FAST MAPPING

Efficient 3D Scene Understanding for Autonomous Robots

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1.0 Introduction

New emerging service robots are used for commercial applications in various industries like retail, banking, hospitality, education, healthcare, warehouses, law enforcement, and agricultural sectors. To serve these applications scenarios efficiently, it is a fundamental requirement for robot to understand the scene it is interacting with. Considering a service robot want to safely navigate indoor and outdoor, it must perceive the free space accurately. More-over, to place a bottle on a table, it must recognize the objects in the scene.

Scene understanding is the process of fusing frame or video centric information into a persistent scene model. It is crucial to any mobile Artificial Intelligence (AI) agents that are supposed to work in a place for an extended period. The first step towards modeling the scene is to reconstruct it geometrically, and then semantically. Efficient scene constructions are important to ensure robot can navigate with constant speed. With scene understanding, robot can provide more intuitive and personalized service based on customer needs.

2.0 Challenges

To understand the scene, robot not only need to reconstruct space information accurately, but also need to identify other information like people, things, behavior, emotion, and then memorize and keep learning all this context information in a dynamic environment.

The basic scene reconstruction is 2D or 3D map, build based on Simultaneous Localization and Mapping (SLAM) algorithm. Most SLAM algorithms construct a sparse map with only landmark information. The sparse map can be used for localization, but it has limited information to support interactive applications.

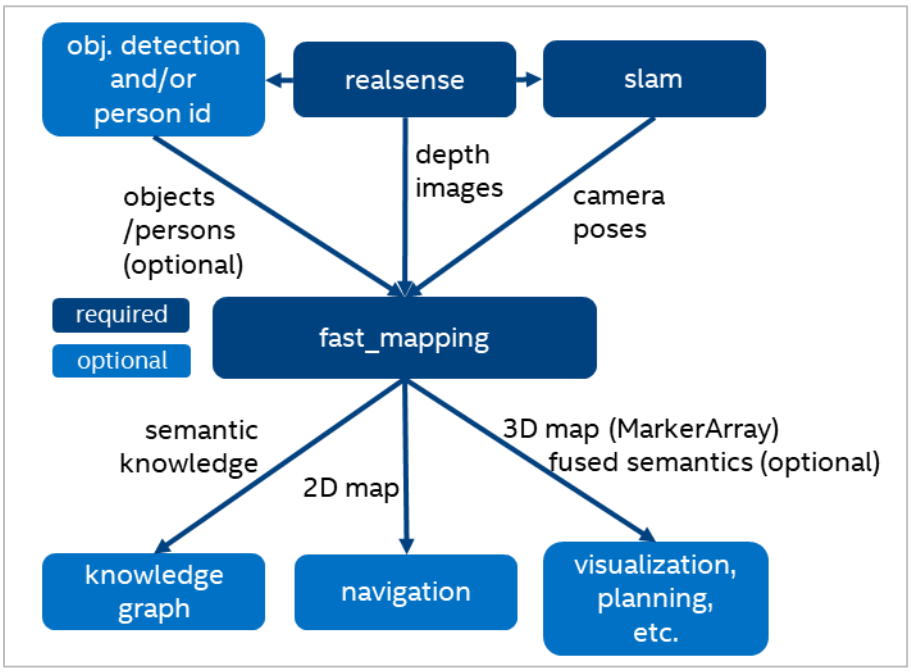
Dense maps based on 3D sensors like depth-camera or lidar allow perceiving additional information. 3D dense maps like point clouds store lots of measurement points and hence are not memory efficient. Furthermore, it does not allow to differentiate between obstacle-free and unmapped areas and provide no means of fusing multiple measurements probabilistically. Voxelized occupancy maps, on the other hand, can model free space explicitly. However, the existing implementations encounter lack computation and memory efficiency for real-time applications. Octree is good at full space modeling, but its frame rate is low to support real-time applications.

With these limitations, current robots are highly depending on predefined knowledge and procedure to interact with the environment. These robots cannot identify scene context, recognize people emotion, understand customer real intention. Their services are based on fix patterns and cannot provide personalized high-quality services to customers.

3.0 Intel's FAST Mapping Solution

FAST Mapping is a Robot Operating System (ROS) package for real-time scene modeling from sequential depth-images. The scene can be dynamic, and the depth images can be noisy. Intel research activities have demonstrated it is possible to enhance the FAST Mapping produced map to fuse semantic information, resulting a volumetric map with instance-level semantics.

