Raspberry pi and Matlab based 3D Scanner

Sera Mathew[1], Ahnas Muhammed [2], Allen Boby[3], Sahid P[4]

Assistant Professor, Dept. of EEE, MA Engineering College, Kothamangalam, Kerala, India[1]

B. Tech Student, Dept. of EEE, MA Engineering College, Kothamangalam, Kerala, India[2]

B. Tech Student, Dept. of EEE, MA Engineering College, Kothamangalam, Kerala, India[3]

B. Tech Student, Dept. of EEE, MA Engineering College, Kothamangalam, Kerala, India[4]

ABSTRACT: A 3D scanner is a device which analyses a real world object to collect raw data on the shape and appearance of the object. Digital 3-dimensional model can be constructed by the data that has been collected.3D scanners are relatively new technologies that have many useful applications, but yet very few people own them, mostly due to the expense of the product. We will propose a way to create an economic standalone 3D scanning system, through which by the information taken by a camera and line lasers, digitized 3D models can be created. The proposed 3D scanner uses laser triangulation method for obtaining the 3D model. Raspberry pi is the main controller used. The 3D models created can be used in digital animation or printed with 3D printers for a wide variety of applications.

KEYWORDS: Laser triangulation, scanning, 3d model, Raspberry pi.

I.INTRODUCTION

3D scanners are very analogous to cameras. Like cameras, they have a cone-like field of view, and like cameras, they can only collect information about surfaces that are not obscured. While a camera collects color information about surfaces within its field of view, a 3D scanner collects distance information about surfaces within its field of view. The "picture" produced by a 3D scanner describes the distance to a surface at each point in the picture. This allows the three dimensional position of each point in the picture to be identified. For most situations, a single scan will not produce a complete model of the subject. Multiple scans, even hundreds, from many different directions are usually required to obtain information about all sides of the subject. These scans have to be brought in a common reference system, a process that is usually called alignment or registration, and then merged to create a complete model. This whole process, going from the single range map to the whole model, is usually known as the 3D scanning pipeline 3D laser scanning developed during the last half of the 20th century in an attempt to accurately recreate the surfaces of various objects and places. The technology is especially helpful in fields of research and design. The first 3D scanning technology was created in the 1960s. The early scanners used lights, cameras and projectors to perform this task. Due to limitations of the equipment, it often took a lot of time and effort to scan objects accurately. After 1985, they were replaced with scanners that could use white light, lasers and shadowing to capture a given surface. Next is a brief history of the 3D scanning development. Real world object or environment are analyzed by a 3D scanner device which helps in collecting raw data on the shape and appearance of the object. Digital 3-dimensional model can be constructed by the data that has been collected. The technical goal ofthis project is to make a 3Dappearance of the structure or object so that we can scan as well as compute the whole of it. Basically our main concern is to find out the specific dimensions and to make a digital replica of an object. We are not only bothered for the shape and size but we do need to consider the color as well. Specifically we need to compute whole surface reactance of each and every point that are scanned on the structure. 3D models generally represent an interesting tool for documentation and interactive visualization purpose, so that a virtual replica is formed. Many efforts are being taken into consideration to achieve and compare visually pleasant 3D models. The fundamental needs of user are based on the criteria's like geometric and metric quality of 3D model, amount of time processing, modeling problems and equipment cost which should be less as well as efficient with precision. There are two different basic operating principals which are used for 3D laser scanning techniques. The first uses the interference phenomena of laser light and analysis of the optical fringes produced, to detect an image of an object surface texture and profile. It is applied to small areas (smaller than 1 cm2) and high resolution (less than 1 micrometer) can be achieved. This technique is known as micro-profilometry which is mainly

used in micro technologies but are not found Secondly the other operating principle is known as laser triangulation, which mathematically relates between the directions the emitted laser beam and the direction of the detected refection which isallowed for gaining the information of the position of an object surface point. Thistechnique is applied toobjects with typical dimensions from 1 cm to 1 m and can achieve a few micrometers resolution. This technique is very well used for musiologicalartwork and to gain further details of the selected parts of the larger monuments. The overall scanning of laser beam over the complete surface of an object is obtained in different manners, associated to the dimensions of the imaged areas and the required resolutions.

