Sensitivity analysis of localisation accuracy with respect to camera parameters and environment

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Introduction

For this thesis, pose determination using cameras is studied. Different types of cameras can be used in applications such as e.g. robot navigation, object pose tracking and augmented reality. To find out most suitable camera for an environment, testing is required which can be a time consuming and costly process.

Camera pose estimation
The challenge of establishing the position and orientation of the camera relative to the object (or vice versa).

This thesis proposes two simulators, which can help determine the camera type with its localisation accuracy. The Python simulation does a theoretical analysis and gives faster results, this uses PnP to resolve the detected points. The detected points are converted to the world coordinate system. From there on the pose can be estimated. The Gazebo simulator uses a virtual camera combined with a marker detector, this provides a six degrees of freedom pose for the markers. The calculation and conversion step is similar to the theoretical simulator.

Problems & objectives

The problem when choosing a camera are the different intrinsic parameters and distortion models, these factors affect the localisation accuracy in various ways. A different problem lies in camera calibration which has to be done manually using a real camera. In a simulator this process can be automated and be done in a few seconds.

The objective for the sensitivity analysis is to be able to study the accuracy of the camera pose determination when adjusting the camera parameters. To have control over these parameters, there is a need for a simulator where a pose estimation of a camera is performed using markers.

For both simulations a series of tests will be performed to verify the precision and repeatability of the pose estimation. The results of the error analysis of both simulators will be shown in graphs and discussed. The difference between the two simulators will also be compared. Finally, from these results, research questions will be answered.

Simulators

Python simulation:
For the Python simulation a library ‘SimLib’ is written. The framework of this library is built around the OpenCV library and provides functionality for handling Perspective and Point problems. An automated simulation can be run with pinhole- or a lens camera model where a sensitivity analysis is performed on a chosen parameter.

Advantages	Disadvantages
- Theoretical approach - Control over all camera parameters	- Object points need to be known - No real image capturing

Graphical set-up

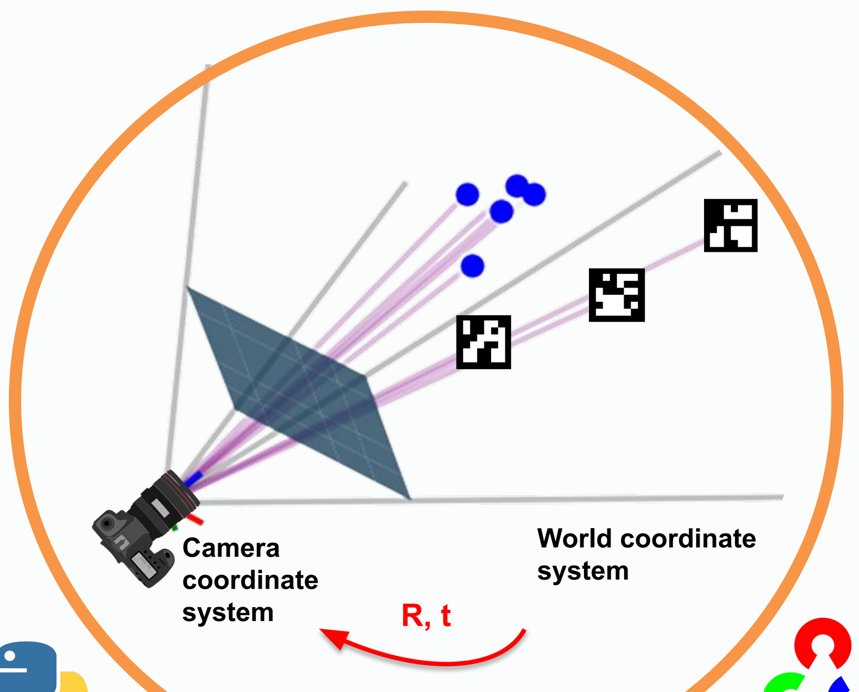

Figure 1: simulator visualization

[1] OpenCV [2]

ROS simulation with Gazebo:
The ROS environment is built using packages available in OpenCV implemented in a Gazebo environment. The simulator performs a localization using an ArUco-marker detector module. And provides an environment to perform a sensitivity analysis for various marker sizes and respective distance to the camera. An analysis on a camera matrix error is also available in the automated simulation.

