3D Laser Scanner

Prince Khatarkar, Rahul Gupta and Ayush Shakya

Abstract—*The problem statement is to build a 3D Laser Scanner on Arduino platform. This scanner will use a linear laser to scan objects and make their point cloud. A linear laser has projection as a line (in comparison to point laser which has projection as a point). Using this laser, we will generate a 3D point cloud of the object with the help of code written in Processing IDE. This software is favoured as its IDE is similar to Arduino. The object to be scanned is placed on a rotating platform and laser is made to fall on it (preferably in dark). The webcam takes pictures of the object with line projection of the laser using which, the code returns Cylindrical co-ordinates of all bright points from the picture taken, which creates a 3D point cloud, executable in Meshlab.*

Index Terms—*Arduino platform, linear laser, point cloud, Processing IDE, rotating platform, webcam, Cylindrical co-ordinates.*

1 Introduction

Basically a 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance (i.e. color). The collected data can then be used to construct digital three-dimensional models.

Many different technologies can be used to build these 3D-scanning devices; each technology comes with its own limitations, advantages and costs. Many limitations in the kind of objects that can be digitized are still present, for example, optical technologies encounter many difficulties with shiny, mirroring or transparent objects.

Collected 3D data is useful for a wide variety of applications. These devices are used extensively by the entertainment industry in the production of movies and video games. Other common applications of this technology include industrial design, orthotics and prosthetics, reverse engineering and prototyping, quality control/inspection and documentation of cultural artifacts.

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2 Motivation Behind the Project

When it comes to 3D scanning, thoughts often tend towards the endless opportunities to study things and shapes that were previously impossible. However, 3D scanning is also a perfect technology for fixing the previously unfixable. The purpose of a 3D scanner is usually to create a point cloud of geometric samples on the surface of the subject. These points can then be used to extrapolate the shape of the subject (a process called reconstruction). If color information is collected at each point, then the colors on the surface of the subject can also be determined.

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. One example of using 3D scanning to fix a simple problem was a broken Ceiling Lamp. One of the clips holding the glass cover had gone missing, which would make the lamp dangerous, as the glass cover could easily fall down.

Throwing the lamp away or buying a new lamp seemed like such a waste just because a tiny little piece was missing. After scanning a similar clip, the 3D design was ready. Its a simple design of a small piece that needs to bend in order to fit the socket in the lamp. Then by using a 3D printer one can generate a exact copy of it. Exceeding all expectations the piece fit perfectly!

We three were fascinated with the futuristic scope that 3D Laser Scanning hold.

3 Background Theory

The technology that we are using for our project is known as **Structured Light Method**. Structured-light 3D scanners project a pattern of light on the subject and look at the deformation of the pattern on the subject. The pattern is projected onto the subject using either a laser or other stable light source. A camera, offset slightly from the pattern projector, looks at the shape of the pattern and calculates the distance of every point in the field of view.

Structured-light scanning is still a very active area of research. Perfect maps have also been proven useful as structured light patterns that solve the correspondence problem and allow for error detection and error correction.

The advantage of structured-light 3D scanners is speed and precision. Instead of scanning one point at a time, structured light scanners scan multiple points or the entire field of view at once. Scanning an entire field of view in a fraction of a second generates profiles that are exponentially more precise. This reduces or eliminates the problem of distortion from motion. Some existing systems are capable of scanning moving objects in real-time.

4 Implementation Details

We have to find Cartesian coordinates of points which belongs to scanned object. Basically, we are looking for distance, between rotation axle(of rotating platform) and a point marked red by laser ("ro" on the "Picture 1"). To found this, we have to measure how many pixels are between optical axle of camera and laser-marked point. On picture, this distance is marked as "b". Angle between laser and camera axle is constant and equals "alpha". Using simple trigonometry, we can calculate "ro":

$$\sin(alpha) = \frac{b}{ro}$$

,

which means that

$$ro = \frac{b}{\sin(alpha)}$$

This operation repeats every layer, then rotating platforms move by some angle and whole operation repeats.

Let's move to second picture. Previous operations gave us coordinates in polar coordinates system. In polar system, every point look something like that: P = (distance from Z axis, angle between point and X axis, Z)

which is

$$P = (ro, fi, z)$$

.

