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IMPLEMENTATION OF A PORTABLE AND LOW-COST 3D LASER SCANNER

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Abstract- The ever increasing interest in 3D printers is due to their wide application areas starting from hobby projects to professional applications. Also the decrease in the size and the weight of them increases their daily usage. Despite these advantages, probably the main drawback is to design/model the digital image of the object to be printed-out since it is a time consuming and difficult process especially for detailed objects. One possible solution to this problem is 3D scanners. Through scanning and constructing processes, the 3D models can be obtained directly with the help of 3D scanners. In this paper, implementation of a low cost and portable 3D scanner is presented and the results are discussed.

Keywords: 3D Scanner, DAVID3 Laser Scanner, MeshLab, 3D Modeling.

I. INTRODUCTION

Nowadays, 3-Dimensional (3D) printers are commonly used in many areas from professional applications to simple hobby applications. They are currently affordable with small sizes. The initial task of the 3D printing process is called slicing, which can be defined as constructing the 3D model of the object to be printed-out. Technically, slicing is the process to divide the 3D model into hundreds or thousands of horizontal layers with the help of a software [1]. For this purpose, Computer Aided Design (CAD) programs can be used but strictly speaking, it is a time consuming and hard process especially for detailed objects. However, 3D scanners can be used effectively to get the 3D digital model of an actual object to be stored in a computer. Then, the obtained 3D image/model can be used to develop, analyze or regenerate the existing object.

Currently, there exist many 3D scanners with different scanning technologies which are used worldwide. Some are ideal for short range scanning while others are better suited for mid or long range scanning. The 3D scanner technology needed to scan a very small object is very different from scanning a large aircraft [2]. An overview on 3D laser scanning techniques can be found in [3].

One of the most popular 3D scanner companies is DAVID-3D [4] which is now an HP company. In this paper, the well-known 3D scanner "DAVID Laser scanner v3" or just DAVID3 is implemented with low cost and some valuable extra features like automatic image rotation and automatic image lighting operations. DAVID3 indeed supplies all required source code, image pattern for calibration and technical solutions to the users freely without the need of a license. All those features of the software are the key enablers for our work.

The paper is organized as follows. In section II, DAVID3 is explained in detail. In section III, the proposed extra features of DAVID3 software is given and final design is presented. Finally, the results are discussed at the conclusion part.

II. DAVID LASER SCANNER V3

DAVID3 is officially defined as a complete solution for generating a watertight 3D surface model of a real world object [5]. Main blocks of the scanner are a laser unit (or a projector) to light the object, a camera to record the object under the laser beam, a computer to combine the recordings for image construction and calibration plates to calibrate the hardware. The block diagram of 3D scanning with handheld Laser and Webcam - DAVID Laser scanner v3 is illustrated in Figure 1.

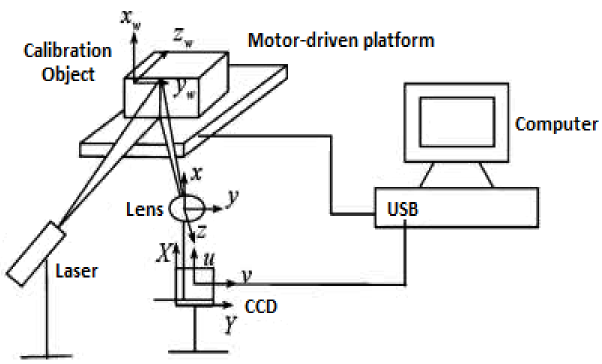


Figure 1. The block diagram of the 3D scanning with handheld Laser and Webcam - DAVID Laser scanner v3 [6]

Initially the hardware is easily configured through David's software. After selection of camera (or projector), the laser and camera must be calibrated using calibration pattern which is shown in Figure 2. A fixed object is illuminated using a horizontal narrow (green or red) laser beam in vertically.

