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# SATISFYING CUSTOMER REQUIREMENTS BY APPLYING IMAGE PROCESSING

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*Abstract*— **This research focuses on the application of generating 3D model from 2D multi-views images. Only 2D visual view could not be delivered a clear explanation of the requirement, so the non-scanning data acquisition method has been applied in this research for increasing capability of the communication between customer and manufacturer. The proposed approach can be divided into four main sections. Preparing the object for capturing purpose is started first. Then, taking images of the different views of the desired object is applied. The third step is constructing a 3D model from the 2D images. After generating 3D model, the surface reconstruction and correction is performed to enhance the quality of the 3D result. The main advantage of generating 3D model from 2D multi-views images is to capture the desired object directly and easily where the basic or compact digital camera can be applied with less skill levels required.**

*Index terms*- **Image &Signal Processing Applications, Image Acquisition and Display, Reverse Engineering, 3D Model Construction, and Customer Requirement.**

## I. INTRODUCTION

Recently, the various technologies and measurement methods can be used to provide realistic presentation between consumer and manufacturer for reducing the mistakes in communication and the transportation time. To quickly capture the geometric shapes of an existing object and construct 3D model, reverse engineering (RE) process has been applied. This process is very useful in increasing design motivation and task performance where time spent for creating a new model is reduced. It also encourages a designer by exploring the final object into the origin without any background information

Image processing technique is one of the assisting methods for supporting reverse engineering (RE) process to convert 2D images into 3D model where a non-scanning device (e.g., a digital camera) is applied to capture surface details of a master object. The series of images, which are set to be the obtained data, are constructed to be a 3D model through surface registration and surface fitting processes. One of the main advantages of the applications from image processing technique is to assist the customers to make their decisions for selecting the product by using basic and simple or everyday equipment such as a DSLR or mounted digital camera in the smart phone. The customer's requirements can be sent directly to the design engineer for quickly initialing and creating some ideas for a virtual model of desire point. The designer can make corrections or can modify a model after receiving some comments from a customer [1].

## II. RELATED RESEARCH

This section presents the literature reviews of reverse engineer emphasizing on non-scanning acquisition technique where the image processing technique applies the results of capturing process and surface registration to construct a 3D model. The relevance of surface registration to image processing technique is that the common positions presenting on each image view are detected and merged for constructing 3D model.

### *A. Reverse Engineering*

Reverse engineering is the process of extracting knowledge or design information from anything man-made. Reverse means that the direction, arrangement or nature of something is changed into its opposite platform. Engineering is about the science of applying knowledge of the properties of the matter and natural source of energy to the practical problems of industry. Therefore, the RE describes about the process that applies the scientific method such as making the3D virtual model directly from the real part where the engineering drawing is not required [2].

The method covers discovering of device, object, or system through analysis of the structure, function, and operation without understanding the original one. Initially reverse engineering starts from analysing the final product, and revealing the detail of the object which could be consisted of processing, material, components, and product design.RE consists of 3 main steps: data acquisition, surface reconstruction, and surface fitting. In order to increase the accuracy of the obtained 3D model, the techniques selected for acquiring surface data is very important. In data acquisition step, the main methods are applied: contact, and con-contact [3]. For fast detecting and capturing geometric shapes of the object's surface, non-contact with non-scanning technique is emphasized where the camera has been played as the vital device which will be applied in the proposed approach. The concept of non-scanning technique and its application will be explained in the next section [4].

### *B. Non-Scanning Data*

Non-scanning acquisition technique can capture the entire surface details of the object with a few snapshots. The obtained

images can be directly used for constructing a virtual model with less time consuming.

Data acquisition systems are products and/or processes used to collect information to document or analyse some phenomenon. Focusing just on data obtaining, contact and non-contact method would be the two types of data acquisition at the present moment.

The advantage of image processing compared to scanning technique (e.g., 3D laser scanner, displacement sensor) is more suitable for bigger size models because it can be moved to everywhere for capturing purpose. For obtaining the 3D model, the multi-system is defines to analyse the details of the entire surface, and the quality of the obtained images can be controlled by adjusting camera parameters (e.g., shutter speed, aperture size, or ISO) properly to avoid any distortions that might be occurred [5].

