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EDITORIAL

Guest Editorial: Special issue on "Topological methods in robotics"

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1 Preface

Over the past several years topological methods have been used extensively in a variety of problems in robotics. One such method uses topological invariants and topological abstractions to reason about shapes of configuration spaces and for dimensionality reduction, while preserving some topological properties. Invariants have also been used to develop algorithms for classifying and computing optimal solutions in distinct topological classes in configuration spaces. These approaches have been applied toward multi-robot exploration, systems involving flexible cables and robotic manipulation. Another topological construct uses simplicial complexes which have transcended the conventional graph representations in context of sensor networks, making way for new methods in reasoning about the shape of configuration spaces and in developing effective coverage algorithms. With advances in persistent homology algorithms, topological data analysis techniques have been used on large data sets (such as 3D point clouds in context of visual mapping) and sensor networks for identification and classification of spaces based on their topology.

2 Introduction

This special issue of Autonomous Robots brings together a diverse set of high-quality research papers on the scientific foundations and the applications of topological methods in various aspects of robotics, including perception, mapping, localization, planning, manipulation and C-space learning and abstraction. While significant progress has been made in bringing topological methods at the forefront of robotics research in recent years through numerous workshops and conferences, much work remains to be done. The goal of this special issue has been to bring together a growing community of researchers in topological robotics and has strived towards bridging the gap between the applied topology community and the robotics community. The following 10 contributions provide a sample of current works on the application of topological methods in robotics ranging from long-standing classical directions investigating problems related to the topology of robotic configuration spaces, to approaches that combine machine learning with topological ideas.

3 Author contributions

The special issue opens with the article "Herding by caging: a formation-based motion planning framework for guiding mobile agents" by Song et al. in which the authors propose algorithms for hearding of a group of agents using a group of mobile robots, and formalize the propoerties of the algorithms using topologicl methods. The article "Topological navigation graph framework" by Daniušis et al. combines tools from machine learning and topological metods to design a novel immitation learning based topologica navigation framework for goal-directed navigation. The next article, "Partial caging: a clearance-based definition, datasets, and deep learning" by Welle et al., also uses machine learning techniques in conjunction with topological reprsentations and abstractions to predict the quality of caging in context of object manipultion from 2D images. The work "An optimal property of the hyperplane system in a finite cubing" by Buralnik and Ghrist study a class of nonpositively curved cubical complexes C that arise as configuration spaces of reconfigurable systems and, when C is Cat(0), develop methodologies for learning such a complex from a set of point-separating Boolean queries on its 0-skeleton from outputs

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of such queries along a suitably chosen path in the complex. The article "Decidability in Robot Manipulation Planning" by Vendittelli et al. develops an approach to proving the decidability of a manipulation problem consisting of a robot manipulating objects in the plane with techniques that enjoy a wider applicability to problems that exhibit stratified configuration spaces. The article "Motion Planning for a Pair of Tethered Robots" by Teshnizi, et al. introduces the notion of reduced visibility graph to model the topological constraints in motion planning for robots that are connected with each other via a cable of limited length. In the article "Enhancing the Morphological Segmentation of Microscopic Fossils through Localized Topology-Aware Edge Detection", authors Ge, et al. use a homological approach in conjunction with a generative model for predicting and correcting errors in automated morphological segmentation and classification of images of single-celled marine organisms known as foraminifera. In "A Topological Extension of Movement Primitives for Curvature Modulation and Sampling of Robot Motion", the authors Colomé, et al. use a topological classification of trajectories to generate new trajectories that can adapt to changing situations while satisfying curvature specifications. In "Topological representation of cloth state for robot manipulation" by Strazzeri, et al. the authors use topological techniques to describe low-dimensional representations of C-space of cloths for the purpose of textile manipulation. The paper "Hierarchical Topometric Representation of 3D Robotic Maps" by He et al. describes algorithms for construction of a mixed topological and metric map of an environment fron 3D point clouds.

4 Conclusion

This special issue samples a diverse set of applications of topological methods to the field of robotics. While significant progress has been made in bringing topological methods at the forefront of robotics research in the recent years through numerous workshops and conferences, much work remains to be done. We believe this special issue has served as a first step towards that objective.

The editors would like to thank the authors and reviewers for their time and effort in making this special issue a success. We would also like to thank the editorial office and the editor-in-chief, without whose help this special issue would not have been possible.