Lifelong localization of a mobile service-robot in everyday indoor environment using omnidirectional vision

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Localization and mapping are fundamental problems in service robotics. Knowledge about the robot pose and a representation of the environment are needed for a series of high level applications. Due to the lack of GPS/ DGPS/ RTK-GPS in indoor environments it is quite difficult to determine the robot pose. The introduced approach will compensate this problem by solving the SLAM Problem (Simultaneous Localization and Mapping Problem) in indoor environments using visual sensors.

Service robots should be designed for life-long and robust operation in dynamic environments. Typically, SLAM approaches just accumulate features over time and do not discard them anymore. Therefore, the required resources in terms of memory and processing power are growing over time. A lifelong running SLAM approach requires means to select landmarks such that they best cover the working environment given bounded SLAM resources like the maximum number of manageable landmarks. In our approach, the absolute number of landmarks can be restricted by an upper bound by selecting and replaceing landmarks once the upper bound has been reached. The main problem thereby is to determine which landmarks are useful for the ongoing SLAM. We think that it is relevant from which position a landmark can be observed by the robot and that the position of a landmark is not relevant itself. Thus, we quantify the benefit of a landmark in terms of observability regions and not only in terms of its pose uncertainty. The rationale behind this approach is that moving close to a landmark position does not yet make sure that it can be reobserved. However, if the robot moves into the region where it observed the landmark previously, the chance of reobservation is much higher. Of course, the ability to improve the robots pose also depends on the variance of the landmark pose estimate. Thus, the observation region of a landmark together with the landmark pose uncertainty form a good starting point for defining a measure for the benefit of a landmark with respect to robot localization.

This raises the question, how we can cover the working area with landmark observation positions, considering the landmark quality. We propose a solution of removing landmarks where the landmark observation position lies within a region with high density of landmark observation positions. In the paper we will describe algorithms for spatial classification of landmark observation positions using clustering algorithms. The aim of the clustering step is to identify those representatives of landmark observability that cover nearly the same observation region (see figure 2). Landmarks with high uncertainty included in the cluster, can be deleted without decreasing significant the overall localization quality.

Figure 1: Robot plattform Pioneer 3DX equipped with Microspace PC and omnidirectional camera

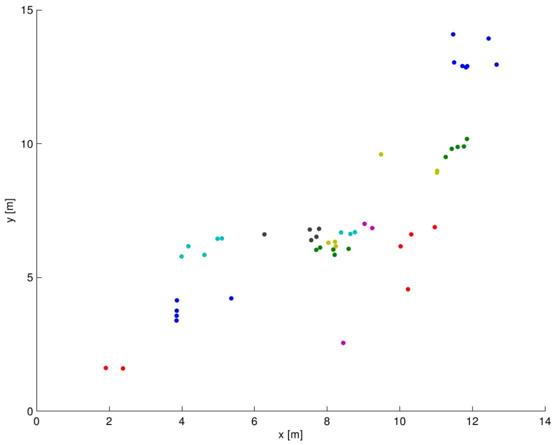

Figure 2: A cluster comprises several landmark representatives. A landmark representative is the position from where a landmark can be observed. All representatives belonging to a cluster (spatial closeness) are drawn with the same color.

This can be drawn back to the fact that the robot can observe further landmarks with lower position uncertainty from this region.

The theoretical basis for our system will be discussed in detail in the paper. Within real-world experiments we demonstrate the performance of our approach. These experiments are performed on a P3DX-platform (see figure 1) with a bearing-only SLAM approach. The bearing-only SLAM approach uses two types of sensors, odometry and an omnicam. In the first part of the experiments, we compare the recommended methods relating to the localization quality of the robot in the environment. The problem of ever growing number of landmarks must not affect significantly the localization quality. In addition to that we test the capability of the methods to cover the environment with observation positions. A good landmark coverage is elementary for the localization of a service-robot. The method should select those landmarks that best cover the working environment under taking into account the benefit for localization purposes.

Life-long and robust operation are important goals service robots have to solve on the way to everyday usability. Our approach to handle the problem of ever growing number of landmarks without significantly reducing the localization quality is a further step towards life-long operation. In particular the potential to limit the number of landmarks and hence to cope with the resource limitation of real systems is a step towards robust service robotic applications.