MASTER IN INFORMATICS AND COMPUTING ENGINEERING | 4TH YEAR
EIC0104 | COMPUTER VISION | 2020/2021

PROJECT NO. 1

3D Data Acquisition using a Structured Light Technique

Introduction

Structured light techniques for 3D data acquisition play a central role in many 3D data acquisition applications, namelly when the surfaces to be measured do not have feature points or when it is necessary to obtain dense 3D data. They are used in numerous applications: industrial (ex: dimensional control or quality inspection), reverse engineering, urban (ex: road inspection) and medical, are just a few examples. These techniques are based on the acquisition of an image of a scene over which a light pattern is projected; this pattern ranges from a single light ray or a single light sheet to a set of parallel sheets or a pseudo-random pattern. Frequently, laser light is used to simplify the detection of the projected patterns.

In this work you will have the opportunity of implementing a 3D data acquisition system based on structured light, using a single sheet of light/shadow (figure 1).

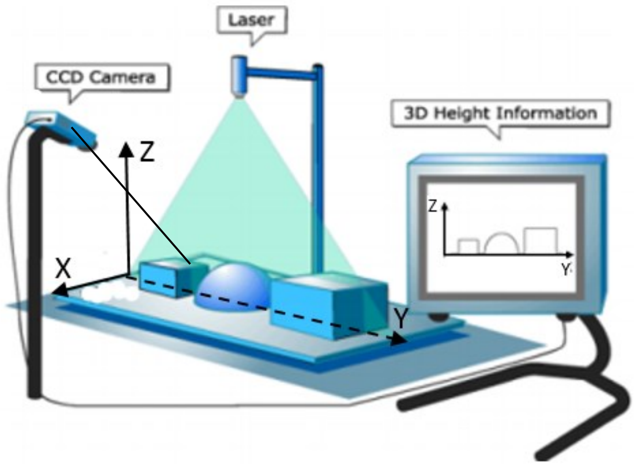

Figure 1 - Structured-light 3D data acquisition system.

General aims

To apply the theoretical knowledge about computer vision techniques, acquired in this course, namely, basic image processing techniques, camera calibration, from a geometrical point a view, and the use of structured light techniques for the calculation of the 3D coordinates of scene points from their 2D coordinates in the acquired images, using the OpenCV library as development tool.

Specific aims

The program to be developed must allow:

- the acquisition of an image of a 3D object, with known shape and dimensions, illuminated by a light/shadow plane;
- the calculation of the 3D coordinates of the points lit by the light/shadow plane.

The work must be done by groups of 4 students.

Equipment and methods

Equipment

The following equipment is needed:

- Camera.
- Laser line projector. Instead of projecting a light plane, using a laser projector, you may project a shadow plane, created using a point light source and a straight object, like a stick, as in [3].
- Object of known size (e.g., a cube).

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Methods

The following processing sequence is suggested:

- Camera calibration (intrinsic parameters): determine the intrinsic parameters of the camera [4].
- Acquisition setup: place the equipment as illustrated in figure 1.
- Camera calibration (extrinsic parameters): determine the extrinsic parameters (pose) of the camera, using one of the methods available in the OpenCV library [5]; check the camera pose by computing the reprojection error.
- Light projection system calibration: you can choose between two solutions: 1) simplify the calibration of the system, by placing the light projection system so that the light/shadow plane is as much as possible perpendicular to the table on which the object is placed (plane x=0, figure 1), in which case the obtained measures may not be very accurate; 2) develop an improved solution (10% of the grade), in which the equation of the light/shadow plane is calibrated.
- Image acquisition: acquire an image of a 3D object with known size (ex: a cube), placed over a flat surface (figure 2), so that it is lit by the light/shadow plane and seen by the camera.
- Line detection: detect the light/shadow line in the acquired image and obtain the coordinates of its central (or edge) points.
- Calculation of 3D coordinates: calculate the 3D coordinates of the points of the object lit by the light/shadow plane, given their 2D coordinates in the acquired image.

Project report and submission

A short report (max. 3 pages) must be delivered (15% of the grade), including:

- any additional specifications (if needed);
- the description of the proposed global solution, including illustrations of the results of the main intermediate steps;
- relevant comments about the efficacy of the used methods, describing the main problems that were encountered and any proposed solutions;
- the status of the proposed method and the degree of fulfillment of the aims;
- an analysis of performance of the system, illustrated with some results; additional results may be presented in annex.

The code, with significant comments, must be presented in annex.

The deadline for work submission is the end of **2021/Apr/16th**. Details about the submission process will be given before the deadline.

After submission, each student must review one report of another group (5% of the grade). It will be a double-blind review, meaning that the authors don't know who the reviewers are and the reviewers don't know who the authors are.

References

- [1] - D. Kim, S. Lee, H. Kim, S. Lee, "Wide-angle laser structured light system calibration with a planar object", International Conference on Control, Automation and Systems 2010, Oct. 27-30, 2010, Gyeonggi-do, Korea, pp. 1879-1882
- [2] - H. Luo, J. Xu, N.H. Binh , S. Liu , C. Zhang, K. Chen, "A simple calibration procedure for structured light system", Optics and Lasers in Engineering, vol. 57, June 2014, pp. 6-12
- [3] - J.-Y. Bouguet, P. Perona, "3D Photography on Your Desk", http://www.vision.caltech.edu/bouguetj/ICCV98/html_report/extended.html
- [4] - OpenCV "Camera Calibration", https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_calib3d/py_calibration/py_calibration.html
- [5] - OpenCV "Pose Estimation", https://docs.opencv.org/4.5.1/d7/d53/tutorial_py_pose.html