

Laser Triangulation for 3D Profiling of Target

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ABSTRACT

In this paper, a simple and low occlusion laser triangulation based 3D scanner with one laser and one high quality web camera is proposed. Laser triangulation technique is used to find the depth of any object. Also finding the angle between incident laser ray and the reflected ray captured by the webcam is one of the critical issues in 3D laser scanning. A simple procedure is proposed to accurately find the same. The scanner design is straightforward, involving simple trigonometry for finding the depth. Its range is small but the accuracy is relatively high then time-of-flight technique. The price of components used also affect the accuracy of the laser scanner. The scanner we have proposed eliminates the need of two lasers, two web cameras and calibration of moving components.

Key words

Laser triangulation, 3D laser scanner, printer port, laser line thinning, low occlusion.

1. INTRODUCTION

One of the most common principles of 3D scanning is laser triangulation because of its simplicity and robustness. The scanner design is very straightforward, involving simple trigonometry. The image captured by the webcam is 2D. The depth of the object cannot be determined from the image. In order to find the depth, laser scanning is done. [1] In laser triangulation, the laser is projected over an object and the image is captured by a camera. Since the price of components used also affect the accuracy of the laser scanner, higher price and branded components will produce better result than low price components. Hence, higher the accuracy to cost ratio, higher will be the optimization. The line joining the laser, object and the camera makes a triangle, hence the term triangulation is coined.

[1] A 3D scanner is used to create a point cloud which can extrapolate the shape of object. The process is called reconstruction. If color information is collected at each point, then the colors on the surface of the subject can also be determined. The proposed approach is cost effective, efficient as the number of laser to reconstruct the 3D image will be one. The size of the apparatus will be compact and no calibration required.

The paper is organized as follows. In the following section, the experimental setup is introduced. In the third section, the system structure for mapping the world coordinates with the window coordinates is introduced. In the fourth section, the algorithm for Laser Line thinning is presented. The fifth section is results followed by conclusion, future scope and the last section is references.

2. TECHNIQUES FOR LASER SCANNING

3D laser scanning can be done by following two ways:

2.1 Time-of-flight technique

It is a distance based technique where the laser is incident on the object and the reflected signal from the object is captured by the webcam and depending upon the difference between the times of there capture, the 3D image is drawn. The signals from the bulged surface will be captured early as compared to the non bulged surface. This technique finds its much use in robotics. Robot can easily sense if there is any obstruction in their path ant depending upon that they can change their path.

2.2 Triangulation technique

In laser triangulation, the laser is projected over an object and the image is captured by a camera and the line joining the laser, object and the camera makes a triangle as shown in the Figure 1, hence the term triangulation is coined.

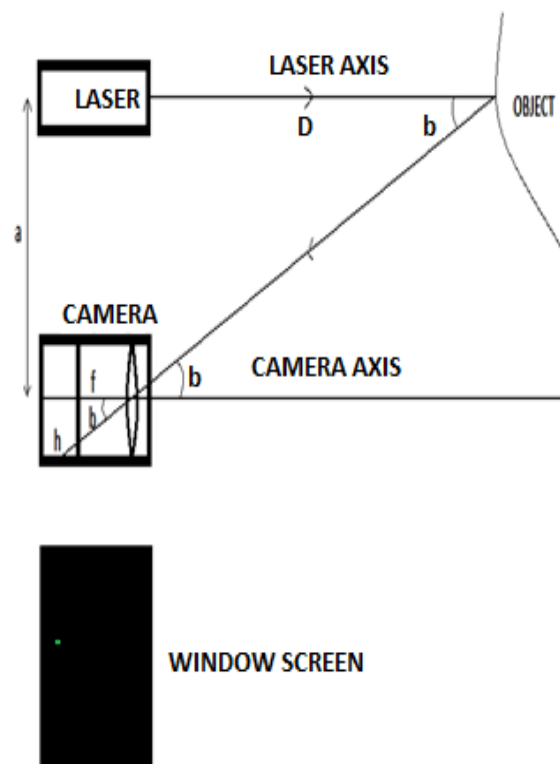


Figure 1: Triangulation technique for laser scanning

The mapping of world to window coordinates can be done when we know the angle between the laser axis and the reflected ray from each position of the object. Laser and camera are kept at a known distance say a . Distance between the laser and the object is say D . Focal length of camera is also known say f . [2] Finding the angle between the laser axis and the reflected ray "b" is a big problem. A simple, less time and space consuming way of finding b is proposed here.

From the figure 1

$$\tan b = a/D$$

Also, $\tan b = h/f$

From above two equations:

$$\Rightarrow \begin{aligned} h/f &= a/D \\ D &= (a * f)/h \end{aligned}$$

D for each point is calculated and is stored in a 2D array and for each D corresponding value of b is calculated. In the above Figure D and b for a particular point is calculated and depending upon their values the point is plotted on the screen as shown by the dot. When all the points on the object are scanned, the image formed on the screen is 3D.

[3] Once the point is drawn on the screen, we can rotate the axis in any direction, so that we can have a 3D visual. The axis and the point are shown in Figure 2.