II.DESIGN OF 3D SCANNER

This 3D scanner uses a very simple triangulation setup using a camera and a line LASER. The LASER diode is positioned such that it creates a triangle with the view direction of the camera. As you can see from the image, the LASER line projects on the object and intersects the view direction of the camera exactly at the axis of rotation of the object.
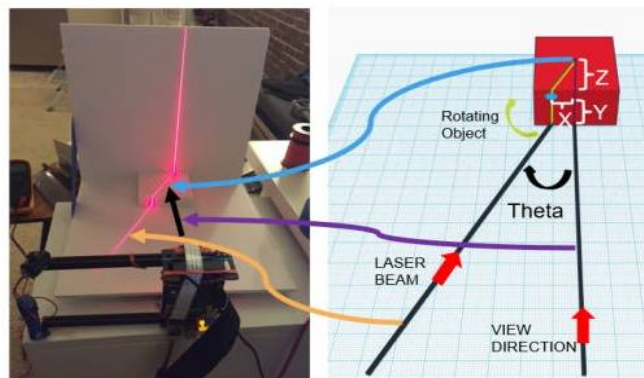

Fig. 1 Laser triangulation

The angle at the intersection of the LASER line and the view direction(we will call it THETA) provides us with the first tool for extracting depth related information from the image captured by the camera.

III.PRINCIPLE OF WORKING

In this project, we decided to use one of the most basic scanning techniques focusing more on getting the entire mechanism to work with the shelf components rather than get the best possible results. Raspberry Pi serves as the main controller board for the setup, capturing the images using the Pi Camera, controlling the Line LASER diode and providing control signals to the EasyDriver (Stepper Motor Driver). I have used MATLAB and the Raspberry Pi Hardware support package to implement the algorithm and deploy it to the Raspberry Pi. This step helped me reduce the time required to setup the controller board, and allowed me to focus on getting the mathematics behind the scanning algorithm correct. An image of a 3D object provides the projection of the object onto a two dimensional plane. It is trivial to extract the X and Y coordinates of any point on the object since they lie within the image plane. However, the information related to the depth of the point with respect to the center of the object is lost due to the projection. In order to retrieve this information, we need some special help. Thankfully, this is not as difficult as it sounds. Let us assume that the Y coordinate corresponds to each line of pixels in the image and maps to the actual Y coordinate through some scaling factor. At each Y coordinate, the point on the surface of the object where the LASER line projects itself, the intersection of the LASER line with the view direction of the camera (if there was no object to block its path) and the perpendicular dropped from the point on the surface to the view direction form a right-angled triangle. The length of the perpendicular dropped on the view direction gives us the distance of the surface point from the view direction and can be considered as our X coordinate with some scaling factor. The other smaller side of the triangle gives us the

depth of the surface point with respect to the axis of rotation, again with a scaling factor. As you can see, the calculations are basic trigonometrical operations. Now, let's use this information to build our basic scanning algorithm. In order to extract 3D information of each point lying on the surface of the object, we need to first deter-mine the points at which we can extract this information. This can be achieved very easily by capturing two images once without the LASER on and once with the LASERon. Since everything else in the view of the camera remains the same, difference of the two images should give us all the points that lie on the LASER line projected on the object. By converting the difference image into a binary image, we can remove most of the extraneous information in the difference image and mark all points lying on the LASER line in white and the remaining pixels of the image as black. We can further narrow down our region of interest by making assumptions about the rectangular area that covers the entire object in the image. Now we have all the necessary components available for extracting the 3D coordinates of every point lying on the surface of the object. There is still one part that still needs to be taken care of. The points extracted from the images lie on the same image plane and are not oriented correctly in the 3D space. For this, we need to rotate each extracted 3D point by some amount about the axis of rotation. By carefully keeping track of the rotation of the object, we can easily determine the angle by which the points need to be rotated after each rotation step.

