Realtime Extended 3D Reconstruction from Stereo for Navigation

Radu Bogdan Rusu, Aravind Sundaresan, Benoit Morisset, Motilal Agrawal, Michael Beetz, and Kurt Konolige

***Abstract*— We report some of our experiences on Leaving Flatland, an exploratory project which studies the key challenges in closing the loop on autonomous perception and action in challenging terrain. A primary objective of the project is to demonstrate the acquisition and processing of robust 3D geometric model maps from stereo data and Visual Odometry techniques. The 3D geometric model is used to infer different terrain types and construct a 3D semantic model.**

I. Introduction

Most of the navigation systems today rely on 2D representations of the world (e.g. occupancy maps), which are solely used to plan the robot's motion. With such a flat representation, the geometry of the world is lost, which means the robot can only go around possible obstacles and not over them. To increase the mobility of the robot, we propose the creation of three-dimensional models of the environment that preserve the geometric structure of the scene and more importantly all the obstacles in it. The model is built and updated online as the robot moves, and contains additional semantic labels, by associating each part of the model to a predefined class of environment such as "stairs", "flat ground", "elevated flat ground", "ramp" or "irregular obstacle".

II. System Overview and 3D Model construction

Our system builds a 3D model of the world using images obtained from a stereo camera attached to the robot (see Figure 1). Each disparity image is transformed into a 3D point cloud and registered into the global coordinate framework using our Visual Odometry system. To keep the computational complexity low, we further make use of space decomposition techniques (i.e. octrees) to fit polygonal models to each point subset separately. We finally analyze the geometrical properties of the resulted patches and based on commonsense knowledge (e.g. stairs are formed from polygons of certain sizes perpendicular to each other) we add semantic annotations to them. Finally, neighboring groups of polygons sharing the same class are grown together to simplify the resultant model. Figure 2 presents partial results obtained on the stairs dataset, together with its computational properties.

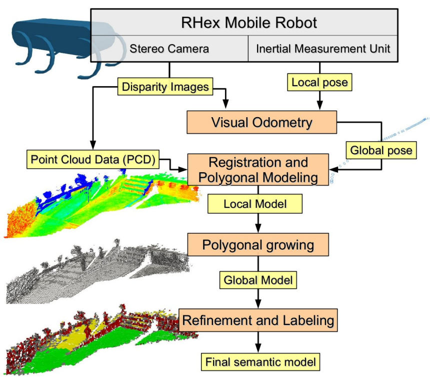

Fig. 1. The overall system architecture.

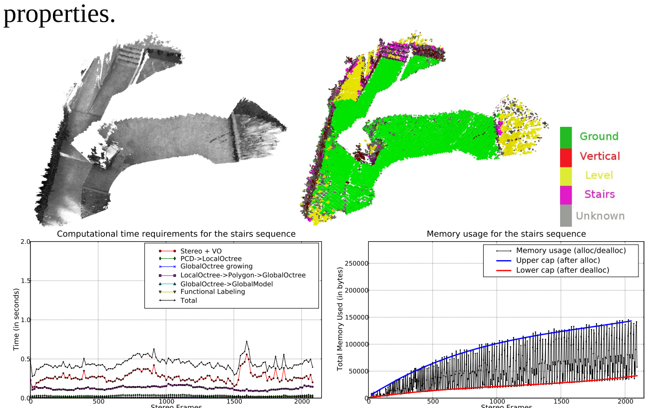

Fig. 2. Top: a snapshot of the point cloud data and semantic model for the stairs data set; bottom: computational time and memory usage requirements per useful stereo frame.

III. Conclusions

We have presented a complete system for 3D realtime semantic polygonal mapping using point cloud data from stereo. The computational properties of our system, namely fast processing time and low memory requirements, make it extremely suitable for fast, online 3D mapping, planning and over-the-shoulder view for teleoperation.

References

[1] Radu Bogdan Rusu, Aravind Sundaresan, Benoit Morisset, Motilal Agrawal, and Michael Beetz, Leaving Flatland: Realtime 3D Stereo Semantic Reconstruction, in: Proceedings of the International Conference on Intelligent Robotics and Applications (ICIRA) 2008, October 15-17, Wuhan, China, 2008.

This work was done as part of the "Leaving Flatland" project (DARPA contract #FA8650-04-C-7136) at the Artificial Intelligence Center, SRI International, with partial support from the CoTeSys (Cognition for Technical Systems) cluster of excellence at the Technische Universität München. The authors thank their former colleague Brian Gerkey for his work on the project during his affiliation with SRI International.

Aravind Sundaresan, Benoit Morisset, and Motilal Agrawal are with the Artificial Intelligence Center, SRI International, 333 Ravenswood Avenue, Menlo Park, CA 94025 USA {aravind, morisset, agrawal@ai.sri.com}. Kurt Konolige is now at Willow Garage, Inc., 68 Willow Road, Menlo Park, CA 94025 but was affiliated with the Artificial Intelligence Center, SRI International for the duration of his work on this project {konolige@willowgarage.com}

Radu Bogdan Rusu, and Michael Beetz are with the Technische Universität München, Computer Science Department, Intelligent Autonomous Systems group, Boltzmannstr. 3, 85748, Garching bei München, Germany {rusu, beetz@cs.tum.edu}