Computational Geometry in Navigation and Path Planning

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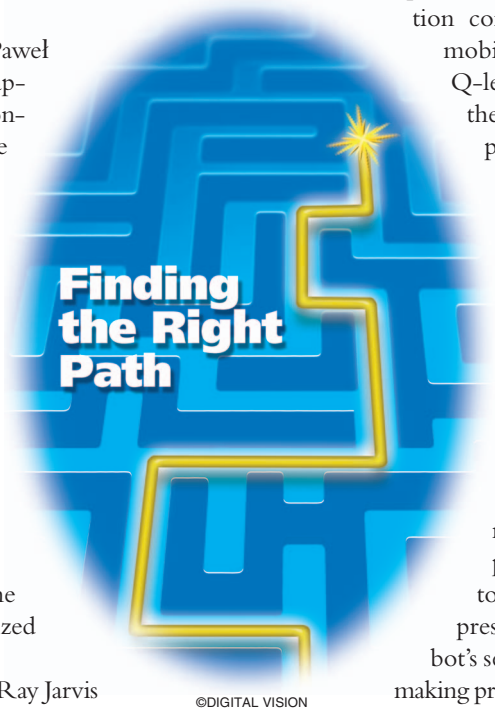
This special issue on computational geometry in navigation and path planning presents a collection of state-of-the-art articles reporting on the unique aspects of topology-based approaches in robotics. This issue presents the applications of computational geometry in obstacle avoidance, path planning with minimum clearance, autonomous mobile robot navigation, exploration of unknown polygonal environments, and it explores the practical relevance to the geographical information systems, mobile networks, risk avoidance, security, games, and online system design. The six contributions carefully selected for this special issue are connected by a common theme: the application of recent theoretical advances in computational geometry to the important robotics and path planning problems.

The article by Ichiro Suzuki and Paweł Żyliński presents a number of new approaches to capturing an evader in a constrained space. The authors provide several new strategies for a group of mobile robots on a three-dimensional grid such as a randomized algorithm for detecting an evader by one robot having the same maximum speed as the evader, a randomized algorithm for capturing an evader using two or more robots who can move slightly faster than the evader, and a deterministic algorithm for capturing an evader under specific constraints. The article critically compares all the proposed algorithms on their efficiency and robustness and makes a unique contribution to the areas of pursuit game design, randomized algorithms, and mobile robot planning.



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The article by David Rawlinson and Ray Jarvis explores a challenging problem of teaching a robot to navigate directly to goals in unfamiliar or unknown environments. Language allows people to exploit other people's knowledge in such situations, by transferring all necessary information from one person to the other, whereas what means can assist robots in doing the same is the question asked by this article. The proposed solution directs an autonomous robot using efficient and universal topological instructions that can be incrementally interpreted by a moving robot that does not initially have its own map of the environment. Many real-world experiments featuring autonomous exploration and mapping led to the remarkable conclusion that for this type of navigation, better object recognition capabilities are more important than better mapping capabilities.

Another approach to autonomous robot navigation is presented in the article by Chunlin Chen, Han-Xiong Li, and Daoyi Dong. In this work, the authors present a control method based on hierarchical Q-learning for mobile robot navigation in unknown environments. Hybrid control here refers to the integration of reactive control for local navigation and deliberative control for global navigation. The environment is represented by grid-topological maps that are constructed online during the process of learning to achieve the cooperative optimization of global and local navigation control. The navigation controls of the mobile robots are implemented by extending Q-learning to a hierarchical setting based on the model of a hybrid Markov decision process. The simulated and real experimentation shows that the proposed approach is capable of optimizing global navigation and avoiding the local minimum trap, so that the method works well in unknown dynamic environments and can be utilized as an effective integrated control scheme for navigation.

The article by Ellips Masehian and Mohammad Reza Amin-Naseri is devoted to the problem of sensor-based motion planning and proposes an approach based on the tabu search method to resolve it. The online motion planner presented in this article incorporates the robot's sensory data into the intelligent decision-making process guided by the tabu search technique. The information from the environment is collected by performing a visibility scan, and the distance from the new robot location to the surrounding obstacles is computed by means of its radial rangefinder sensor readings. The proposed method is compared extensively with other offline and online techniques, such as the potential fields, distance transform, and the generalized Voronoi diagram methods.

The article by Priyadarshi Bhattacharya and Marina L. Gavrilova presents an efficient technique for computing a shortest path for a mobile agent moving among polygonal obstacles that will satisfy the specified clearance requirement. The algorithm utilizes the properties of the Voronoi diagram to obtain a path approximation and then proceeds to refine the path

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through the corner-cutting technique. Extensive experimentation demonstrates that the method produces high-quality paths that are near optimal with respect to the length and have the required clearance from obstacles. The ease of implementation makes it an attractive technique for a number of applications, including real-time terrain visualization, risk avoidance, environmental modeling, and motion planning.

The article by Subir Kumar Ghosh, Joel Wakeman Burdick, Amitava Bhattacharya, and Sudeep Sarkar integrates some constraints from visual processing and robot navigation into the well-studied computational geometry problem of exploring unknown polygonal environments with obstacles. The authors propose online algorithms that can be used to explore an unknown polygonal environment by a point robot. The algorithms compute visibility polygons from a set of chosen points on the path of a robot and use the reduction of the number of visibility polygons as a criterion for minimizing the cost of robotic exploration, thus improving efficiency. In addition, the article demonstrates that the presented exploration algorithms for a point robot can be also treated as approximation algorithms for the art gallery problem with an additional visibility constraint.

This special issue presents a collection of articles on topology-based approaches in robotics.

We would like to extend our sincere appreciation to all the authors who submitted their articles to the special issue and to all the referees for their meticulous and valuable reviews. It is our hope that this fine collection of articles presented in this issue will be a valuable resource for all the readers of *IEEE Robotics and Automation Magazine* and will stimulate further research into the growing area of the applications of computational geometry methods in robotics and path planning.