Truncated Signed Distance Fields
Applied To Robotics

av

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Abstract

This thesis is concerned with topics related to dense mapping of large scale three-dimensional spaces. In particular, the motivating scenario of this work is one in which a mobile robot with limited computational resources explores an unknown environment using a depth-camera. To this end, low-level topics such as sensor noise, map representation, interpolation, bit-rates, compression are investigated, and their impacts on more complex tasks, such as feature detection and description, camera-tracking, and mapping are evaluated thoroughly. A central idea of this thesis is the use of truncated signed distance fields (TSDF) as a map representation and a comprehensive yet accessible treatise on this subject is the first major contribution of this dissertation. The TSDF is a voxel-based representation of 3D space that enables dense mapping with high surface quality and robustness to sensor noise, making it a good candidate for use in grasping, manipulation and collision avoidance scenarios.

The second main contribution of this thesis deals with the way in which information can be efficiently encoded in TSDF maps. The redundant way in which voxels represent continuous surfaces and empty space is one of the main impediments to applying TSDF representations to large-scale mapping. This thesis proposes two algorithms for enabling large-scale 3D tracking and mapping: a fast on-the-fly compression method based on unsupervised learning, and a parallel algorithm for lifting a sparse scene-graph representation from the dense 3D map.

The third major contribution of this work consists of thorough evaluations of the impacts of low-level choices on higher-level tasks. Examples of these are the relationships between gradient estimation methods and feature detector repeatability, voxel bit-rate, interpolation strategy and compression ratio on camera tracking performance. Each evaluation thus leads to a better understanding of the trade-offs involved, which translate to direct recommendations for future applications, depending on their particular resource constraints.

Keywords: 3D mapping, pose estimation, feature detection, shape description, compression, unsupervised learning