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The Automated Selective Acquisition System

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***Abstract*—**To support design process for launching the product on time, reverse engineering (RE) process has been introduced for quickly generating 3D CAD model from its physical object. The accuracy of the 3D CAD model depends upon the data acquisition technique selected, contact or non-contact methods. In order to reduce times used for acquiring surface and eliminating noises, the automated selective acquisition system has been developed and presented in this research as the alternative channel for non-contact acquisition technique where the data is selectively and locally scanned contour by contour without performing data reduction process. The results present as the organized contour points which are directly used to generate 3D virtual model. The comparison between the proposed technique and another non-contact scanning technique has been presented and discussed.

***Keywords*—**Automated selective acquisition system, Non-contact acquisition, Reverse engineering, 3D scanners.

I. Introduction

REVERSE ENGINEERING (RE) technology has been introduced to industry as a tool that allows 3D CAD model to be constructed directly from its physical object and to be improved quality for further implementation [1]. According to the steps required for accomplishing RE process, selecting the appropriate scanning device (i.e., contact, and non-contact) in data acquisition step is the main issue for obtaining high accuracy of the data.

For contact acquisition method, the scanning device touches object at the area of interest point by point. Acquiring surface with contact method can preserve the geometric shape of the object and the scanned data can be sent directly to generate 3D surface in the subsequent process; however, it is time-consuming process, and requires high labor required.

In order to apply fast scanning technique, 3D laser scanner is introduced, using this technique can acquire surface of the object region by region with less human required comparing to contact-technique. However, the obtained data contain some noises which need to be eliminated before constructing 3D surface.

In order to shorten time and steps required for completing the reverse engineering process, local scanning technique called selective data acquisition had been introduced where the scanning positions are recommended according to the complexity of the object which is analyzed by image processing algorithm [2]. The obtained contour points can be sent directly to generate a prototype in rapid prototyping process or to construct 3D virtual model without performing data reduction process.

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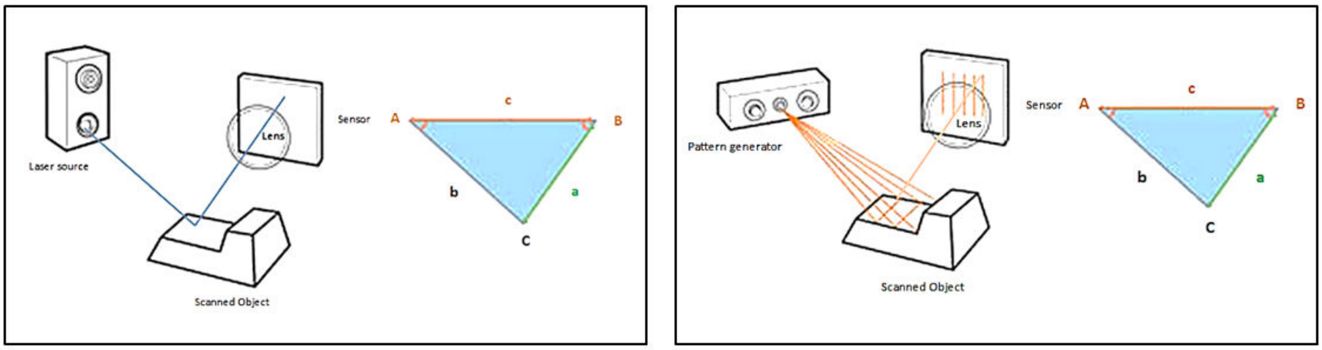
In order to enhance the scanning performance of the preceding local scanning technique to be more robust where the measuring unit can be worked smoothly and continuously with fewer errors, the components of the acquiring machine (i.e., scanning axes, scanning sensor, and controlling algorithm) have been modified and developed in this research. The developed version is called automated selective acquisition system. Applying the developed technique can generate the organized contour points which present no noises or unwanted data (e.g., the unwanted areas of the background or the platform that is used to position the object). The points are formed in a simple format which can be saved in a small file size. From scanning process to surface reconstruction step, times used for transferring data and constructing surface can be minimized. The comparison between the data obtained from the proposed technique and another laser scanning technique is presented in Section IV.

II. Related Works

3D scanning techniques have been introduced as measuring devices that apply the reflective concept to generate dense point clouds or polygon meshes which represent the geometric shape, or possibly its appearance (i.e., color) of a physical object [3], [4].

