Fiducial Marker-based Multiple Camera Localisation System

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Motivation

Systems capable of precisely and reliably estimating the positions of objects across large areas are crucial not only in robotics research but also in manufacturing or logistics. The currently available localisation and motion capture systems for large spaces are commonly based on closed and expensive technology that tracks special markers in the infrared spectrum. Such systems are restricted to indoors only, and their setup is cumbersome and time-consuming. Their high price often discourages smaller research groups from conducting experiments requiring precise localisation to evaluate the researched methods. Thus, introducing an open-source, modular and accessible localisation system capable of outdoor deployment would accelerate the research and development in robotics.

Progress beyond the state of the art

The thesis evaluates the marker in a single-camera application showing comparable precision to the SOTA methods while achieving real-time performance. Then, the multiple camera system based on the WhyCode marker is enhanced with full image thresholding and segmentation, allowing the localisation of a variable number of markers in a scene. The final pose estimation is fused across all cameras resulting in more robust and precise localisation. As in Fig. 3, the configuration can vary from overlapped fields of view (FOVs) to extending them for better area coverage. The system is capable of custom extrinsic calibration to avoid additional tools during deployment. The system is an efficient and accessible external localisation tool for evaluating robotic experiments or closed-loop control of robotic swarms over large spaces.

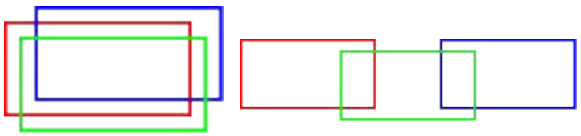

Fig. 3. Configurations of cameras: overlapped FOVs and extended FOVs

The Problem

Design and implement a versatile vision-based fiducial marker tracking method for multi-camera systems. The method should be capable of tracking many fiducial markers in real time while estimating their 6 DOF pose. The system would require only off-the-shelf cameras, and contrary to the current SOTA methods, it could be deployed in outdoor environments.

Fig. 1. Real-world experimental setup of three cameras and a mobile robot.

Fig. 2. Tag use for honeybee queen tracking in the EU project `Roboroyale'

Datasets and experiments

The proposed system was evaluated on a synthetic dataset covering thousands of randomly sampled marker poses and a real-world dataset with three heterogeneous cameras and a mobile robot, see Fig. 1. In both scenarios, the method showed an increase in robustness, detection rate and area coverage.

References and applications

The thesis outcomes were presented at an international conference [1], and an extended version was invited for publication in a journal [2]. The method was already deployed in the swarm [3] and evolutionary robotics domain [4] as well as in a European research project concerning biohybrid systems [5,6], see Fig. 2.

1. ULRICH, Jiří, et al. Towards fast fiducial marker with full 6 DOF pose estimation. In: Proceedings of the 37th ACM SIGAPP Symp. on Applied Comp. 2022.
2. ULRICH, Jiří, et al. Real-time 6 DOF pose estimation for fiducial marker localisation system. ACM SIGAPP Applied Comp. Review. (invited paper, in preparation)
3. NA, Seongin, et al. Bio-inspired artificial pheromone system for swarm robotics applications. Adaptive Behaviour. 2021.
4. NA, Seongin, et al. Federated Reinforcement Learning for Collective Navigation of Robotic Swarms. IEEE T-CDS. (major revisions)
5. STEFANEC, Martin, et al. A Minimally Invasive Approach Towards "Ecosystem Hacking" with Honeybees. Frontiers in Robotics and AI. 2022.
6. ALEMDAR, Hande, et al. Robotic Replicants for Improving Queen Bee Health and Persistence of the Honey Bee Colony. In: APIMONDIA. 2022.

Open source, freely available

The method is available for Linux as open source and as a demo for Android.