At the same time, camera records this illuminated object and sends the recorded image to the computer. This process is repeated eight times from eight different directions of the object. Different directions are achieved by rotating the object 45 degrees apart for each case. Then, these eight different sight of views are combined in computer using another open source program "MeshLab" [7, 8]. The image formation process is out of the scope of this paper and the detailed information on theoretical background and mathematical derivations to obtain 3D model using laser beam and camera can be found in [6, 9, 10, 11].

Figure 2. The calibration patterns [12]

DAVID3 can be used in two modes: Classical DAVID setup and motorized DAVID setup. In classical DAVID, the object and camera are fixed and scan is done with a hand-held line laser as shown in Figure 3. On the other hand, in motorized DAVID, laser is moved by a step motor controlled by DAVID [5].

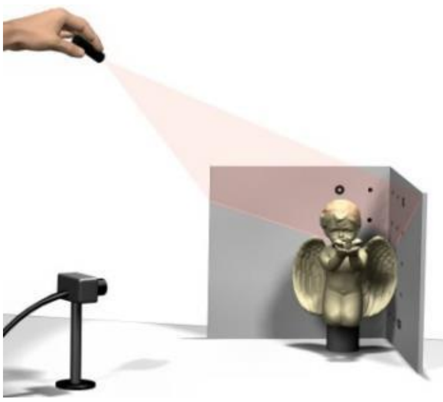


Figure 3. Scanning with a hand-held line laser [5]

After scanning process is completed, the camera recording is saved as a distinct scan. Then, these distinct scans can be combined and the resultant image can be improved by a computer software. In Figures 4 and 5 such a combination process of DAVID3 itself can be seen.

Figure 4. Five distinct scans from different directions 72° apart [5]

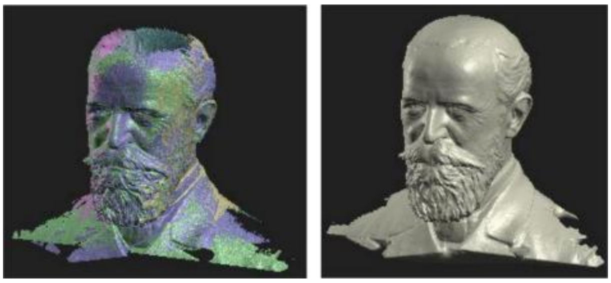


Figure 5. Combined and improved object [5]

In our own design, laser unit and platform of the object is controlled through a microcontroller and laser scanning and object rotating operations are completely motorized. The details can be found in the following section.

III. FULL AUTOMATED DAVID V3

As explained in section II, DAVID 3 is able to construct 3D model by using its original software together with some peripheral devices. Our motivation is to implement a fully motorized 3D scanner with low cost. The laser unit and object platform are controlled using stepper motors, hence the NEMA17 stepper motor [13] which is widely used in 3D applications is chosen. Object's platform is rotated by 45 degrees for each case and the laser unit is moved vertically with step sizes of 0.9 degrees and this step size can be tuned by a potentiometer. The circuit diagram of microcontroller and stepper motors for motorized scanning operation can be seen in Figure 6.

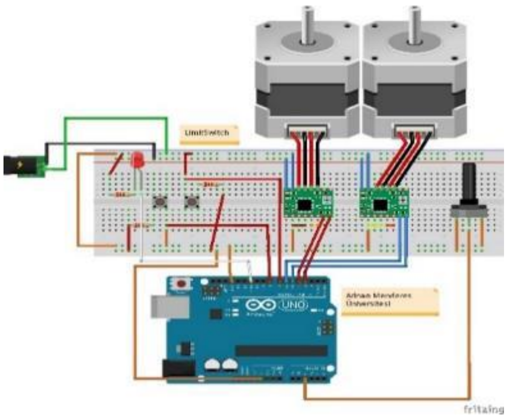


Figure 6. Circuit Diagram of microcontroller and stepper motors for scanning operation

The motion of the platform on which the object is placed is controlled with stepper motors. The laser and platform mounted NEMA17 stepper motors can be seen in Figures 7 and 8.