The registration process is required for merging the multi-view images from their different common positions to be in the same plane. The technique starts with finding the coordinated point in the images and then extracts the area of interest in the circles method where conformity is occurred, this technique helps to simplify the captured details and to reduce time for merging but the camera parameters should be well controlled [6].

Camera is the instrument for capturing the image in short period of time. Camera was firstly built in the fifth century B.C. by the Chinese philosopher Mo Ti noted that a pinhole can form an inverted and focused image, when light passes through the hole and into a dark area. When the time has passed, the camera innovation has been developed to many technology application types to be used in proposed evidence.

The camera parameters must concern about high intensity and avoid from dark lighting images. Shutter speed, pixel, aperture size, and ISO will have a measurable and specific impact on how the image ultimately looks (e.g., make environment around image brighter by reducing shutter speed to increase the amount of light hitting the image sensor) to obtain clean and clear 3D model.

Well-known and popularly camera's parameter that most mention is the sensibility of the pixel. In digital imaging, a pixel, or picture element is a physical point in a raster image or in the simple, it means fundamental elements of the image. It could be used to compare the camera quality; more pixels would provide more clean and clear images [7]

Application of Image processing technique can allow much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise [8] and images distortion during processing. Since images are defined over two dimensions digital image processing might be modelled in the form of multi-dimensional systems smoothly and perfectly. Images from digital cameras can be further processed to improve the quality or to create desired special effects. This additional processing is typically performed by special software programs (e.g., Autodesk 123D, CAD/CAM) that can manipulate the images in a variety of ways.

After data acquisition, a set of range images representing multiple viewpoints around an object is obtained. The task is to reconstruct a CAD model from these multiple range images. Model reconstruction is a multi-faceted problem that is one of the most difficult problems in computer vision and attracts more attention [9]. The fundamental problems for reconstruction are aligning multiple views into a whole coordinate frame and integrating and merging aligned views into a CAD representation.

Multiple views of an object are necessary to overcome occlusions. As the camera moves to capture a new view of the object, the result is relative to the new view position. Registration is the process to align multiple views of an object and the related coordinate frames into a whole single coordinate frame. The main problem of the registration is recovering the rigid transformation from the given raw data [10].

### *C. Resolution of the Camera*

In photography, resolution is all about the ability of the camera to capture as much detail as possible. Camera manufacturers' strive to create cameras that can capture more details by adding more pixels. The more detail you capture, the more accurate a record you have of the thing you are photographing

Millions of pixels that make up the image sensor in a digital camera are actually tiny light-sensitive squares. Each pixel registers the brightness of the light striking it, when you click a snapshot. These pixels in a photograph cannot be identified unless you magnify a digital image. On enlarging an image, you will find that the whole picture is a web of inter-connected lines known as rows and columns forming small boxes or squares filled with colors. These boxes are known as the pixels. Resolution is the camera's ability to classify and effectively present discrete image information, such as details, patterns and textures within a given photographic image and it corresponds to how large a photo can become without becoming unacceptably blurry or grainy. Camera and image resolution is measured in Pixels per Inch or PPI [11].

Resolution can be identified by the measurement of pixels in dimensions of height and width. For example, a camera manufacturer can describe the resolution of the camera as 3904x2598 (W x H) pixels, which again can be termed as 3904x2598=10,142,592 pixels [11]. If this number is divided by 1 million, the figure attained will come out to be 10.1 megapixels (one megapixel is equivalent to one million pixels). Hence, the resolution of the image can also be described as 10.1 megapixels, or 10.1 MP.

The amount of resolution depends on the type of work. A drawback of highly detailed pictures is that can create very large digital files, which make the file unsuitable for emailing people or posting on the web. However, editing programs enable the user to reduce the pixels and file size to more manageable proportions.

The size of the image can be increased. Enlargement is a useful editing problem when making huge prints, for example. A seemingly capable 18Mp camera produces an uncropped image measuring 5,184×3,456 pixels [11]. To create a high-quality print at 300 dots per inch means that the maximum size for printing at is just over 17×11 inches. But if huge image as 18Mp is required, the individual pixels will show up as recognizable squares.

