Shape acquisition of rotating objects based on Laser Line Scanning

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Abstract. The present work proposes a methodology for 3D shape acquisition of objects through rotation-based Laser Line Scanning. This enables the acquisition of an object's 3D shape from multiple views, which leads to a more complete and accurate model.

Keywords: Computer vision · Laser line scanning · 3D shape acquisition.

1 Introduction

A methodology was developed to acquire the 3D shape of a rotating object. It is based on Laser Line Scanning, a widespread [6,1] shape acquisition technique that uses a laser line to obtain the 3D shape of a moving object. The traditional method, using linear motion, usually has the drawback that only a single view of the object can be acquired with a system. By rotating the object, the current methodology aims to allow the acquisition of the whole shape.

The application of the proposed methodology starts with a calibration procedure, involving three components: a Camera, a Laser plane and Motion.

The camera calibration defines the intrinsic and extrinsic parameters and the distortion coefficients and is based on the acquisition of multiple images of a calibration pattern [2].

The second step involves defining the laser plane, i.e. the spatial location of the laser. This can be done using three images where the laser is aligned with notable locations of the calibration pattern, where the world coordinates of those notable points are extracted. Using these, it is possible to define a plane by plane fitting [3].

The motion calibration is performed at a constant frame rate, acquiring an image sequence of the same calibration pattern performing the target motion. From a subset of evenly spaced frames, the axis, angle and centre of rotation between each pair of sequential frames are calculated. This includes the use of a Least-Squares method developed by Spoor and Veldpaus [5] to calculate a best-fit rotation matrix.

Having completed the calibration procedure successfully, the 3D shape of the object under study is obtained using an image sequence of the laser line on the surface of the object under rotation, acquired at a constant frame rate.

The image coordinates of the laser line are extracted from each frame [4] and the laser plane calibration is used to extract the world coordinates of the line, as defined in [3]. This originates a partial model of the object, i.e. a small subset of points, acquired from the laser line at a particular angular position, which is combined with the others to form the final point cloud.

An incremental rotation matrix, i.e. from one frame to the next, is defined from the calibrated data and then the reconstruction of the point cloud from the partial models is performed incrementally. The reconstruction steps can be summarized as:

1. Add a new partial model to the point cloud (matrix $[p]$);
2. Rotate the current state of the point cloud using the incremental rotation matrix (R) and the rotation centre (X_0): $[p] = R \cdot ([p] - X_0) + X_0$;
3. Repeat steps (1) and (2) for every partial model.

At the end of the procedure, a point cloud is obtained for the object under reconstruction.

2 Experimental Setup and Results

The experimental implementation of a 3D laser line scanning based approach requires at least three different components: a camera, a laser line and a positioning system, Figure 1.

The camera was positioned in front of the positioner, forming an angle with the laser line, which was approximately aimed at the centre of rotation.

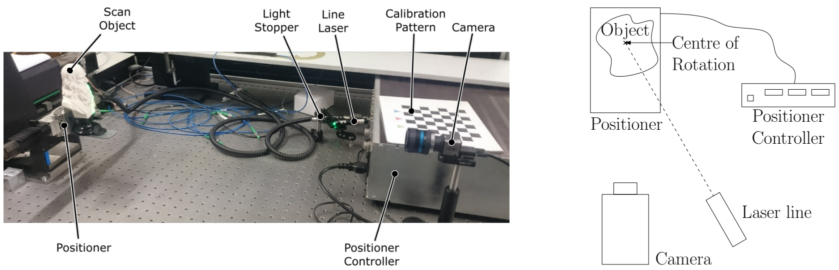

Fig. 1: Used Experimental Setup

The laser line was created using a 520 nm, 50 mW laser from CivilLaser (China) and the positioning system includes a goniometric cradle, BG50-0.01 from Micro-Controle (France). This cradle provides the needed motion, but does not reach a 360° rotation. Nonetheless, for proof of concept, it is enough.

The methodology was applied to the acquisition of a small statue of Leonardo Da Vinci and the results were promising, having obtained a shape that is close to the reality, Figure 2.

Fig. 2: Experimental object used (left) and 3D acquired shape (right)

For validation, the width of the statue's nametag, which measures approximately 40 mm, was compared to the acquired shape. The obtained value was 40.4596 mm, indicating an error below 1.5 %.

3 Conclusions

This work involved the development and application of a methodology for 3D shape acquisition of rotating objects that is based on laser line scanning.

The proposed methodology was applied to the acquisition of a small statue of Leonardo Da Vinci and the results were promising, having obtained a shape that is close to the reality with small errors, around 1.5 %. Meanwhile, the angular resolution of the experimental application was around 0.13° and the radial resolution was approximately 0.35 mm.

The stability of the image acquisition frame rate and of the motion are important factors to consider in order to minimize the errors. Fluctuations in either of those parameters can lead to inaccurate calibrations.

Finally, considering the obtained results, it is possible to conclude that the proposed methodology is a very capable tool for shape acquisition, specially when a 360° 3D shape reconstruction is important.

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