In 3D laser scanning technique, two main principles are applied: short-range and mid-and-long-range where the key component is the distance between the acquiring sensor and the object that is being acquired [5]. When the distance between an object and a sensor is less than 1m, the short-range principle is applied. This principle applies trigonometric triangulation technique where the laser beam is emitted to the object and the receiver (e.g., camera) gets the reflected signal back, and the distance can be converted to be XYZ-coordinates [6].

The triangulation technique can be classified into two types: a laser scanner, and a structured light scanner as shown in Figs. 1 (a) and (b), respectively.



(a) (b)

Fig. 1 The short-range principle: (a) Laser scanner, (b) Structured light scanner [4]

For a laser scanner, this type is available in many forms such as area scanner, handheld, or portable arm [4]. The scanning performance of laser scanner depends upon the wavelength of the light source applied. Applying long wavelength (e.g., red, 638nm) provides more robust and less distortion and suspension from the dust in the air. To acquire surface details of a small object where the surface accuracy can be maintained, a red light source is recommended [7].

For structured light scanner, a series of linear patterns is projected onto an object where the distance from the scanner to the object's surface can be calculated by examining the edges of each line in the pattern [4], [8]. The distortions of the examined edges represent the geometric shape of the surface. Using this technique can provide more accuracy of the surface details and less noise, comparing to data obtained from laser scanner. However, this scanner is not available for scanning a small object, and the specific lighting is probably required.

Illustrated in Fig. 2 is the mid-and-long-range principle which is applied in time-of-flight scanner for acquiring the object that is located far from the measuring device (i.e., the distance is higher than 2m) [9].

The key component of this technique is the speed of light. When the speed of the light is precisely known, the time that the laser takes to reach an object and reflects black to the sensor is found, the distance can be determined.

In practice, the laser pulse is sent out to the object and then it generates the point cloud data from the length of time between sensor and object [10]. Using this technique can acquire data from very long distance; however, it contains less accuracy, slow data acquisition, and higher noises compared to the short-range principle.

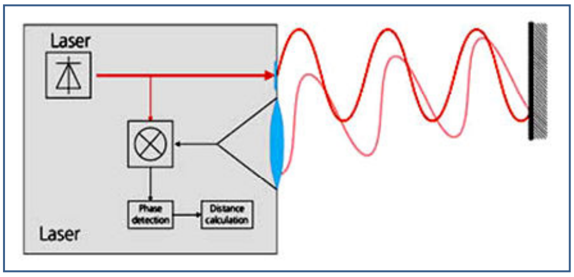


Fig. 2 The mid- and-long-range principle [9]

In order to acquire surfaces that contain various shapes with less noise obtained, the red light laser scanner has been studied in this research.

Among the different forms of the laser triangulation techniques, handheld form provides more flexible for freely moving all around the object, and it requires less set-up time, less calibration and alignment [11]. Using handheld form can support fast-scanning purpose. However, it is quite expensive device. The application of this technique has been presented and discussed in Section III.

Another type of the red light laser scanner, called spot-beam laser which is cheaper than handheld form has been applied in this research to selectively acquire object's surface where the results present the organized points and less time required for constructing 3D surface model in the subsequence step. The concept and application of the proposed technique has been shown in Section IV.

III. Laser Scanning with Handheld Form

This section presents this application of laser scanning with handheld form where the glossy glass is used as the sample model to be acquired the surface details as shown in Fig. 3, and the entire steps of the technique is shown in Fig. 4.

Fig. 3 A sample model, glossy glass

Before scanning the glossy glass, coating surface with flat-white color was required in object preparation step. The coated glass was located onto the reference platform, and then it was scanned by 3D laser scanner with handheld form. The obtained surfaces can be checked whether or not some areas are missed where the re-scanning activity might be required.

As the results, the acquired data from 3D handheld laser scanner contains noises and unwanted regions. In order to obtain a clean and clear 3D model, data reduction process is required for eliminating some noises from the scanned data.

IV. The Automated Selective Acquisition System

Recently, the selective data acquisition approach proposed by Rianmora et.al was introduced to acquire data selectively and locally layer by layer according to the recommended scanning positions which are analyzed from surface's complexity, rather than acquiring the entire surface as resulted in 3D laser scanning technique [1].

