

Development of Fast and Low Cost Vision-Based 3D Scanner for Surface Registration of 3D Shapes

J.M.L.C. Piyathilaka and R.M.T.C.B. Ekanayake
Uva Wellassa University, Badulla, Sri Lanka

Introduction

A 3D scanner is a device that inspects three dimensional objects to collect data on its shape and possibly its appearance. The collected data can then be used to re-engineer, three dimensional models useful for wide variety of applications. Unlike conventional 2D scanners used in office environment which can only scan plane objects like images on paper, 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.

3D scanning technology can be used to produce highly value added products in existing local industries. Potential uses of 3D scanning technology in the Sri Lankan industries are endless.

Reconstruct replicas of precious artifacts, national monuments are possible applications. These replicated models have higher demand in local and international markets.

Another application area is the garment industry. The 3D scanner enables us to examine the human body in ways never before possible, including the shape of a cross section, slice area, surface area, and volume. This not only makes the body measurement process much more convenient for the customer, it also estimates the need for changing rooms. This technology can be used to manufacture custom stitched highly value added garments for international markets.

3D scanning can also be used in quality control and inspection. It can precisely analyze the "as built" condition of parts after they have been manufactured. Typically, non-contact technology is used to quickly inspect the overall shape and size of parts, quickly detecting issues such as overall scale issues. 3D scanners existing in the market are in the range \$100k to \$400k.

In our previous research (Ranasinghe *et al.*, 2010) we developed a scanner projecting laser beam onto the object and capturing video sequence while rotating the platform via a stepper motor. Recorded video sequence is then processed to construct the 3D shape of the object. Main limitation of this project's outcome was that scanning process took more than 3 minutes to complete, dimensions of the object were not recorded and image processing and surface construction was done off-line. In the present research, we further developed the existing system in order to overcome these limitations. We introduced a spiral shaped platform that replaced the circular platform. Since the radius of the used spiral shaped platform changes as a function of rotation angle we were able to record the rotational angle real time by image processing the video. Also the known dimensions of the spiral shaped platform are used to calibrate the dimensions of the scanning object. Introduction of the spiral shaped platform reduced the scanning time considerably and allowed recording the dimension of the objects real-time.

Methodology

A light proof compartment is created and the object is placed on the rotatable spiral shaped platform. A vertical laser line is created using a pointed laser source and projected onto the object which deforms rendering shape of the object. 16MP digital camera is mounted inside the compartment at an angle of 35 degrees (25 to 40 degrees was tried and this angle depends on the convex details present on the object being inspected).

While rotating the spiral shaped platform a video clip is captured using the camera that covers the full rotation of the object. When the laser line hits the spiral shaped platform it creates a vertical projected 2D image sequence. This video is then transferred to the computer for processing. Special software was created using Matlab® and OpenCV® to process the video clip. Using this software the video clip was analyzed frame by frame basis and the 3D shape was reconstructed. Spiral shape of the platform was used to obtain the angular orientation of the object. System was calibrated using the dimensions of the spiral platform known prior to analysis.

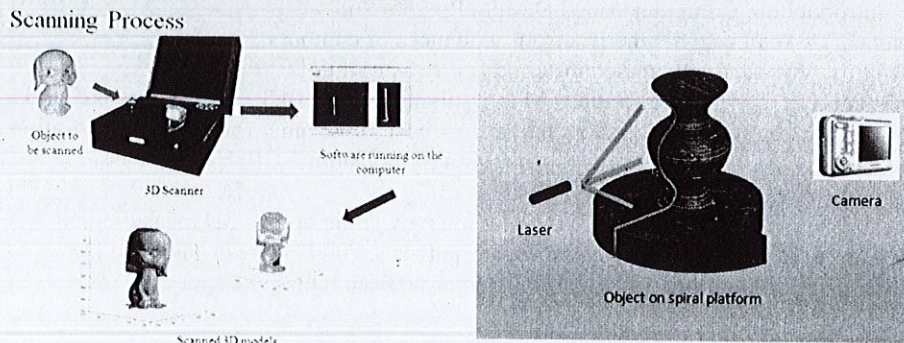


Figure 1: Schematic view of the Scanner

Results

3D objects were successfully reverse engineered using the developed system. Trial runs were done for several objects with different shapes and compared them with their original dimensions. Our system was able to produce dimensions with an accuracy of $\pm 25\%$ even for complex shapes. Full scanning process only took less than 30s and is a considerable improvement for the previous method.

Discussion

It is clear that most of the applications we discussed in the introduction concerns about the reverse engineering of the proper shape than the dimensional accuracy. Therefore, it is clear that our system can be applied to most of the applications that in need of this kind of low cost 3D scanner with required accuracy. Even though we regenerated the object shape using the point cloud produced by our scanning mechanism we were able to obtain surfaces with sufficient smoothness.

Conclusions

It is clear that our scanner is suitable for reverse engineering applications for entertainment industry, fashion industry, ornamental industry etc. The system processing time is less than 30s for a simple object.

As further improvements to the system, we suggest to improve the system to have the ability to import the resulting surfaces to 3D modeling software like AutoCAD®, PTC Creo®, SolidWorks®, CATIA®, Autodesk 3D Max®, Autodesk Maya® etc.

Using high density cameras and very fine beams of laser it is possible to improve the dimensional accuracy of the system further.

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