Figure 1. FAST Mapping Works with ROS



3.1 Geometric Mapping

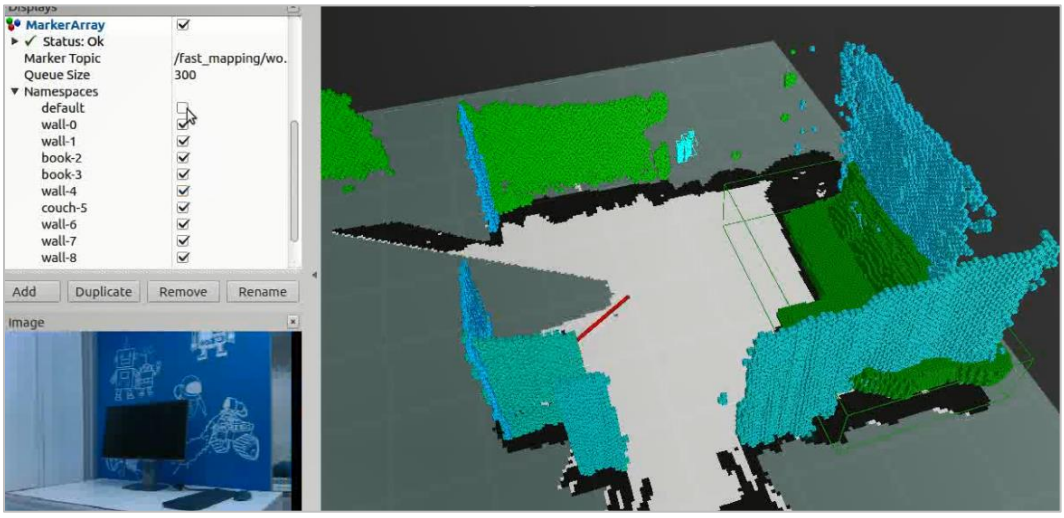
A typical usage is to run FAST Mapping with an RGB-D camera like Intel® RealSense™ D435i and a SLAM module. The SLAM module can either be a visual SLAM algorithm like RTAB-Map which estimates the pose of the RGB-D camera in real-time and publishes it onto a ROS topic or the ROS tf tree, or be an external device providing such information, such as Intel® RealSense™ T265 tracking module. FAST Mapping then builds both 3D and 2D maps and publishes them with ROS, which can be used for robot navigation or manipulation.

3.2 Semantic Mapping

FAST Mapping can also be extended to fuse semantic information extracted from multiple images with multiple models. For example, an object detection algorithm can be applied to the RGB-D images, and the resulted object information (categories and bounding boxes) can be filtered spatially and temporally on the 3D map maintained by FAST Mapping. Customized perception modules can be integrated if the semantics are published in pre-defined format. Besides external

semantic input, FAST Mapping will provide a built-in module to detect walls and floors based on a plane detection algorithm, as these elements cannot be detected by common object detectors, yet important to scene understanding.

Figure 2. Semantic Mapping with FAST Mapping



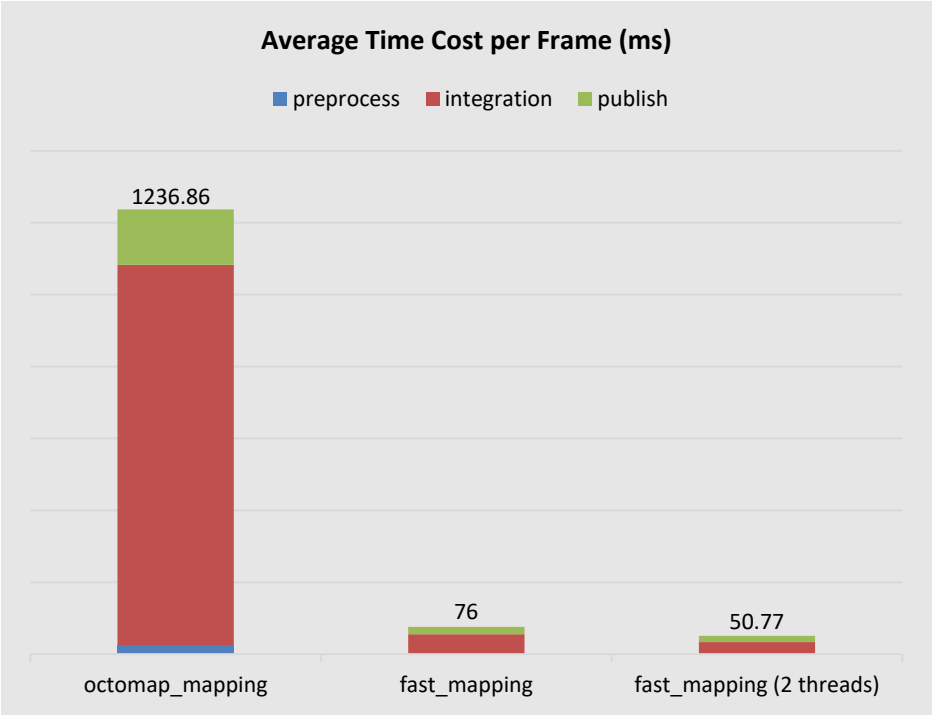
3.3 Spatial Inference

FAST Mapping framework is designed with capability to extract spatial knowledge from the internal semantic map. It can be extended to report spatial relations of close objects. Those could be processed by a knowledge graph module, for further inference and inquiries.

