19.12.2021

Localization and mapping in multiple mobile robot systems

Abstract

The key feature of autonomous mobile robots is the ability to create maps of unknown environments and estimate pose on these maps. The simultaneous localization and mapping (SLAM) is a fundamental problem of mobile robotics because robots need to know their state and the state of their surroundings, even for basic operations like motion planning or trajectory following. In the case of multiple mobile robot systems, the data from robots sensors are processed in such a way as to create a consistent, global model of the environment and to localize robots on it. There are two main approaches to multi-robot mapping. The first one is based on the exchange of raw data from sensors between robots. The second approach is based on the independent mapping of the environment by multiple robots. Such maps are exchanged between robots and integrated with a dedicated method into one model. This dissertation focuses on the second approach, what means the independent mapping of the environment by each robot and methods of the maps integration.

This paper introduces a new, developed 3D maps integration method that works with octree based maps (octomaps). The approach solves the case when the initial poses of robots are unknown and meetings between robots do not occur during the exploration process. The method detects and matches overlapping regions on maps, and based on that it estimates the transformation between partial maps. The process of maps integration consists of a few steps. The first one is related to the model extraction from one map that is matched to the second map in the global alignment process. This operation is based on the detection of key points, description of features and finding similarities in two sets of descriptors. For this purpose, there were used two methods: probabilistic Sample Consensus (SAC) method and geometry consistency clustering (GCC) approach. As a next step, the local correction is applied. The local alignment process is based on the iterative closest point (ICP, OICP) algorithms and the normal distributions transform (NDT) based method. Finally, one of the maps is transformed to the coordinate system of the second map and the data from both maps are integrated into a single model. The developed solution has been implemented and released as an open source software. In addition, the paper presents results from multiple experiments with wheeled mobile robots and publicly available datasets with octomaps. The presented results of experiments confirmed that data exchange between robots in a multi-robot system allows increasing the efficiency of the simultaneous localization and mapping (SLAM) process.

Moreover, the dissertation presents a multi-robot 3D maps server with experiments results. It contains the developed position calibration method dedicated to a depth sensor and the system for automatic SLAM methods tuning. This paper also presents results of localization and SLAM methods experiments based on the data from a motion capture system used as a ground truth.

Michał Drwięga

Michał Drwięga