The data acquisition unit which was built in house for demonstrating implementation of the selective data acquisition approach has been developed and modified in this research where the construction and layout of the 4-axis motion control system, X, Y, Z, and c (rotating around the Z-axis), and the point-based scanning sensor have been renovated to be more robust and flexible to support various types of the object's shapes. Using this developed version can reduce time for preparing object which contains glossy, shiny surface where the coating powder is not required.

However, only for transparent surface, the flat-white powder spray is still required. The same sample model, glossy glass, has been also used in this proposed technique.

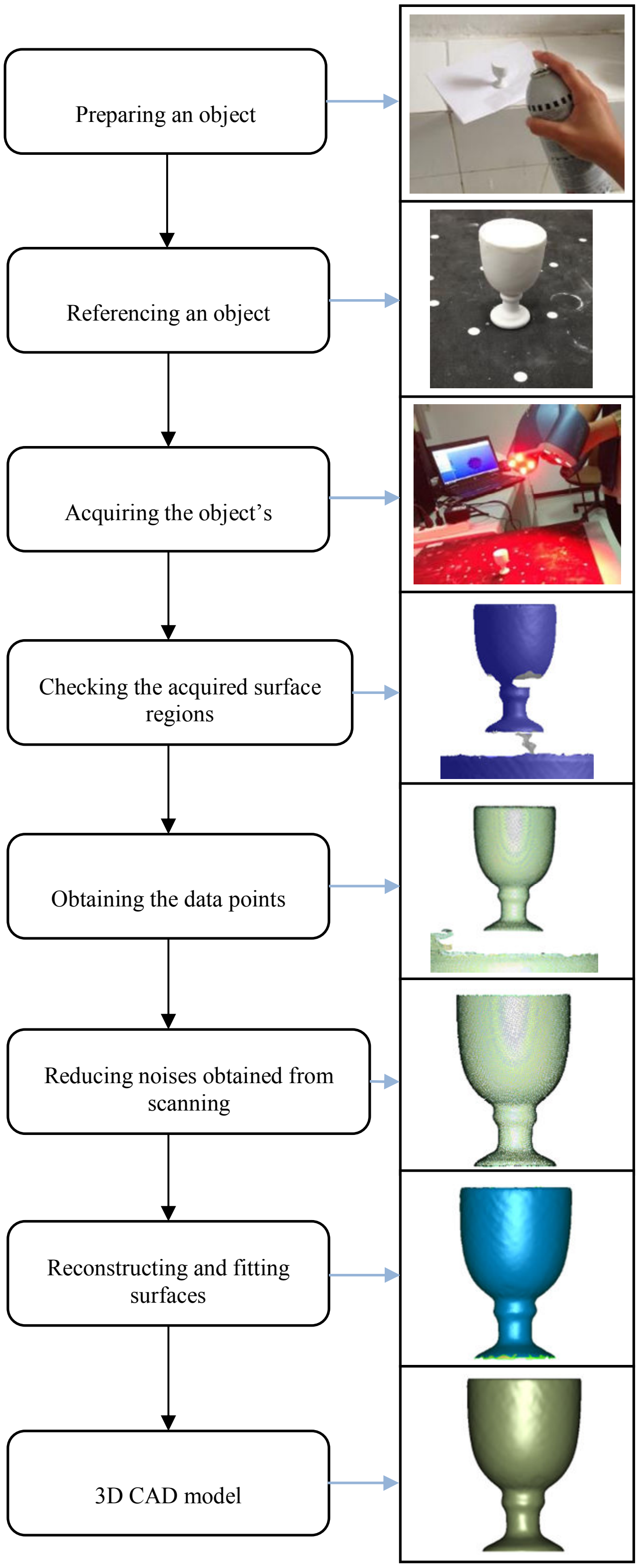


Fig. 4 The application of red light laser scanner with glossy glass model

The activities of proposed technique starts with preparing an object by measuring object's height, following by locating an object at the reference position on the rotary table and assigning the object's parameters for controlling motors, and sensor. The scanning process is then performed where the sensor is activated to acquire the object's surface based on the bottom-up direction.

Once the rotary turns for 360˚, a contour point is obtained. The acquired contour points can be immediately saved into a simple format (*.txt) which represents as XYZ-coordinates. Z-axis is moved down with the assigned height (i.e., layer resolution, 1mm.) for scanning the next contour. These activities are repeated until obtaining the topmost contour. All contour files are imported into the surface reconstruction program to construct 3D surface model. The completed 3D CAD model is sent to rapid prototyping machine (i.e., FDM process) for fabricating a prototype. The overview of the automated acquisition system is illustrated in Fig. 6.