Figure 7. Platform mounted NEMA17 stepper motors

Figure 8. Laser and laser holder

Laser pointer pen Leisure 303 green laser and Logitech V-UBM46 webcam are used to implement 3D scanner together with NEMA17 stepper motor. Also, Arduino Uno [14], which is widely used for controller applications in the literature [15-17] acts as a central controller unit in our design. All of these plastic holder parts are modelled and produced via 3D printer by ourselves as seen in Figure 9.

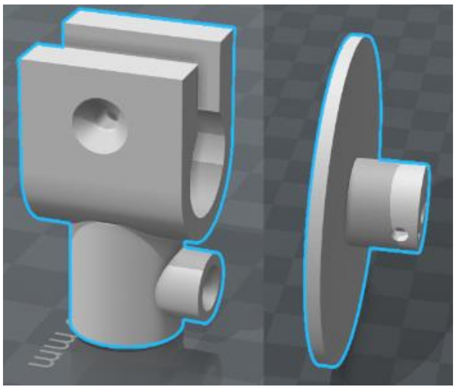


Figure 9. 3D modelling of holder parts

DAVID software just generates activation signals for laser and platform motions. Then, these signals are interpreted by Arduino and the required signals are applied to the stepper motors for scanning.

The calibration patterns are placed near to the 3D printer, "Flyingbear DIY 3D Printer", and hence portable 3D scanner-printer unit is obtained for 3D modeling applications. The complete view of the system can be seen in Figures 10 and 11.

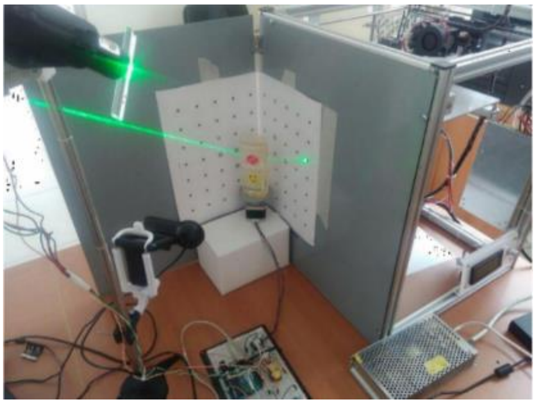


Figure 10. Implemented 3D scanner

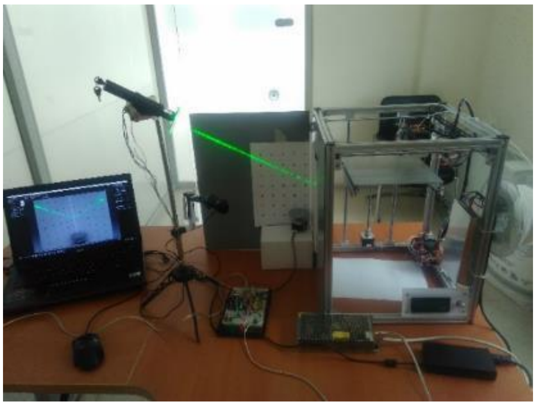


Figure 11. Implemented 3D scanner with 3D printer unit.

In Figure 12, the flowchart of full automated 3D scanning process can be seen. In first stage, the initialization of the hardware and placement of the camera and calibration patterns should be done using DAVID3 software. Then, in order to determine the initial position of the object, the object is illuminated with the laser beam which is controlled vertically with NEMA17 stepper motor. After scanning operation is initiated, the end point of the laser is sensed via DAVID software via the camera view. When a scan is completed in y-axis, the laser is moved to the initial position of it by stepper motor via microcontroller.

When the scanning process is completed, the camera recording is saved as a distinct scan. Then, the object is rotated by 45 degrees with another stepped motor via microcontroller. The laser scan is repeated to get another distinct scan until a total of 360 degrees rotation is completed. Finally, the eight distinct scans are combined using another open source program "MeshLab". In Figure 13, scanning of an object (a paper cup) can be seen from beginning to end.