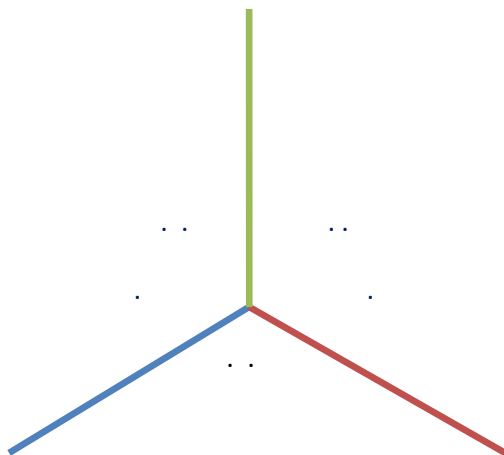


Figure 2: 3D location of various points

3. EXPERIMENTAL SETUP

The setup consists of a laser, webcam, motor, motor driver, power supply, mirror printer port as shown in the Figure 3. Laser beam directly hits the mirror mounted on the motor. The use of motor reduces the overload of laser to scan the object directly. The motor constantly moves clockwise and counter clockwise direction. Hence, the reflected laser from the mirror also moves clockwise and counter clockwise direction. The object is placed in front of the reflected laser. The scan area of laser is adjusted in such a way that it should cover only the object and nothing beyond that. There is a webcam placed parallel to the laser source which captures the image of the object while it is scanned. Printer port is connected to the motor driver which helps in moving the

mirror in both directions. The speed of motor can also be adjusted.

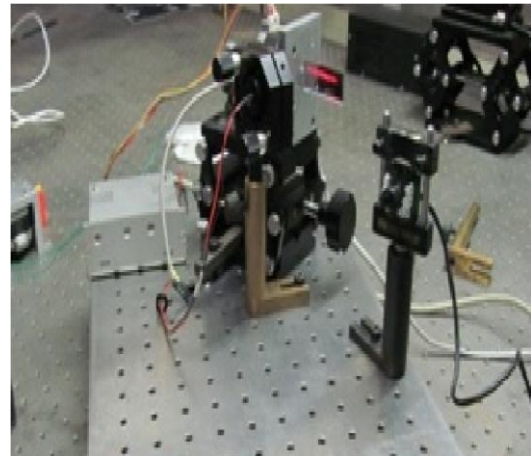


Figure 3: Experimental setup

[4] A point laser can also be used for the same experiment but we have to place a cylindrical lens in front of it to make it a line as shown in Figure 4. When the object is in the scanning phase, all the points are plotted on the screen simultaneously. A line will cover more than one pixel. In order to avoid this, thinning algorithm is used. [5] Line thinning is important to data compression, raster to vector conversion and pattern recognition.

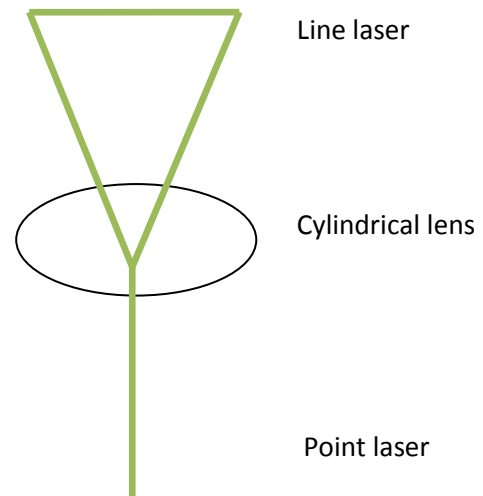


Figure 4: Point to Line laser conversion

4. ALGORITHM FOR LASER LINE THINNING

Consider an array $a[m][n]$ as shown in Figure 5, where m is the number of rows and n is the number of column. The algorithm used will scan the array column wise from left to right. The boxes shown are the pixels and the corresponding pixel values are shown.

The algorithm will consider the first '1' encountered in the column and that '1' will be printed at the same position in another array say $b[m][n]$. After the first '1', the control goes to the second column, bypassing the rest 1's in the same column. This algorithm considers the upper pixels. The logic is based on first come first serve strategy.

a[1]				
a[2]				1
.			1	1
.		1	1	
.	1	1		
.	1	1		
a[n]	1			

Figure 5: Original array i.e. a[m][n]

The output of the following algorithm is Figure 6 where the line passes through only one pixel.

```

for (j = 1 to m )
{
    for( i = 1 to n )
    {
        if(a[i][j] == 1)
        {
            b[i][j] = 1
            Break and come out of inner for loop
        }
        Else
            b[i][j] = ""
    }
}
    
```

a[1]				
a[2]				1
.			1	1
.		1		
.	1			
.				
a[n]				

Figure6: New array i.e. b[m][n]

5. RESULTS

When the scanning is done, the 3D image of the object is obtained. We can do scanning vertically as well as horizontally, Figure 7 shows output by horizontal scanning of object and Figure 8 shows output by vertical scanning of object. Scanning is not done in one go. It is a gradual process and takes many iterations (say 5 to 6) to form a 3D image of any object. We can change the speed of scanning by simply changing the speed of motor. This can simply be done by using a delay function.