After acquiring object surface by using both 3D laser scanning and the automated selective acquiring techniques, it was found that using the 3D laser scanner required several activities to adjust, set up, calibrate, and align the equipment for interfacing between measuring device and software before performing the acquisition task. The comparison of both techniques is shown in Fig. 7.

In results of the experiment, the number of triangular facets of the complete model constructed from the modified points acquired by 3D laser scanner was higher than the organized points acquired by the proposed technique about 33.36%.

Illustrated in Fig. 5 is the automated selective acquisition machine developed in this research.

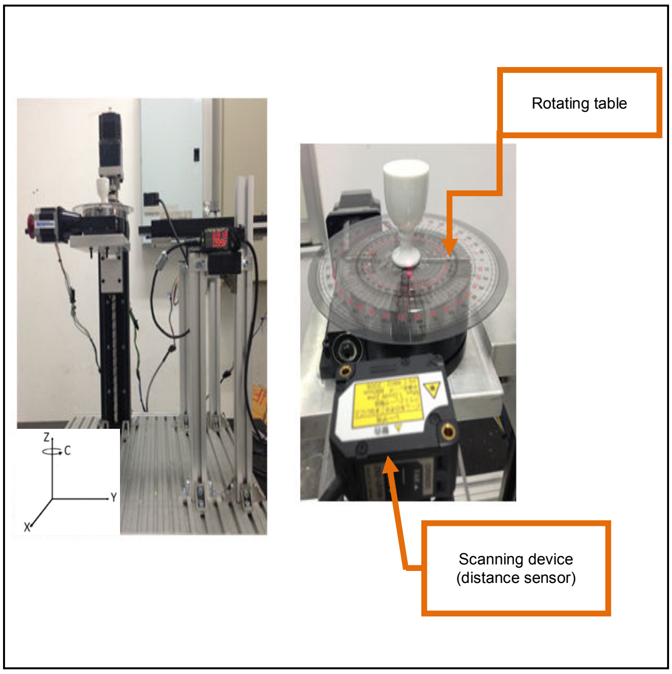


Fig. 5 The automated acquisition machine with a sample model, glossy glass

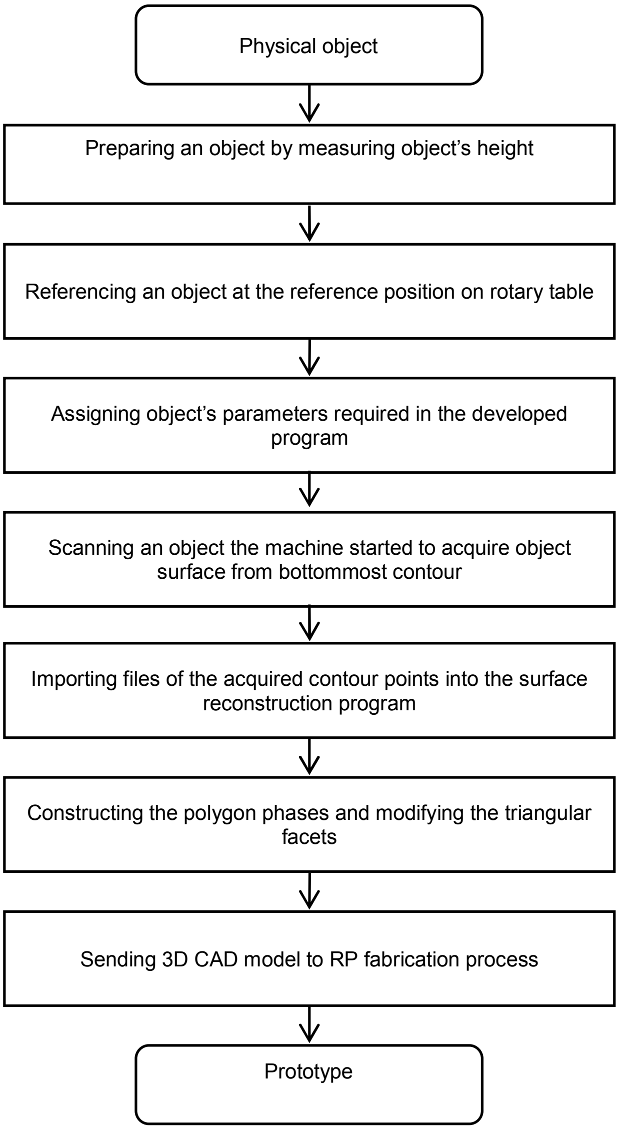
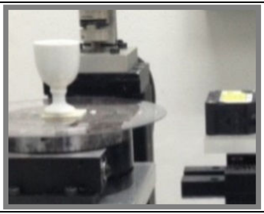
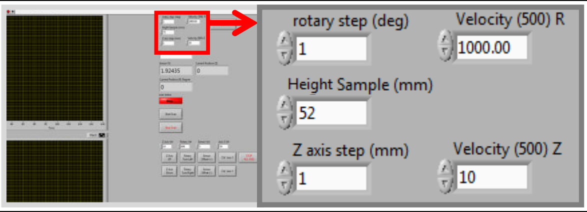
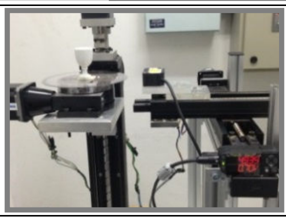
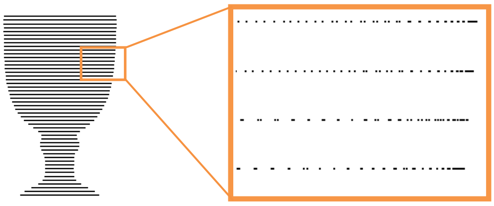
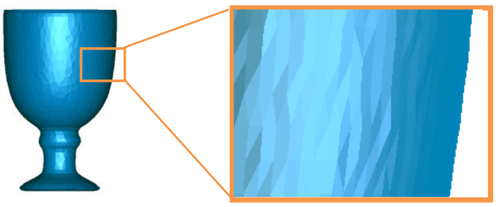
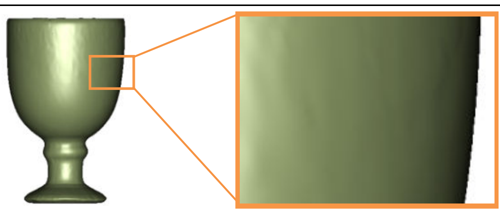
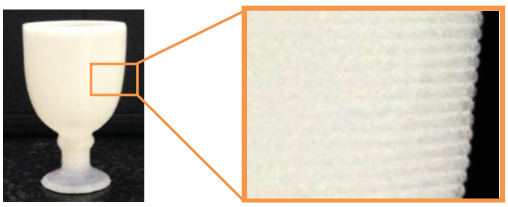
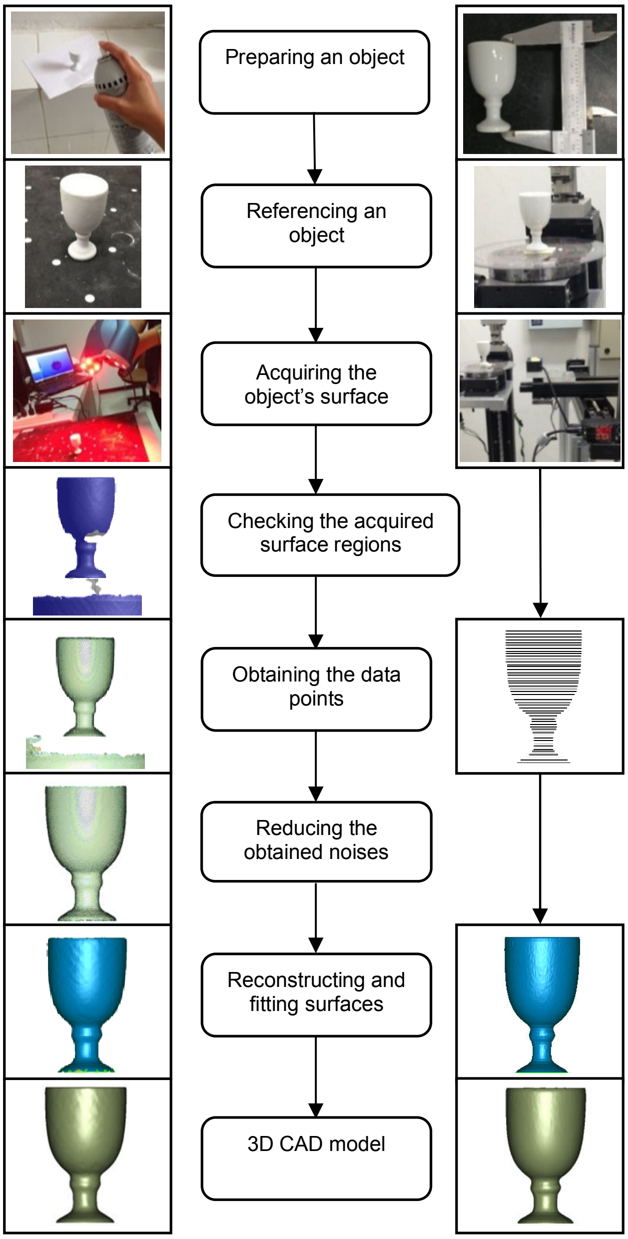


