Calibration of Heterogeneous Multi-View Camera Systems for Illumination-Robust 3D Reconstruction in Operating Rooms

Project Management and Software Development
for Medical Applications

General Info

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Project Abstract

Develop a framework in C++ to calibrate two RGB cameras into an existing and calibrated multi-view RGB-D setup for operating room reconstruction. By addressing dynamic range limitations, the project enables capturing both the brightly lit surgical site and the low-lit OR, creating a comprehensive 3D view for workflow analysis.

Background and Motivation

Capturing high-quality 3D reconstructions of surgical procedures in operating rooms (OR) is essential for workflow analysis [1] and enhancing surgical training [2]. However, the intense illumination from surgical lights focused on the operating site creates a significant disparity in lighting conditions within the OR [3]. This high dynamic range environment poses a challenge for standard cameras, which cannot simultaneously capture both the brightly lit surgical site and the dimmer surrounding areas due to hardware limitations.

To address this issue, we developed a multi-view RGB-D camera setup consisting of four RGB-D cameras to capture the low-lit room area of the OR and two additional RGB cameras dedicated to capture the brightly illuminated operating site. Our existing framework can calibrate the four RGB-D cameras using an ArUco fractal marker, obtaining their intrinsic and extrinsic parameters to create a coherent 3D representation of the OR's less illuminated regions.

In this project we want to integrate the two RGB cameras into the existing calibration framework, enabling the creation of a comprehensive 3D view that includes both the texture of the surgical site and the surrounding OR. By achieving this, we can enhance the quality of OR reconstructions and provide valuable insights from the operating site for workflow analysis.

Student's Tasks Description

The assigned student will develop a C++ framework to calibrate two additional RGB cameras into the existing multi-view RGB-D camera setup. The primary tasks include:

1. Familiarize themselves with the current calibration process of the four RGB-D cameras using ArUco markers.
2. Implement calibration procedures to determine the intrinsic and extrinsic parameters of the two RGB cameras and align the RGB cameras with the existing world coordinate system of the RGB-D cameras. This involves capturing calibration images, detecting markers, and computing camera parameters.
3. Develop methods to effectively project the 2D RGB images from the now calibrated cameras into the 3D world

Please send the completed proposal to tianyu.song@tum.de, shervin.dehghani@tum.de and felix.tristram@tum.de. Please note that this proposal will be evaluated by the BMC coordinators and will be assigned to a student only in case of acceptance.

space, effectively mapping high-quality textures onto the 3D view of the OR.

The student will gain hands-on experience in camera calibration techniques and multi-view geometry. The student will enhance their C++ programming skills, working extensively with computer vision libraries such as OpenCV.

Technical Prerequisites

Good C++ Programming Proficiency

Basic knowledge of multi-view geometry is helpful

References

[1] L. Bastian, T. Czempiel, C. Heiliger, K. Karcz, U. Eck, B. Busam, N. Navab, Know Your Sensors — a Modality Study for Surgical Action Classification, Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization. (2023)

[2] B. Liu, G. Soenens, J. Villarreal, J. Jopling, I.V. Herzeele, A. Rau, S. Yeung-Levy, A Human Mesh-Centered Approach to Action Recognition in the Operating Room, Artificial Intelligence Surgery. (2024)

[3] J. Hein, N. Cavalcanti, D. Suter, L. Zingg, F. Carrillo, L. Calvet, M. Farshad, M. Pollefeys, N. Navab, P. Fürnstahl, Next-Generation Surgical Navigation: Marker-less Multi-view 6DoF Pose Estimation of Surgical Instruments, arXiv, 2023.