Distributed Semantic Mapping for Heterogeneous Robotic Teams

Yunis Fanger[1], Tim Bodenmller [1], and Rudolph Triebel[1]

***Abstract*— In this paper we summarize our current work on distributed semantic mapping within heterogeneous robot teams in large scale unstructured environments. We extract semantic information from sensor readings and use it to perform robust registration of sub-maps from different agents. We further use it to reduce network traffic by excluding detected areas of high uncertainty. For fast development and verification of our approaches, we employ a multi-robot real-time simulation.**

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I. Motivation and Problem Definition

We consider the problem of generating accurate and efficient 2D or 3D map representations with a distributed team of heterogeneous mobile robots. While such a robot team can produce environment maps much more efficiently compared to single systems, there are also a number of additional challenges. These include the requirement to keep the individual maps consistent for the lack of a centralize map, the ability to identify map elements that have been recorded from different view points, and the problem of fusing map data from different sensor modalities with different resolutions. In our work, we propose to leverage semantic information in additon to the geometric data to tackle these problems. More precisely, we propose to use terrain and object classification methods to find correspondences in the maps (see Sec. III).

II. Related Work

Simultaneous localization and mapping (SLAM) has been extensively researched and implementations such as ORB-SLAM [1] were developed which work well in static environments. More recently, researchers have started to exploit the progress made in the field of semantic image segmentation [2] in order to improve SLAM approaches. In [3] and [4] extensions to ORB-SLAM are presented which filter out feature points if their semantic label indicate them to belong to dynamic objects. However, in both these works only the most likely semantic label are considered.

In [5] a distributed semantic SLAM approach is proposed that takes into account how the viewpoint of different robots affects their ability to accurately assign objects to semantic classes. However, the issue of how to perform data association is not addressed here. It has also been shown [6] that considering semantic labels when aligning point clouds using the well known the IPC algorithm yields improved results. Finally, authors in [7] provide a conceptional framework for creating modular software for distributed semantic mapping systems.

[1]Institute of Robotics and Mechatronics, German Aerospace Center(DLR), Germany

III. Own Approach and Contribution

In our work we propose the incorporation of semantic information in the map building process of our heterogeneous multi-robot team consisting of two lightweight rover units [8] and a quadrocopter. For the application case of extraterrestrial exploration the semantics are considered to be information about different rock and terrain types found in the environment, while for scenarios on earth additional semantic labels for objects such as trees, water, and foliage are possible. In a first step we use pixelwise semantically segmented RGBD-camera images [2] to incrementally build a local map of a robots surroundings. Taking multiple measurements of a single location in the environments from different points of view enables us to generate a distribution over semantic labels from the discrete classification in the segmented images. The semantic local maps are then used for multi-robot map registration. However, instead of sending the entire local map to other robots, we propose to only communicate the subset that contributes most to accurate map matching. Thus, the parts of the map that have a semantic class that hints on dynamic elements or high uncertainty are excluded. When a robot receives a new partial sub-map from one of its team members a map matching procedure is triggered. Hereby, possibly matching sub-maps are first selected according to current pose estimates and then precisely aligned, by utilizing the semantic labeling. In contrast to other approaches we consider not only the most likely semantic class for each point in the map but rather the entire probability distribution by weighting points accordingly in a final semantic IPC step. For fast development and testing, we implemented a simulation that generates sensor readings and semantic labels in real-time from photo-realistic virtual extra terrestrial and large scale outdoor environments.

References

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