However, the huge image can be effectively added more pixels by using standard editing software to upscale the image.

*D. Software Programming*

According to this research, the online Web Self-Service Technologies WSST, are realized to be the core tools that apply to use in product development phase based on customer requirement. Web self-service is a type of electronic support (e-support) that allows customers and employees to access information and perform routine tasks over the Internet, without requiring any interaction with a representative of an enterprise. Web self-service is widely used in customer relationship management (CRM) and employee relationship management (ERM).

For employees and customers, self-service offers 24 hour-a-day support and immediate access to information without having to wait for an email response or a returned telephone call. Ultimately, the success of Web self-service depends upon the quality and quantity of information available and the ease with which it can be accessed.

Deploying web self-service applications benefits a company in a variety of ways. The most prominent motivation is the lower cost, as compared with telephone or email service delivered by a company representative [12].

## III. Research Concept

The research is divided into 4 main steps to achieve the objective of the proposed approach (as shown in fig. 1) which can be described as 1) selecting the appropriate body part and cloth's accessory for analyzing the characteristics existing, 2) capturing the body part in multi-views of images by concerning the parameter of pixels and object's degrees of rotation, 3) converting the series of images into 3D model, and concluding the best method for making the best 3D model, and 4) matching the 3D model of body to the accessory.

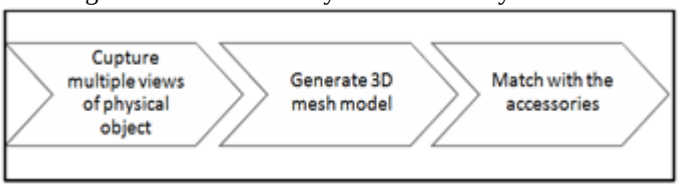


Fig. 1. Research guideline

## IV. Research Concept

*A. Preparation*

Before starting the image capturing process, the equipment and parameter preparation have to be well prepared in order to obtain clean and clear images following as:

1. The body parts as face and head are selected for analyzing and studying in this research since it has the highest organism features and it is the part used for identifying the specific characteristics of person.

2. For supporting the extra situation where the concept of model registration has been applied, the two or more components of the different objects will be registered or united. Since the face and head are chosen to be the main samples for this research, some lists of the equipment or objects which are applied on those areas are raised and considered through the results obtained from the questionnaires (e.g., earrings, hats or glasses). As the results, they are shown that glasses are the most popular accessory put on the area of interest (face and head) of people (94% of 300 participators).

3. The capturing equipment used in the experiment is Canon 450D, which could be adjusted the pixels to be 3.4, 6.3, and 12 megapixels.

4. For capturing image activity, the colour of the background is recommended to be contrasted with the object where the reference points are required.

5. The sample (a man who wears T-Shirt with some details printed on) for demonstrating the proposed approach is asked to sit on the platform with the template of degree of rotational, as shown in fig. 2). During the capturing process, he will change his sitting position in clockwise direction (5, 10, 15, 20, 25, and 30 degrees) when his head and face will be fixed in the same posture.

6. The camera has to be fixed with the tripod to reduce the error from the vibration.

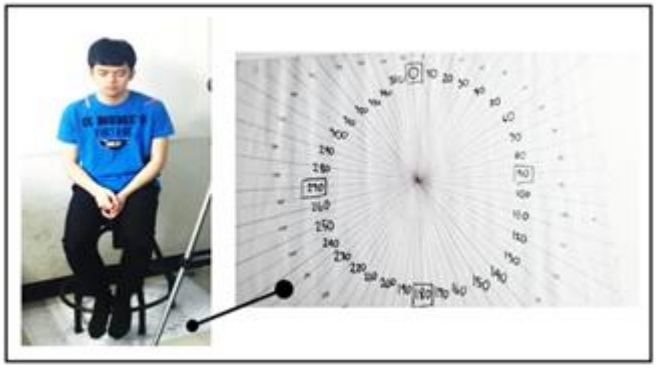

Fig. 2. Template of degree of rotational

*B. Image Capturing*

In the image capturing steps, the proper camera's parameters have been adjusted to generate the best model which can be used as the reference for the next step. Therefore, the images of the desired object are recommended to be taken from different pixels of camera (i.e., 3.4, 6.3, and 12 megapixels) and angles of rotation (i.e., 5, 10, 15, 20, 25, and 30). Moreover, the camera should be suitably adjusted into the appropriate distance to the sample (as shown in fig. 3) for quickly snapping the images without unwanted regions. These obtained images will be easily transferred and combined into the 3D surfaces while minimizing the registration time.