"ro" is our distance, measured in previous operation, "fi" is an angle of rotating platform. It grows an constant amount, every time platform rotate. This constant amount in equal

$$\frac{360^\circ}{numberofoperation}$$

, for example- for 120 profiles around object, platform moves about

$$\frac{360^\circ}{120} = 3^\circ$$

. So after first move, $fi = 3$, after second $fi = 6$, after third $fi = 9$ etc.

"z" value is the same value as "z" in Cartesian system.

Conversion from polar to Cartesian is very simple:

$$x = ro \times \cos(fi)$$

$$y = ro \times \sin(fi)$$

$$z = z$$

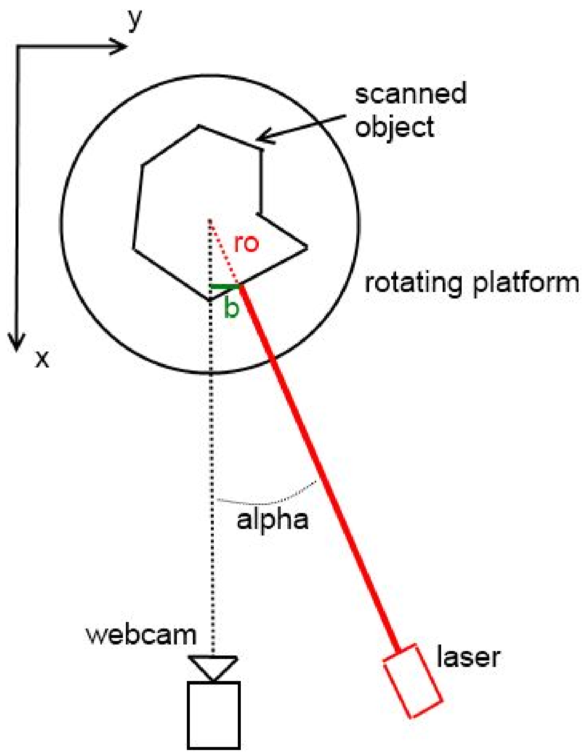
In our hardware we are using a laser diode, to make it linear we have used a glass rod, used a webcam to capture images. For rotating the platform (on which object to be scanned is kept), we have used a continuous rotating servo motor. All this setup is assembled on a base of aluminium sheet covered by a box of perspects fibre.

After capturing images from webcam, we do image processing and obtain brightest point

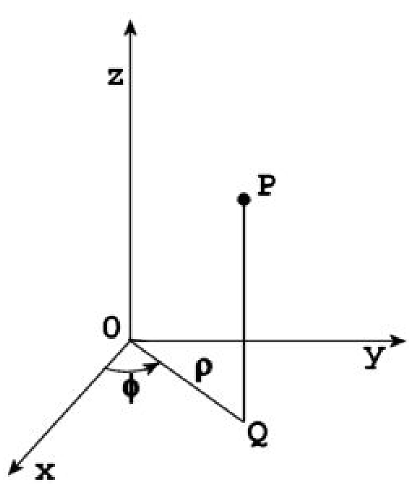
from every row of each image, and then save the data as a file.
Link for the codes-

https://github.com/ayushsha/laser_scanner.git

5 Block Diagrams



Picture 1



Picture 2

6 Compromises made

- Reflective surfaces such as metal or glass make it difficult for the laser scanner to pinpoint a location on the object and often distort the laser beam creating spikes or inaccuracies.
- 3D scanning also has difficulty scanning furry objects, translucent objects, non-solids, or moving objects.
- Highly detailed objects require several more points to be captured accurately, and therefore can be quite tedious to scan or clean the resulting data.
- Sharp points/edges, such as the edge of a knife, are incredibly difficult to scan.
- We could not find a proper gear that could fit in the motor to increase the accuracy of scanning, thus we directly used the motor.
- 3D Scanning is most often used for capturing single objects rather than environments, but some experimental techniques are being evaluated that make use of LIDAR or the Kinect.

7 Future Scope

- Increase effectiveness working with complex parts and shapes.
- Help with design of products to accommodate someone else's part.
- If CAD models are outdated, a 3D scan will provide an updated version
- Replacement of missing or older parts
- Large cost savings when conducting as-built design services in Automotive Manufacturing Plants. Multiple design disciplines can use the 3D Point cloud generated from laser scanning and shared among the various discilpines / trades via a web based application. Thus "Bringing the plant to the Engineers", many dollars in travel costs can be saved as well.

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