Advantages	Disadvantages
- Realistic approach - Naturally generated noise from simulation as well as chosen deviations - Realistic camera model with its intrinsic parameters and distortion coefficients	- Slower implementation - Various modules that need to work together - Lighting needs to be added

Results

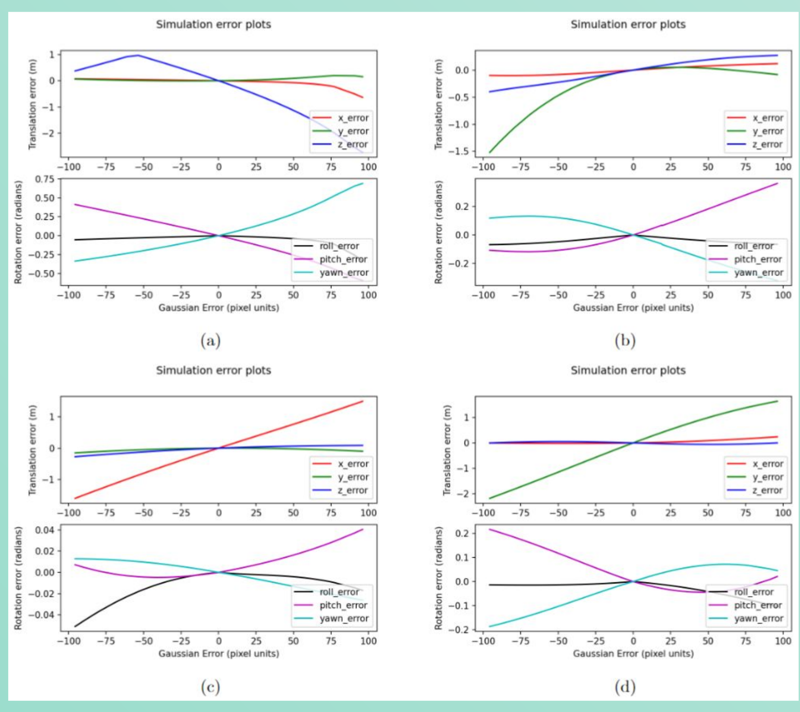

Figure 2: Error on camera localization for chosen range (a) with erroneous fx, (b) with erroneous fy, (c) with erroneous Cx, (d) with erroneous Cy

