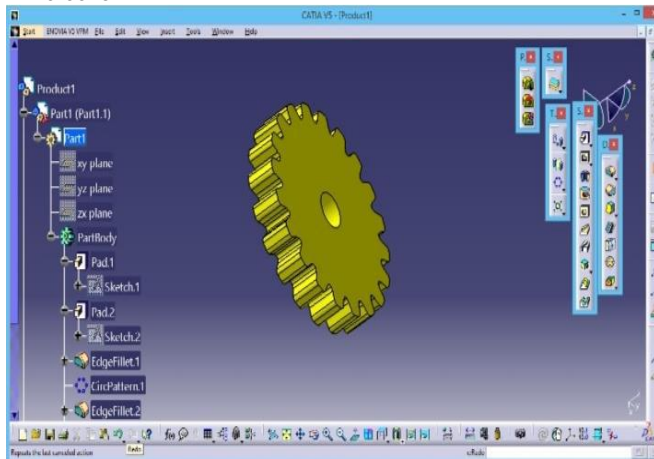
Fig.7 3D model of the gear in CATIA

4. RESULTS AND DISCUSSION

The originality of this research is on the system and methodology used for producing three dimensional results from two dimensional data. The proposed system is not just suitable for remote reverse engineering application, but is also valuable for low budget reverse engineering application as well.

5. CONCLUSION

This research has developed an initial system to perform reverse engineering by digitizing physical object and converting it into 3D CAD surface via a webcam, which makes reverse engineering without a 3D scanner possible. To enable fast processing toward the final virtual surface, image data are converted into 3D point data, and subsequently, into a net surface by conducting both image processing and net-wire processing. All processing steps can be performed on the same computer. Therefore, in situations where a 3Dscanner is unavailable, this webcam imaging technique integrated with a computer system can be used as an alternative to estimate shape because the produced point cloud has a acceptable precision range of less than 1.5 mm. With such precision range, both the point cloud and surface generated from this system can be used as reference geometry by designers to modify the generated surfaces further and create new 3D part models, and thus, this system is suitable to be further developed for reverse engineering applications. Furthermore, the produced point cloud and surface can be read directly in commercial CAD software, which makes the

output of this system universal in terms of compatibility that can be used for a quick product development.

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