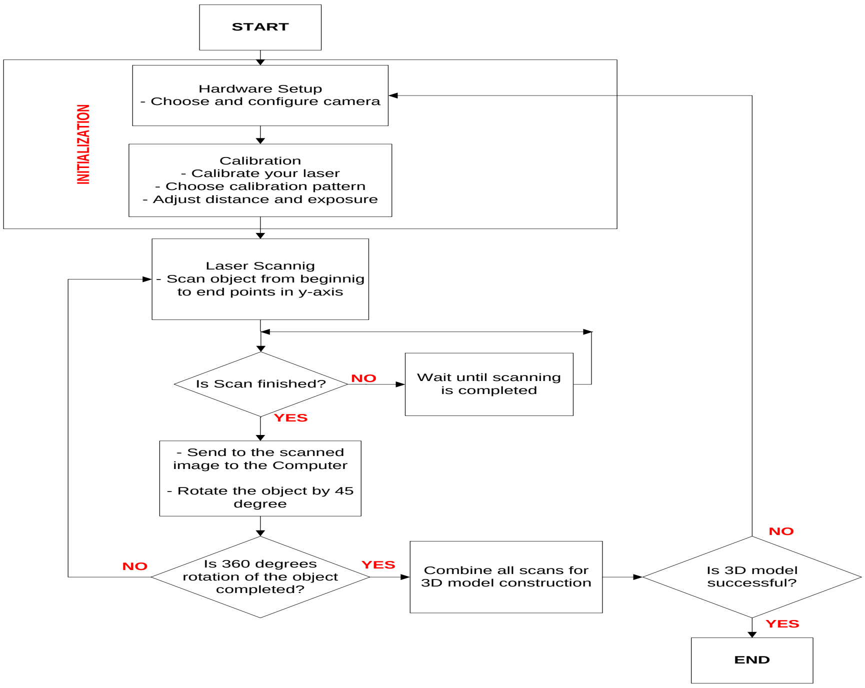
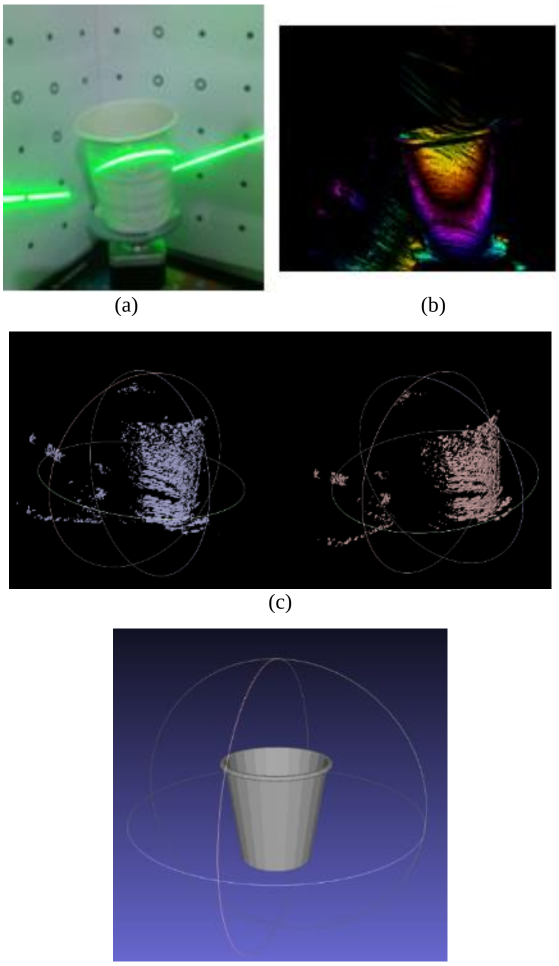


Figure 12. Flowchart for full automated scanning



(a) (b)

(c)

(d)

Figure 13. Complete 3D Scanning process
(a) Laser scanning of an object, (b) Scanning from only one direction in DAVID, (c) Multiple scans are combined in MeshLab, (d) Final 3D model of same object in MeshLab

Our proposed 3D image construction solution is a low cost counterpart of the direct solution offered with DAVID's licensed version of the software. The quality of our solution is reasonable as can be seen from Figure 9. The constructed 3D model output can be later used for different purposes such as reproduction via 3D printer, analyzing or improving the object in computer. In the following figures, some of the scanned objects and their scan results can be seen.

