Master's Thesis Engineering Technology

2017-2018

Calibration and evaluation system for 3D camera systems

Thomas Aerts

Master of Electronics and ICT Engineering Technology

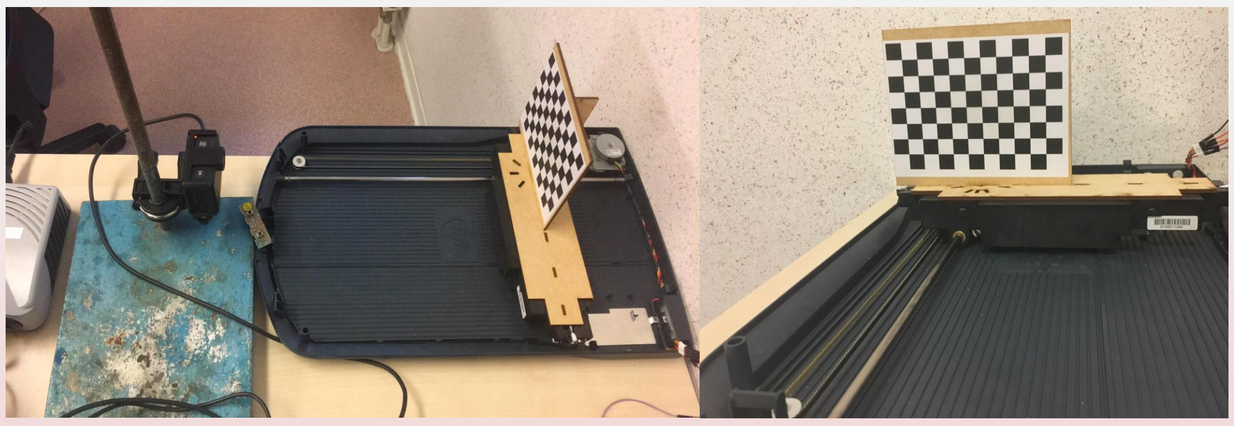
Problem statement

Problem: There is no general setup to test the accuracy of the different available camera pose estimation methods.

Goal: Develop a pose estimation system based on a single-camera setup.

Setup: The practical accuracy of the camera calibration to estimate the XYZ translation and rotation is researched. By measuring the deviation between the practical and ideal model, the deviation can be altered through software implementation that reduce it to a minimum [1].

Use: The camera pose estimation needs to be very accurate, repeatable and user-friendly. It is intended to calibrate cameras that will be used in medical procedures.

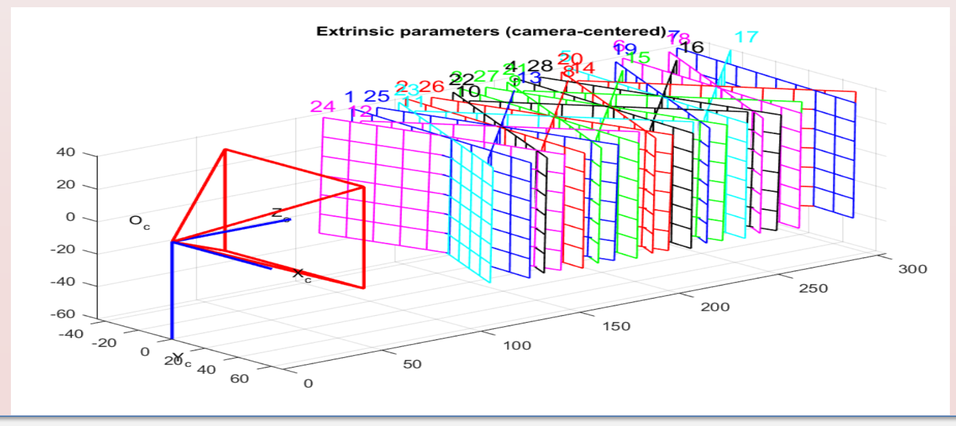


Objectives

- The translation across the axis from which the calibration image will move relatively to the camera must be accurate enough that for a given reference point the calibration is repeatable.
- Rotation along the translation axis will be added. The rotation and the translation must remain stable so that the calibration is repeatable.
- The quantitative data from this calibration must be presented in an interface [2] so that the user can compare the practical data from a current configuration with a previous configuration or an ideal model.
- Testing includes different calibration images, optimizing the used algorithms that provide the ordered data for the user interface and an in depth look at the interface between the microcontroller and the host computer.