IV.EXPERIMENTAL SETUP

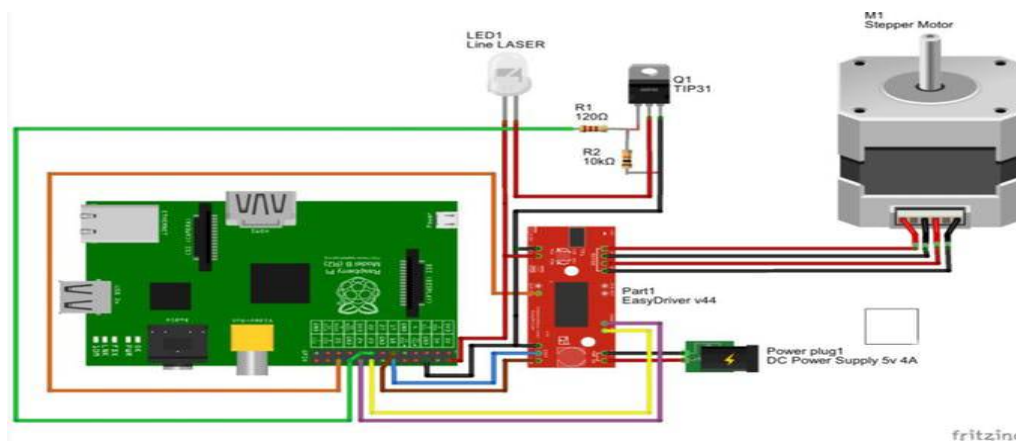The figure given below shows the circuit diagram of a 3d scanner. Raspberry pi is the main controller used.

Fig. 2 Circuit diagram

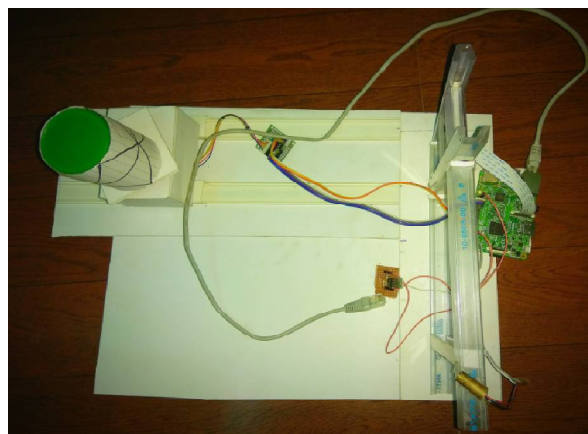The above shown circuit diagram is implemented as shown below

Fig. 3 Experimental setup

As seen in the figure, the object to be scanned is kept on a turn table which is rotated by means of a stepper motor. The pi camera takes the images of the object.

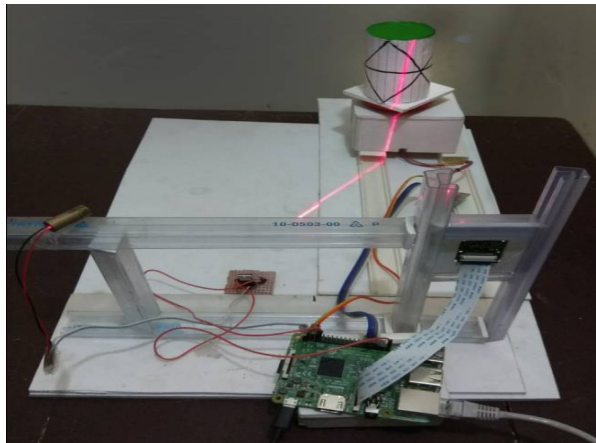The laser used is a line laser and will produce a line on the object as shown below

Fig. 4 working of 3D scanner

An image is taken with this line on the object. Then the laser is made off and another image is taken at the same position of object. Then the object is rotated and this process is repeated.

V. RESULT

The object to be scanned is kept on the turn table. The turn table rotates and imagesof the object with laser and without laser are taken. While taking images, the points are generated by matlab and these points are added to the cloud. After rotation of 360degrees, all the pints are added to the cloud and a file is created in matlab containinginformation of the points. This file is then processed in a software named meshlab to get the 3D image of the object. In this project, a cylindrical shaped object as shown below was scanned.
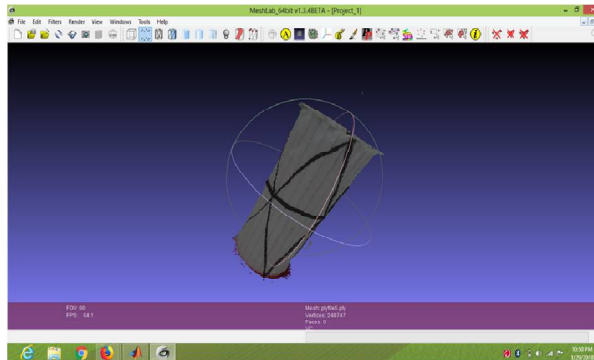

Fig. 5Object to be scanned

Fig. 6 3D image of the scanned object

The above figure shows the 3D image of the scanned object. This figure can be rotated to see all the sides of the image.

