3D Pose Estimation and Mapping with Time-of-Flight Cameras

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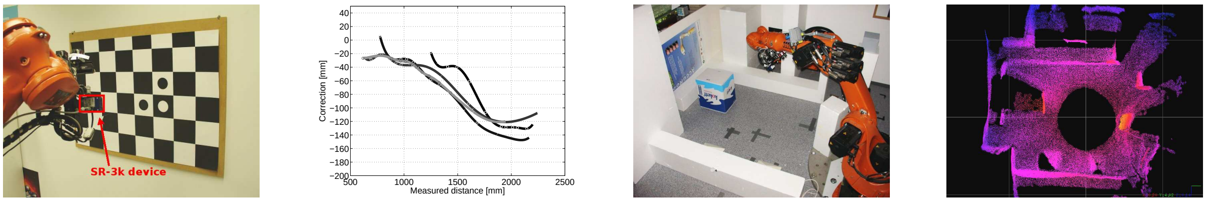
I. Overview

Since their invention nearly a decade ago, Time-of-Flight (ToF) cameras have attracted attention in many fields, e.g. automotive engineering, industrial engineering, mobile robotics and surveillance. So far, 3D laser scanners and stereo camera systems are mostly used for these tasks due to their high measurement range and precision. Stereo vision requires the matching of corresponding points from two images to obtain depth information, which is directly provided by laser scanners but with the drawback of a lower frame rate. In contrast to laser scanners, ToF cameras allow for higher frame rates and thus enable the consideration of motion. However, the high frame rate has to be balanced with measurement precision. Although a lot of effort has been investigated, depth measurements with ToF cameras are still erroneous. It has to be distinguished between systematic and non-systematic errors. Systematic errors are manageable by calibration. In [1] and [2] Fuchs et al. described an appropriate calibration method that estimates these errors. As a result an overall precision of $1\,\mathrm{mm}$ is achievable.

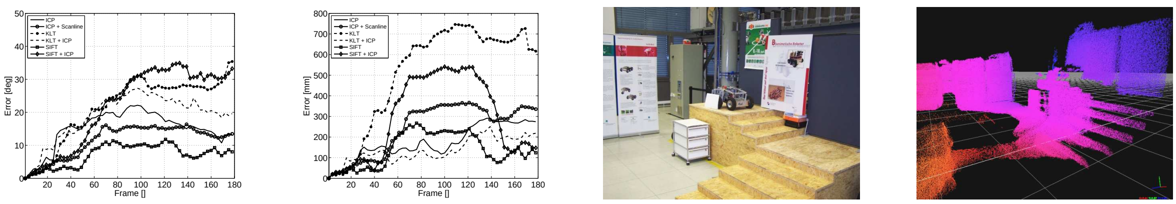


(a) (b) (c) (d)

Fig. 1. a) The improved calibration is performed against a checkerboard pattern. b) Resulting splines of improved depth calibration representing the depth correction for a special amplitude and distance interval. c) Scenario used for ground truth evaluation. d) 3D cloud registered with data taken from a Swissranger SR-3k device (false color code relates distance to origin).

Non-systematic errors include those errors depending on external interfering factors (e.g. sunlight and scene configurations). Thus, the same scene entails large fluctuations in distance measurements from different perspectives that have to be handled by the application.

The presented mapping approach deals with large variations in precision of distance measurements. Mapping is performed on-the-fly with no additional sensory information about the sensor's ego-motion. The approach comprises: feature based ego-motion estimation, filtering of imprecise data and registration of newly acquired data for a consistent 3D environment map. After loop-closure, a refinement step distributes the error and smoothes the measurements yielding in a precise 3D map. A video, showing the performance of the approach, is available at http://www.iais.fraunhofer.de/3325.html



(a) (b) (c) (d)

Fig. 2. Comparison of different pose estimation methods, a) rotational error and b) translational error. c) Scene used for mapping. d) Perspective view of generated 3D map.

References

[1] S. Fuchs and S. May, Calibration and registration for precise surface reconstruction with ToF cameras. In: *Proceedings of the Dynamic 3D Imaging Workshop in Conjunction with DAGM (Dyn3D)*, Vol. I, Heidelberg, Germany, September 2007.

[2] S. Fuchs and G. Hirzinger, Extrinsic and Depth Calibration of ToF-cameras. In. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, Anchorage, USA, June 2008.