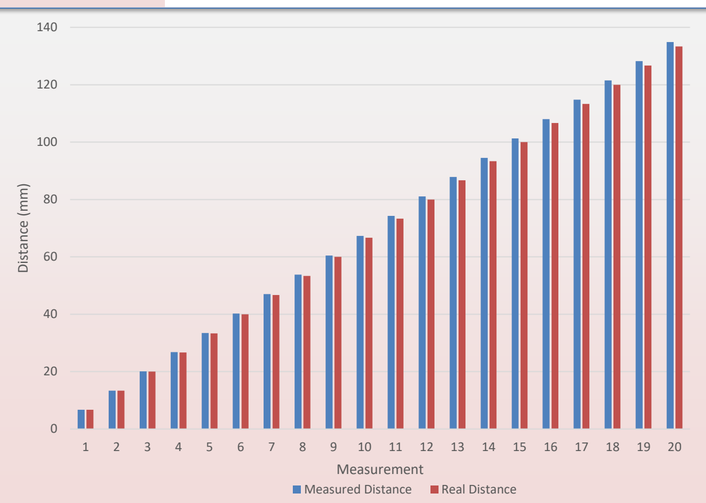
Methodology

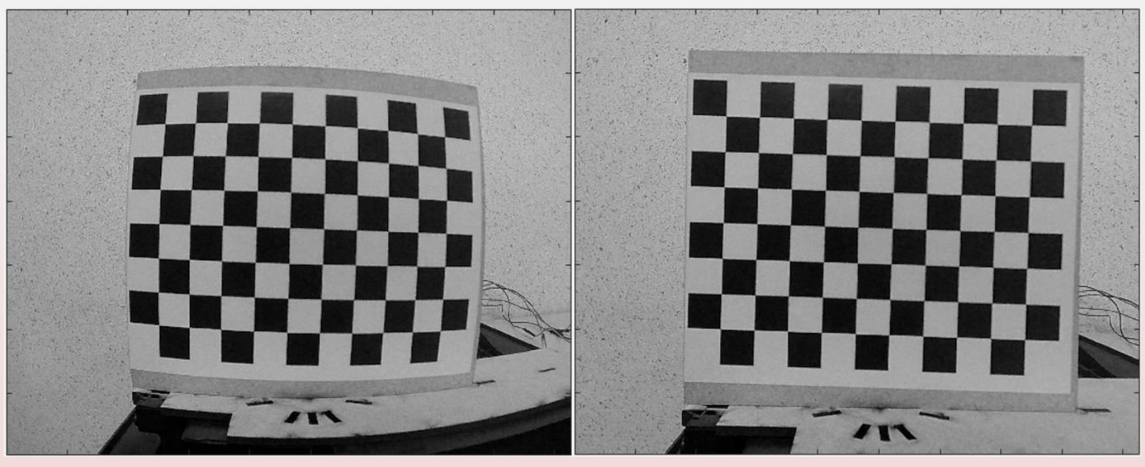
1. The camera for the pose estimation will have to be calibrated so that the intrinsic parameters are known. The radial and tangential distortions must be removed to produce an undistorted image that can be used in all the measurements [3], [4].
2. Testing the camera pose estimations against each other. A test bench that assures that every measurement will take place in the same condition is built. The accuracy of the camera pose estimation relies on the accuracy of the distance from the calibrated image to the calibrated camera.
3. The accuracy of rotation round one of the primary axis is measured using the Rodrigues transform[1].
4. The deviation in the former two parameters is determined from the extrinsic parameters.



Results

- A pattern applicator is designed to attach the checkerboard pattern onto. The pattern can be rotated on a baseplate in fixed angles of -45, °0°, 20° and 45°. The baseplate is designed to fit the moveable scanner head.
- A graphical user interface is implemented to drive the stepper motor.
- The distance and angles are calculated for multiple measurements to determine the deviation from the real values. Deviation in distance is measured for focal length and fixed pattern points. The deviation in rotation is measured for the available angles on the pattern applicator.





Conclusion

- Consistent camera calibration
- Average error of 0,20° for measured angles
- Average error of 0,77 mm for measured distances
- Overall low mean reprojection error

References

[1] G. Bradski and A. Kaehler, *Projection and 3D Vision*. 2008.
[2] J.-Y. Bouguet, "Camera Calibration Toolbox for MATLAB." [Online]. Available: http://www.vision.caltech.edu/bouguetj/calib_doc/. [Accessed: Dec-2018].
[3] Zhengyou Zhang, "A flexible new technique for camera calibration," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 22, no. 11, pp. 1330-1334, November 2000.
[4] Roger Y. Tsai, "A versatile camera calibration technique for high-accuracy 3D machine vision metrology using off-the-shelf TV cameras and lenses," IEEE Journal on Robotics and Automation, vol. 3, no. 4, pp. 323-344, August 1987.

Supervisors / Cosupervisors: Prof. Dr. Ir. Luc Claesen
Ing. Wout Swinkels

UHASSELT

KU LEUVEN