Steps required for capturing images:

1. Set the body to be in the front view (the center of the body and the center of the camera have to be in the same line with 0 degree).

2. Set the pixel to be 3.4 Megapixel.

3. Snap the 5-degree-rotation view (the first set of capturing activity).

4. Save a series of the capturing images of the 5-degree-rotation view to the provided folder.

5. Repeat step 2. to 4. by changing the degree of rotation view to be 10, 15, and 20, respectively.

6. Change the pixel resolution to be 6.3 Megapixel, and then repeat 3. to 5.

7. Change the pixel resolution to be 12 Megapixel, and then repeat 3 to 5.

8. Export all images to the surface registration program for creating 3D surface in subsequent process which will be described in the next section.

Fig. 3. Capturing Method

*C. 3D Model Generating*

A series of 2D images captured from a real object is matched by the corresponding of a specific image point (the line of sight, L12). The position of a 3D point can be found as the intersection of the projection plane as shown in fig. 4. The plane is reconstructed as the triangulations which are the relations between multiple views that convey the information that correspond to sets of points. Then the unwanted noises are deleted from the intersection process, only the union area is preserved. Finally after all of the processes are done, fig. 5 is illustrated the 3D model of face and head.

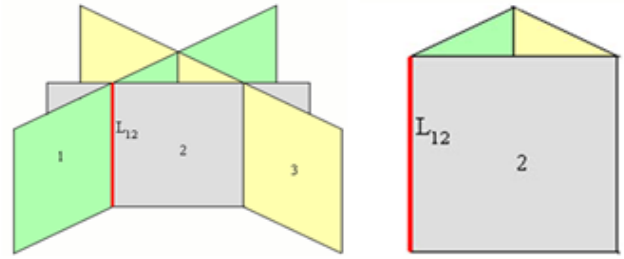


Fig. 4. The intersection of the projection plane
(a) Intersection between planes mapping together
(b) Noise of planes intersection are deleted

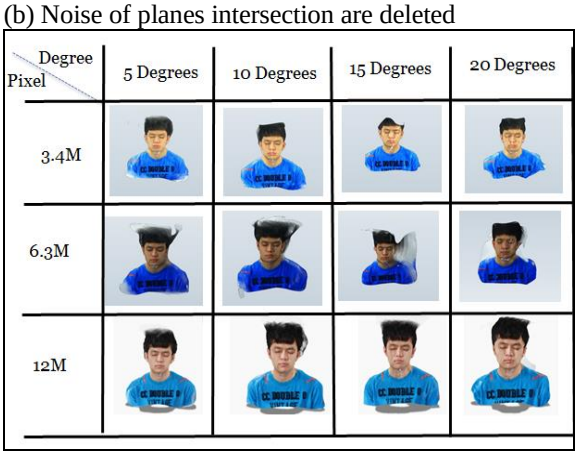


Fig. 5. 3D face model from different parameter

*D. Accessory Matching*

For supporting online-purchasing process where the people cannot try or test the product, using the computer graphic simulation may help them to make decision to select the proper shape and design of the product. Therefore, the extra accessories (i.e., glasses) are asked to form on the face model by applying the registration process as shown in fig. 6.

Fig. 6. Adding the extra accessories on the 3D face model

## V. Results of the Research

When all sets of the data have already been converted into 3D model, the examination is conducted to find out which method and parameters providing the best 3D model. The model is classified and evaluated by using visual inspection and computer software.

Sometimes, the visual inspection method is quickly and easily to use only for checking the rough details of the images and registered surfaces; however, it is not the effective method applied for identifying the errors (fig. 7) happened between the existing object and the virtual model created in terms of numeric values.