VI.CONCLUSION

During the course of this project it was possible to develop a complete 3D scanner by pairing a camera with a laser line projected onto the object to be scanned. Afterstartup, the scan completes entirely autonomously, and after the scan has completed, the resulting file can be copied onto one or more machines to be opened in modelling software. The automatic scanning process first generates a point cloud calculated based on the laser line position in the image captured, then the point cloud is used to calculate faces and generate a solid 3D object. The scanning process takes about 45 minutes to obtain the 3D model of the object.3D scanning makes it possible to easily obtain a highly accurate 3D images of all of the existing components without having to draw them in 3D.

REFERENCES

[1] Cappelletto, E.; Zanuttigh, P.; Cortelazzo, G.M. Handheld Scanning with 3D Cameras. In Proceedings of the IEEE 15th International Workshop on Multimedia Signal Processing (MMSP), Pula, Croatia, 30 September–2 October 2013; pp. 367–372.
[2] L. Gilpin, '8 things you need to know about 3D scanners - TechRepublic', TechRepublic, 2015. [Online]. Available: http://www.techrepublic.com/article/8 -things -you -need -to - know -about -3d -scanners/. [Accessed: 08 - Dec - 2015].
[3] 3dscanco.com, 'Benefits of 3D Scanning, 3D Scanners and Reverse Engineering', 2015. [Online]. Available: http://www.3dscanco.com/about/3d -scanning/benefits.cfm . [Accessed: 08 - Dec - 2015].
[4] LIM Innovations, 'Photogrammetry: Turning photos into 3D scans - LIM Innovations', 2015. [Online]. Available: http://www.liminnovations.com/photogrammetry -photos - 3 d -scans/. [Accessed: 09 - Dec - 2015].
[5] D. Lanman and G. Taubin, "Build Your Own 3D Scanner: Optical Triangulation for Beginners", Mesh.brown.edu, 2016. [Online]. Available: http://mesh.brown.edu/byo3d/links.html. [Accessed: 20 - Nov - 2016].
[6] Pololu.com, "Pololu - A4988 Stepper Motor Driver Carrier", 2016. [Online]. Available: https://www.pololu.com/product/1182. [Accessed: 17 - Oct - 2016].
[7] Bogdanova, G.; Todorov, T.; Noev, N. Digitization and 3D scanning of historical artifacts. Digital Present. Preserv. Cultural Sci. Herit. 2013, 3, 133–138.
[8] Bindean, I.; Stoian, V. Determination of the Remaining Bearing Capacity of an Existing Slab Using 3D Scanning Technology. In Recent Advances in Civil and Mining Engineering; WSEAS Press: Athens, Greece, 2013; pp. 136–140.
[9] Ciobanu, O.; Ciobanu, G. The use of 3D scanning and rapid prototyping in medical engineering. Fiabil. Durab. 2013, 1, 241–247.
[10] Gu, F.; Xie, H. Status and development trend of 3D laser scanning technology in the mining field. Adv. Intell. Syst. Res. 2013, doi:10.2991/rsete.2013.99.
[11] Shih, J.; Lin, T. Fusion of image and laser-scanning data in a large-scale 3D virtual environment. Proc. SPIE 2013, 8881, doi:10.1117/12.2030996.
[12] Dawson, P.C.; Bertulli, M.M.; Levy, R.; Tucker, C.; Dick, L.; Cousins, P.L. Application of 3D laser scanning to the preservation of fort conger, a historic polar research base on Northern Ellesmere Island, Arctic Canada. Arctic 2013, 66, 147–158.
[13] Cong, P.; Xiong, Z.; Zhang, Y.; Zhao, S.; Wu, F. Dense Single-Shot 3D Scanning via Stereoscopic Fringe Analysis. In Proceedings of the 2013 IEEE International Conference on Image Processing, Melbourne, Australia, 15–18 September 2013.