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Doctoral thesis:

Lifelong Visual Localization for Automated Vehicles

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Abstract:

Automated driving can help solve the current and future problems of individual transportation. Automated valet parking is a possible approach to help with overcrowded parking areas in cities and make electric vehicles more appealing. In an automated valet system, drivers are able to drop off their vehicle close to a parking area. The vehicle drives to a free parking spot on its own, while the driver is free to perform other tasks --- such as switching the mode of transportation. Such a system requires the automated car to navigate unstructured, possibly three dimensional areas. This goes beyond the scope of the tasks performed in the state of the art for automated driving.

This thesis describes a visual localization system that provides accurate metric pose estimates. As sensors, the described system uses multiple monocular cameras and wheel-tick odometry. This is a sensor set-up that is close to what can be found in current production cars. Metric pose estimates with errors in the order of tens of centimeters enable maneuvers such as parking into tight parking spots. This system forms the basis for automated navigation in the EU-funded V-Charge project.

Furthermore, we present an approach to the challenging problem of lifelong mapping and localization. Over long time spans, the visual appearance of the world is subject to change due to natural and man-made phenomena. The effective long-term usage of visual maps requires the ability to adapt to these changes. We describe a multi-session mapping system, that fuses datasets into a single, unambiguous, metric representation. This enables automated navigation in the presence of environmental change. To handle the growing complexity of such a system we propose the concept of Summary Maps, which contain a reduced set of landmarks that has been selected through a combination of scoring and sampling criteria. We show that a Summary Map with bounded complexity can achieve accurate localization under a wide variety of conditions.

Finally, as a foundation for lifelong mapping, we propose a relational database system. This system is based on use-cases that are not only concerned with solving the basic mapping problem, but also with providing users with a better understanding of the long-term processes that comprise a map. We demonstrate that we can pose interesting queries to the database that help us gain a better intuition about the correctness and robustness of the created maps. This is accomplished by answering questions about the appearance and distribution of visual landmarks that were used during mapping. This thesis takes on one of the major unsolved challenges in vision-based localization and mapping: long-term operation in a changing environment. We approach this problem through extensive real world experimentation, as well as in-depth evaluation and analysis of recorded data. We demonstrate that accurate metric localization is

feasible both during short term changes, as exemplified by the transition between day and night, as well as longer term changes, such as due to seasonal variation.