Fig. 6 The overview of the automated selective acquisition system

TABLE I
THE STEPS OF THE AUTOMATED ACQUISITION TECHNIQUE

	**1st Step**: Preparing an object by measuring the height of the glossy glass which is 52 mm.
	**2nd Step**: Referencing an object at the referenced position on the rotary table
	**3rd Step**: Assigning the object's parameter requirements in the developed program
	**4th Step**: Scanning an object where the machine started for acquiring object surface from bottommost contour
	**5th Step**: Importing file of the acquired contour points into surface reconstruction program
	**6th Step**: Constructing surface polygon and modifying surface data
	**7th Step**: Sending 3D CAD model to RP process
	**8th Step**: Fabricating a prototype by rapid prototyping (FDM technique)



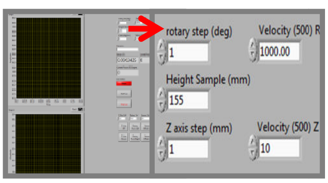
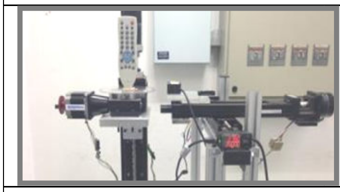
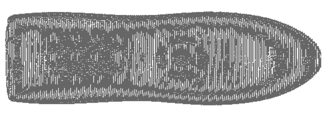
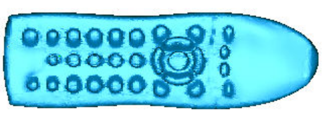
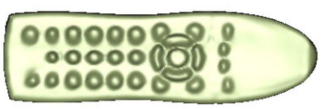
(a) Acquiring surface data with 3D laser scanner

(b) Acquiring surface data with the proposed technique

Fig. 7 (a) The comparison between the laser scanning technique, and (b) The automated selective acquisition system

Illustrated in Table II is another example, remote control, which is used for demonstrating the proposed technique.

TABLE II
THE APPLICATION OF AUTOMATED SELECTIVE DATA ACQUISITION SYSTEM ON REMOTE CONTROL

	**1st Step**: Height of the remote is 155 mm
	**2nd Step**: The remote is located on the rotary table in vertical direction
	**3rd Step**: Degree of rotary table: 1 Degree (360° / rev) Velocity of rotary table: 1000 pulses/rev Velocity of z-axis: 10 pulses/rev Height sample: 155 mm Layer thickness: 1 mm
	**4th Step**: The bottommost contour is firstly scanned.
	**5th Step**: Total number of scanned contours is 155 contours. The results present the organized points where data reduction process is not required.
	**6th Step**: Polygon phase is constructed directly from the scanned contours.
	**7th Step**: 3D virtual model is created and sent to fabricate prototype in RP process.
	**8th Step**: Physical prototype of the remote is generated by fused deposition modeling (FDM) technique.

V. CONCLUSION

The automated selective acquisition system has been developed for selectively and locally acquiring object's surface where coating surface and data reduction steps are not required. The obtained contour points are organized and ready for being constructed 3D virtual. To generate 3D virtual model from the scanned data, comparing between the proposed technique and the 3D laser scanning with handheld form, the proposed system requires less reconstruction time and less human-interface required. In order to acquire the object that contains interior details, the additional scanning sensors are required.

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