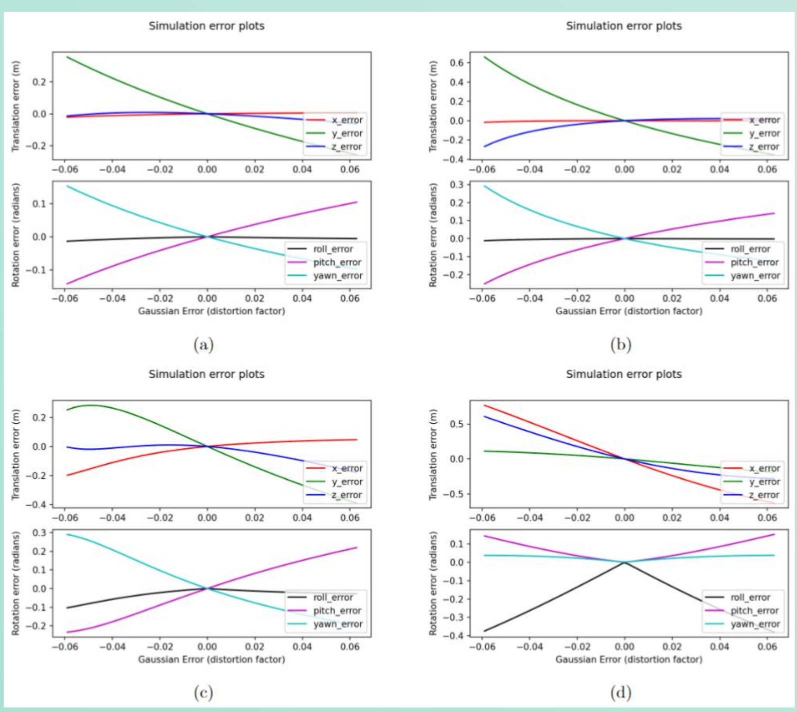

Figure 3: Error on camera localization for chosen range of distortion coefficients (a) with erroneous K1, (b) with erroneous K2, (c) with erroneous P1, (d) with erroneous P2

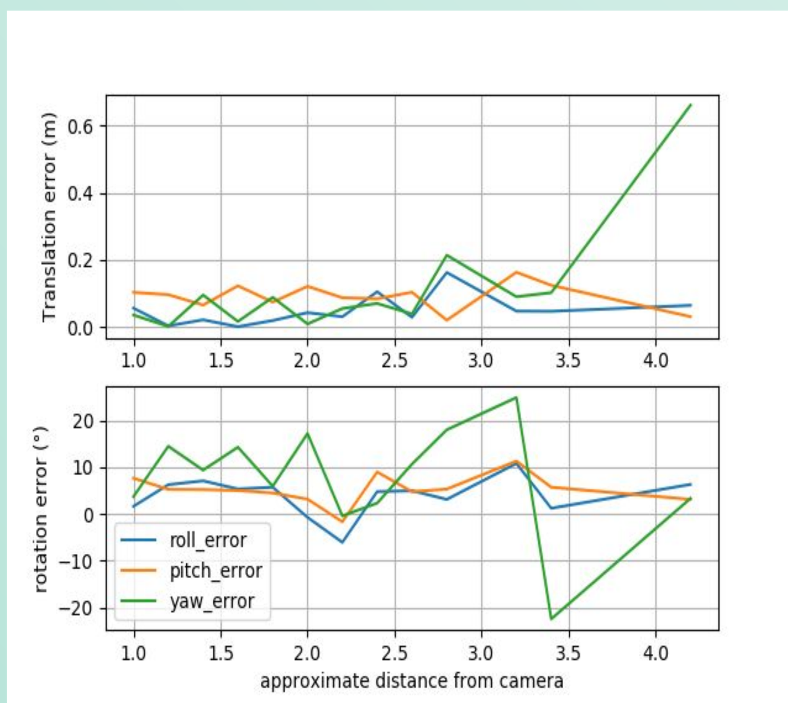

Figure 4: Error on camera localization for markers of 9 cm in size at an approximate distance of 1 - 4 metres

The results of the sensitivity analysis show the effect of the adjustments to the different camera parameters on the estimation of the camera pose. The difference between the ground truth camera position and the estimated camera position is shown in Figures X - X. A second part of the analysis contains the localization accuracy when using markers of various size and respective distance to the camera. An overview of this simulation is given in Figure X

Conclusions

- The two proposed simulators enable full control over various aspects for the camera localization accuracy for the performed error analysis.
- A difference in the camera parameter at pose estimation corresponds to an increasing error.
- The rotation can deviate in the comparison, as a small error in the marker detection can lead to a significant variation in the pose estimate.
- The analysis can be used to do an estimate of the detection range when trying to implement a Visual SLAM system using markers.
- The sensitivity analysis, shows that every deviation on the parameters of the camera matrix or distortion coefficients, has an influence on the localization accuracy.

Supervisors / Co-supervisors / Advisors

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[1] “Python-logo-notext.svg - Wikimedia Commons,” *Wikimedia.org*, Aug. 06, 2008. (accessed Jun. 07, 2022).

[2] “OpenCV Logo with text svg version.svg - Wikimedia Commons,” *Wikimedia.org*, 2006. (accessed Jun. 07, 2022).

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