When the acceptable models are chosen, the dissimilarity of each items are difficult to assortment, so the face detection have been applied to identify the specific portions that are not matched. Face detection detects the point clouds in each view of 2D images and these points are compared to each side of the 3D views. Fig. 8 presents a point-to-point comparison between the captured image and the registered model, to find the error of the model, the lower percentage of error gives the higher quality to the model.

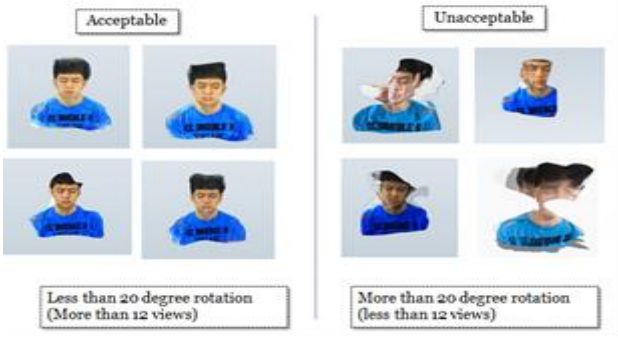


Fig. 7. Visual Inspection Classification

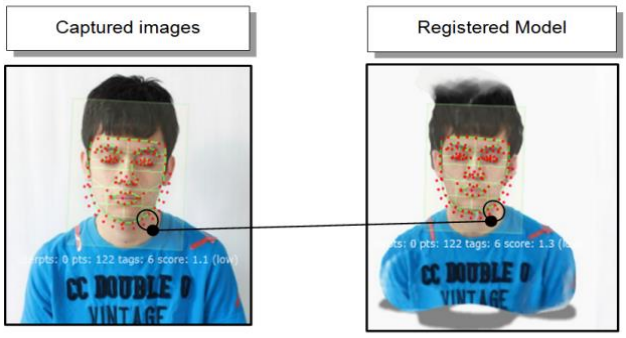


Fig. 8. Point-to-Point comparison

Then the experiment was constructed by using full factorial design method to find error between images and model, when the main factors are resolution, and degree of rotational. And block is defined by replication. The result of errors from each comparison are shown in table 1.

TABLE I
ERROR OF EACH 3D MODEL

| Pixel | Replication | 5° | 10° | 15° | 20° |
|---|---|---|---|---|---|
| 3.4 MP | 1 | 0.167 | 0.180 | 0.164 | 0.202 |
| | 2 | 0.106 | 0.180 | 0.247 | 0.142 |
| | 3 | 0.112 | 0.115 | 0.735 | 1.253 |
| 6.3 PM | 1 | 0.154 | 0.223 | 0.450 | 1.216 |
| | 2 | 0.120 | 0.103 | 0.228 | 0.182 |
| | 3 | 0.123 | 0.130 | 0.155 | 0.336 |
| 12 MP | 1 | 0.116 | 0.123 | 0.209 | 0.276 |
| | 2 | 0.055 | 0.099 | 0.205 | 0.200 |
| | 3 | 0.122 | 0.187 | 0.143 | 0.287 |

After that the error was analyzed by using full factorial design analysis, when the significant variables are sum of squares for an effect (SS), mean square (MS), and F-value (F). The equations of these variables are provided below (1-3) where n is level of factor, k is number of factor, and MSE is the mean square of the error. The result from full model shows that the interaction between pixel and degree rotational is not significant or it has no effect to the error (p-value is 0.933) as shown in fig. 9.

$$SS = constant/((n2)^{\wedge}k\ ) \quad (1)$$

$$MS = SS/Degree\ of\ freedom \quad (2)$$

$$MS = MS/MS_E \quad (3)$$

Analysis of Variance for Error, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| Block | 2 | 0.16672 | 0.16672 | 0.08336 | 1.22 | 0.314 |
| Pixel | 2 | 0.12465 | 0.12465 | 0.06233 | 0.91 | 0.416 |
| Degree | 3 | 0.63226 | 0.63226 | 0.21075 | 3.09 | 0.048 |
| Pixel*Degree | 6 | 0.12030 | 0.12030 | 0.02005 | 0.29 | 0.933 |
| Error | 22 | 1.50194 | 1.50194 | 0.06827 | | |
| Total | 35 | 2.54588 | | | | |