3.4 FAST Mapping

Unlike OctoMap which use an explicit octree representation, FAST Mapping implement implicit octree with hashing to improve efficiency. Attribute to the efficient data structure and memory management, optimized mapping pipeline, advanced probabilistic fusion, flexible voxel representation, and capability to process depth-image input, FAST Mapping achieved more than 10 times (10x) performance boosting as compared to state-of-the-art counterparts. It can run in a single thread of execution or it can be configured to run parallelized in multiple cores achieving higher frame rates. This is important for real-time application where high frame rate required.

Figure 3. Performance Comparison Between Octomap and FAST Mapping



4.0 Application of the Solution

FAST Mapping can easily be integrated into robotic systems in a variety of scenarios. For example, it can build and maintain a map which can be used for path planning, navigation, motion planning and manipulation. FAST Mapping can also visualize the scene for users, as well as extract spatial knowledge to communicate with users by natural language.

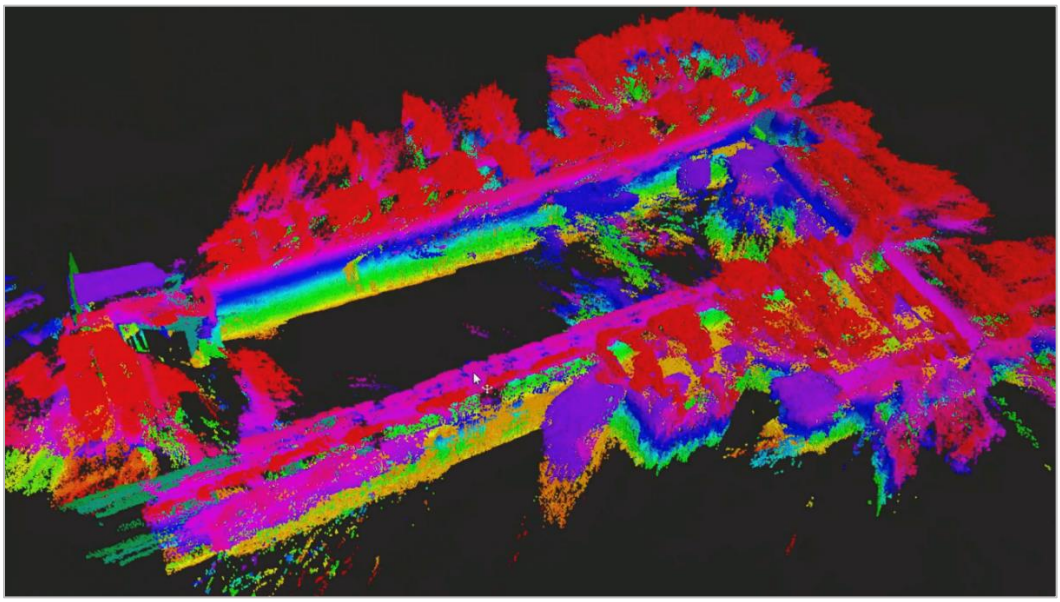
SLAMTEC Apollo is a general-purpose robot platform, which is widely used by robot manufacturers to build retail intelligence robots, delivery robots, usher robots, and etc.

The new generation of SLAMTEC Apollo robot platform based on Intel® Mobile Smart Kiosk Design (Intel® MSK Design) compute platform is more powerful than ever before. It also integrates Intel software such as Intel's FAST Mapping and OpenVINO™ to make the robot smarter and faster.

Figure 4. SLAMTEC Apollo Robot Platform

FAST Mapping is the foundation of the new feature call 3D Scene Reconstruction of this generation of SLAMTEC Apollo. By combining SLAMWARE, an industrial leading SLAM solution by SLAMTEC, and FAST Mapping, our clients can build precise and high-resolution 3D map of their environments in several minutes.

Figure 5. SLAMTEC Apollo 3D Scene Reconstruction with FAST Mapping



5.0 Summary

FAST Mapping is an easy to integrate ROS package that enables robot to build and maintain a 3D model of the scene from what it perceives in an efficient way. With FAST Mapping, robot can perform continuous learning in a dynamic environment, reduce human intervening, and make suitable decision based on scene understanding. FAST mapping can be used widely in many industries like healthcare, retail, hospitality to support more convenient human and robot interacting.

6.0 About

6.1 About SLAMTEC

SLAMTEC was founded in 2013 and focused on development and applications of robot autonomous localization and navigation solution. By providing high-efficient and reliable solution for robot industry via innovative technologies and products, SLAMTEC has become a leading player in autonomous localization and navigation solution in service robot industry.

Currently, SLAMTEC owns three major production lines: RPLIDAR, powerful LiDAR sensors; SLAMWARE, modular autonomous localization and navigation systems; ZEUS, general purpose service robot platforms. SLAMTEC has more than 2000 enterprise users and 100000 personal users in 20 and more countries across Asia, Europe, Northern America etc.

6.2 About Intel

Founded in 1968, Intel's technology has been at the heart of computing breakthroughs. Intel is an industry leader, creating world-changing technology that enables global progress and enriches lives. Intel stands at the brink of several technology inflections—artificial intelligence (AI), 5G network transformation, and the rise of the intelligent edge — that together will shape the future of technology. Silicon and software drive these inflections, and Intel is at the heart of it all.