Preface

This work reports research on mapping, path planning, and autonomous exploration. These are classical problems in robotics, typically studied independently, and here we link such problems by framing them within a common SLAM approach, adopting Pose SLAM as the basic state estimation machinery. The main contribution of this work is an approach that allows a mobile robot to plan a path using the map it builds with Pose SLAM and to select the appropriate actions to autonomously construct this map.

Pose SLAM is the variant of SLAM where only the robot trajectory is estimated and where landmarks are only used to produce relative constraints between robot poses. In Pose SLAM, observations come in the form of relative-motion measurements between robot poses. With regards to extending the original Pose SLAM formulation, this work studies the computation of such measurements when they are obtained with stereo cameras and develops the appropriate noise propagation models for such case. Furthermore, the initial formulation of Pose SLAM assumes poses in SE(2) and in this work we extend this formulation to SE(3), parameterizing rotations either with Euler angles and quaternions. We also introduce a loop closure test that exploits the information from the filter using an independent measure of information content between poses. In the application domain, we present a technique to process the 3D volumetric maps obtained with this SLAM methodology, but with laser range scanning as the sensor modality, to derive traversability maps that were useful for the navigation of a heterogeneous fleet of mobile robots in the context of the EU project URUS.

Aside from these extensions to Pose SLAM, the core contribution of the work is an approach for path planning that exploits the modeled uncertainties in Pose SLAM to search for the path in the pose graph with the lowest accumulated robot pose uncertainty, i.e., the path that allows the robot to navigate to a given goal with the least probability of becoming lost. An added advantage of the proposed path planning approach is that since Pose SLAM is agnostic with respect to the sensor modalities used, it can be used in different environments and with different robots, and since the original pose graph may come from a previous mapping session, the paths stored in the map already satisfy constraints not easy modeled in the robot controller, such as the existence of restricted regions, or the right of way along paths. The proposed path planning methodology has been extensively tested both in simulation and with a real outdoor robot.

Our path planning approach is adequate for scenarios where a robot is initially guided during map construction, but autonomous during execution. For other scenarios in which more autonomy is required, the robot should be able to explore the environment without any supervision. The second core contribution of this work is an autonomous exploration method that complements the aforementioned path planning strategy. The method selects the appropriate actions to drive the robot so as to maximize coverage and at the same time minimize localization and map uncertainties. An occupancy grid is maintained for the sole purpose of guaranteeing coverage. A significant advantage of the method is that since the grid is only computed to hypothesize entropy reduction of candidate map posteriors, it can be computed at a very coarse resolution since it is not used to maintain neither the robot localization estimate, nor the structure of the environment. Our technique evaluates two types of actions: exploratory actions and place revisiting actions. Action decisions are made based on entropy reduction estimates. By maintaining a Pose SLAM estimate at run time, the technique allows to replan trajectories online should significant change in the Pose SLAM estimate be detected. The proposed exploration strategy was tested in a common publicly available dataset comparing favorably against frontier based exploration.

This work was supported in part by a Ph.D. scholarship from the Mexican Council of Science and Technology (CONACYT), a Research Stay Grant from the Agència de Gestió d'Ajuts Universitaris i de Recerca of The Generalitat of Catalonia (2010 BE1 00967), the Consolidated Research Group VIS (SGR2009-2013), a Technology Transfer Contract with the Asociación de la Industria Navarra, the European Integrated Project ARCAS (FP7-ICT-287617), the National Research Projects PAU (DPI2008-06022), PAU+ (DPI2011-2751) and RobInstruct: Instructing robots using natural communication skills TIN2014-58178-R funded by the Spanish Ministry of Economy and Competitiveness.

Pittsburgh, USA — Rafael Valencia
Barcelona, Spain — Juan Andrade-Cetto
February 2017

http://www.springer.com/978-3-319-60602-6

Mapping, Planning and Exploration with Pose SLAM
Valencia, R.; Andrade-Cetto, J.
2018, XII, 114 p. 40 illus., 38 illus. in color., Hardcover
ISBN: 978-3-319-60602-6