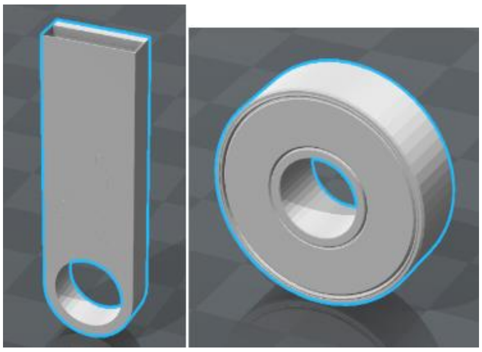


Figure 14. Scan results of two objects

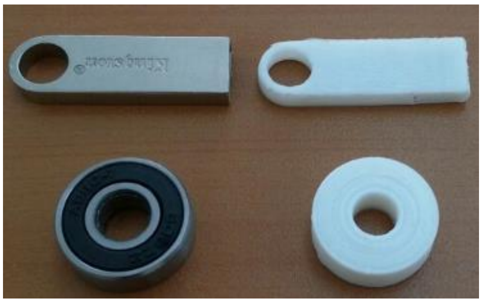


Figure 15. Original objects and their reproductions using proposed 3D-scanner/printer

Figure 16. Original objects and their reproductions using proposed 3D-scanner/printer

IV. CONCLUSIONS

In this paper, implementation of a low cost 3D scanner is presented. It follows the well-known DAVID laser scanner v3 design procedures and uses its open source (free) software together with another free software MeshLab for 3D model construction. Moreover, motorized motion for laser and platform controlled by microcontroller and stepper motors are included into the original design. The total cost of the 3D scanner is approximately $63 with the help of commercial, non-expensive components and using totally free software. Hence, low cost 3D scanner is implemented successfully.

As it can be seen from figures, the 3D model obtained as the output of implemented design has sufficient quality. Hardware setup and calibration phases are very important for scanning performance. When the scanning operation is not satisfied, or failed, firstly the hardware and calibration must be checked. Moreover, stepper motor speed of the laser unit should be chosen to obtain good resolution.

APPENDIX

Construction Cost of 3D Scanner

Table 1 shows the total cost of 3D scanner with and without 3D printer. As seen from Table 1, the implementation cost of 3D scanner is approximately $63.

Table 1. Approximate Cost for 3D scanner

Unit	QTY	Cost ($)
CNC Shield Expansion Board for Arduino 3D Printer + 4 x A4988 Stepper Motor Driver with Heat Sink + micro usb + UNO R3	1	10.30
CE certification 78 oz-in 4-lead NEMA17 Stepper Motor 42 motor NEMA 17 motor 42BYGH 1.7A (17HS4401) 3D printer motor and CNC XYZ	2	8.60
With 18650 Battery 10000 mW laser pointer pen adjustable focus lit match Leisure 303 keyed for 5000-10000 meters green laser	1	8.80
Logitech V-UBM46 Webcam	1	~10
5mW 650nm Red Line Laser Module Focus Adjustable Laser Head 5V Industrial Grade	1	1.48
Bread board + Button + Wire		~5
12v 5A Power Supply		~10
Total Cost for 3D scanner only:		~62.78
Flying bear DIY 3D Printer kit Full metal Large printing size High Quality Precision Makerbot Structure Gift	1	321.10
Total Cost including 3D printer:		~383.88

NOMENCLATURES

3D Three-Dimensional
CAD Computer Aided Design

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This implementation is based on the well-known DAVID laser scanner v3 using the open source programs of DAVID and MeshLab. The authors are grateful to the suppliers for allowing to be used freely. This work has also been supported by TUBITAK 2209/A - Domestic University Students Research Projects Support Program, Turkey.

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BIOGRAPHIES

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