S = 0.261286 R-Sq = 41.00% R-Sq(adj) = 6.14%

Fig. 9. ANOVA of full factorial model

Since the interaction factor has no effects on the errors happened, so the term of interaction could be eliminated and only main factors are considered. After eliminating interaction term, the new model (e.g., reduced model) is analyzed. The result shows that the angle rotation is only one of the main factor that has the direct effect on the error since the p-value is less than 5%. When the pixel parameter provides high level of p-value (fig. 10). The main effects plot indicates that 5-angle rotation and 10-angle rotation provide the mean of error less than 15-angle and 20 angle of degree rotational parameter. When there is no evidence that both 5-angle rotation and 10-angle rotation provide any different significant result as shown in fig. 11. Recommended in this research is 10-angle rotation since processing time and the spent memory can be minimized.

Analysis of Variance for Error, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| Block | 2 | 0.16672 | 0.16672 | 0.08336 | 1.44 | 0.254 |
| Pixel | 2 | 0.12465 | 0.12465 | 0.06233 | 1.08 | 0.355 |
| Degree | 3 | 0.63226 | 0.63226 | 0.21075 | 3.64 | 0.025 |
| Error | 28 | 1.62225 | 1.62225 | 0.05794 | | |
| Total | 35 | 2.54588 | | | | |

S = 0.240702 R-Sq = 36.28% R-Sq(adj) = 20.35%

Fig. 10. ANOVA of reduce model

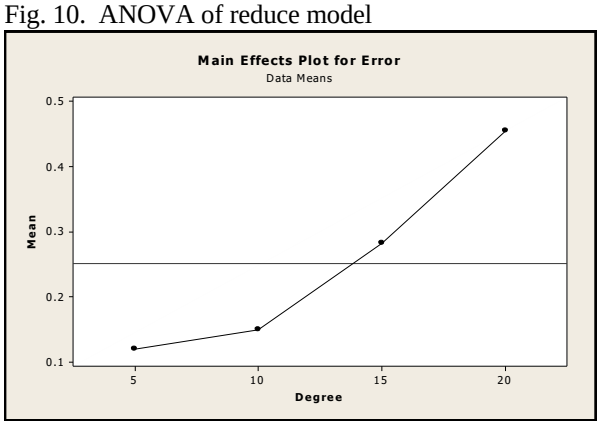


Fig. 11. Result after plotting regression line

## VI. CONCLUSION

Face model was transformed into the 3D model by capturing multi-view of images. The steps are set up the environment to be suitable firstly for applying in image processing technique. Next, capture at least loops of 36 sequential photographs different in 10 degree increasing of rotation about the subject. After capturing all loops of 36 sequential photographs, the best quality that gives the most recommendation feature of the model is 10 degree of rotation. Then use the Geomagic Studio 10 software to match the face model to the accessories, by adjusting the scale and repositioning of both 3D models. Finally, the 3D model of face would be constructed to assist the customer make their decision for selecting the product.

Finally, image processing technique is the rapidly and easily technique to generate the 3D CAD model from 2D multi-views images. The final 3D model and the procedure has

to be suitable to the manufacturing constraint about using 3D model in the further engineering process, and has to have the smallest tolerance as possible. So, the project will give the technique that makes the highest quality in every procedure steps. This technique can help manufacturer to design a product quickly where mistakes and transportation time can be reduced.

Using the proposed technique can support the customers who do not want to wait for in lines and prefer to apply easy searching process for specific product by allowing the manufacture can easily interface the customer through online ordering application. Some of the most misunderstood features of the product can be eliminated since the customers can see the drafted model of their design and add or modify some specific characteristics on the product before it is being produced. At the same time, with the fast-track production, the manufacturer can understand and satisfy all requirements through the images instead of misleading words or conversations as presented in the past. Every online store is designed with unique individual ordering features to purchase the item, which is the availability of online stores giving customers the freedom to shop at their own place and convenience.

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