In Figure 7, the scanning is done from left to right, whereas in Figure 8 the scanning is done from top to bottom. Left to right or top to bottom indicates the movement of mirror and the

corresponding reflected laser. In Figure 7, iteration process is going on but in Figure 8 it is complete.

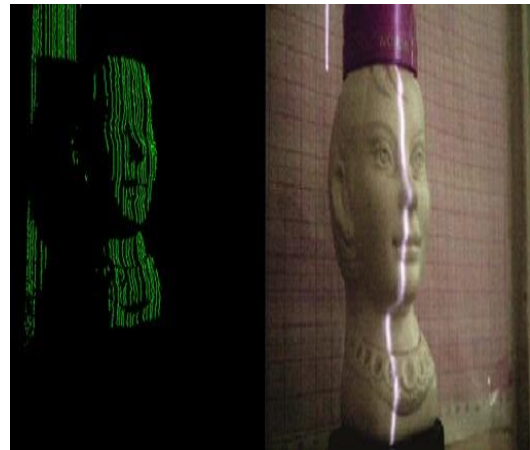


Figure 7: Output by horizontal laser scanning of object

Small gaps may be visible in the output due to irregular speed of the laser. If the laser speed is more, there is every possibility that the output 3D image may miss in some pixel positions. This could be visible even if the speed is too slow. In order to get a perfect gap free output the movement should be normal.

To achieve better quality the object should to be placed near the laser source and dark room is preferred for the experiment. The performance of the scanner depends on many factors discussed in [6].

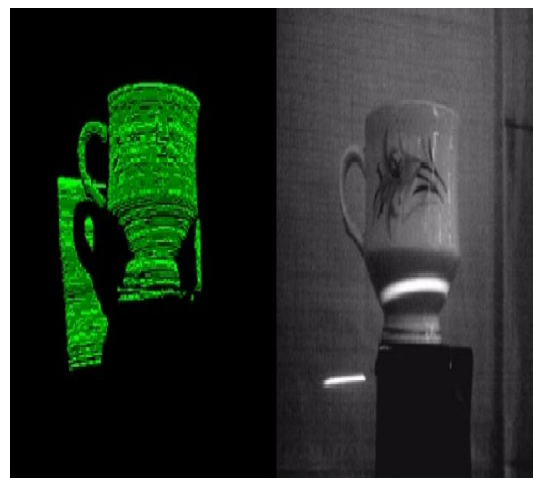


Figure 8 : Output by vertical laser scanning of object

Sometimes thresholding is required since noise is generated while reconstructing the depth which leads to error. [7]A Gaussian filter with a width of a few pixels can be used for filtering purpose.

6. CONCLUSION

Laser triangulation because of its simplicity and robustness gives more accurate results as compared to time-of-flight technique. The scanner we have proposed eliminates the need of calibration of moving components. Also the cost of previous 3D scanner is much more but the scanner we have demonstrated is a working configuration whose components cost much less. Thus, higher quality can be achieved with the same cost.

Table 1 shows the comparison between previous approach and the proposed approach is given below:

Table 1. Comparison between previous approach & proposed approach

Properties	Previous approach	Proposed approach
No. Of Lasers used	Two	One
Cost	High	Low
Output	3D image	3D image
Apparatus Size	Large	Compact
Calibration	Needed	Not Needed
Occlusion	High	Low
Efficiency	Medium	High

The only limitation with this technique is when the laser is reflected from the mirror, its intensity decreases but that can be avoided too by placing the object nearer to the laser source and by performing the experiment in dark room.

7. FUTURE SCOPE

The video chat feature provided by various softwares like yahoo messenger or Skype is 2D but with the use of laser triangulation technique one can have 3D video chat.

Laser triangulation range finders are used in many industrial applications like road profiling, Hoist applications, metal industry, medical Industry. Some other applications are [8][9]. 3D scanners are used by the entertainment industry to create digital 3D models for both movies and video games [10][11]. Laser scanner can also be used at state barriers for checking what the vehicles are carrying (for security purpose). This method is much easier and less time consuming than using a 3D modeling software on a computer that can potentially take hours to complete. If the range of scanner is increased then it can be used in the defence - for finding the size of any explosive material.

3D scanner can be used in accident investigation. Accidents can be 3d laser digitize and the scene of the actual accident can be explored [12] [13].

3D laser scanner can also be used in medical science. Figure 9 [14] shows a 3D scan of cadaver mandible.

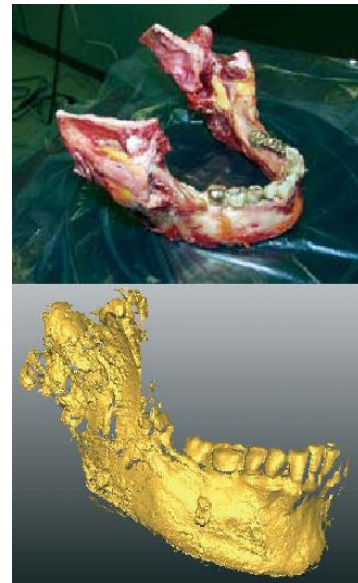


Figure 9: 3D scan of cadaver mandible

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