LNAI 2313

Carlos A. Coello Coello
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MICAI 2002: Advances in Artificial Intelligence

Second Mexican International Conference on Artificial Intelligence
Mérida, Yucatán, Mexico, April 2002
Proceedings

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Cataloging-in-Publication Data applied for

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Advances in artificial intelligence / MICAI 2002, Second Mexican International Conference on Artificial Intelligence, Mérida, Yucatán, Mexico, April 22 - 26, 2002. Carlos A. Coello Coello ... (ed.). - Berlin ; Heidelberg ; New York ; Barcelona ; Hong Kong ; London ; Milan ; Paris ; Tokyo : Springer, 2002
(Lecture notes in computer science ; Vol. 2313 : Lecture notes in artificial intelligence)
ISBN 3-540-43475-5

CR Subject Classification (1998): I.2, I.4, F.4.1, F.1

ISSN 0302-9743
ISBN 3-540-43475-5 Springer-Verlag Berlin Heidelberg New York

Springer-Verlag Berlin Heidelberg New York
a member of BertelsmannSpringer Science+Business Media GmbH

http://www.springer.de

Typesetting: Camera-ready by author, data conversion by Olgun Computergrafik
Printed on acid-free paper SPIN 10846597 06/3142 5 4 3 2 1 0

Lecture Notes in Artificial Intelligence 2313

Subseries of Lecture Notes in Computer Science
Edited by J. G. Carbonell and J. Siekmann

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Preface

Artificial Intelligence has failed to accomplish at least two highly significant predictions as we enter the new millennium. The English mathematician Alan Mathison Turing predicted that by the year 2000 we would have a machine that could pass the Turing test. The film "2001: A Space Odyssey", portrayed an intelligent computer named HAL which, among other things, was able to speak and understand English, and even read the lips of humans having a conversation. Such a machine would be created, according to Arthur C. Clarke, by the year 1997. We have reached the year 2002 and neither of these two predictions have been fulfilled. However, there have been many significant achievements in artificial intelligence and several new challenges are now on the horizon.

Two years ago, we held the first Mexican International Conference on Artificial Intelligence, MICAI 2000, which took place on April 11–14, 2000, in the city of Acapulco, México. After a first highly successful conference, we are pleased to introduce the second Mexican International Conference on Artificial Intelligence, MICAI 2002, which took place on April 22–26 in Mérida, Yucatán, México. The main aim of the conference was to promote research in AI, and cooperation among Mexican researchers and their peers worldwide.

As a historical note, it is worth mentioning that MICAI originated from the union of the Mexican National AI Conference (RNIA) and the International AI Symposium (ISA), organized annually by the Mexican Society for AI (SMIA, since 1984) and by the Monterrey Institute of Technology (ITESM, since 1988), respectively.

Over 85 papers (in English) from 17 different countries were submitted for consideration to MICAI 2002. After a thorough review process, MICAI's program committee and the program chairs accepted 56 high-quality papers which are included in these proceedings.

We would like to acknowledge the support of the American Association for Artificial Intelligence (AAAI), and the International Joint Conference on Artificial Intelligence (IJCAI). We are especially grateful for the warm hospitality and generosity offered by the Universidad Autónoma de Yucatán (UADY) and the Universidad Mesoamericana de San Agustín (UMSA).

A special word of thanks goes to the members of the advisory board, the members of the program committee, our sponsors, and our support staff.

Last but not least, we warmly thank all of the attendants to the conference for their participation.

April 2002

Carlos A. Coello Coello
Alvaro de Albornoz
Luis Enrique Sucar Succar
Osvaldo Cairo

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We would like to thank Alberto Pastrana, Raúl Godoy Montañez, Luis Rodríguez Carvajal, Orlando Piña, the ACM student chapter at UADY, the Student Association at UADY, and the Student Council at UADY for their excellent organizational support. Special thanks go to Nareli Cruz Cortés and the Springer-Verlag staff for editing this volume.

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Motion Planning for Car-Like Robots Using Lazy Probabilistic Roadmap Method

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Abstract. In this paper we describe an approach to probabilistic roadmap method. Our algorithm builds initially a roadmap in the configuration space considering that all nodes and edges are collision-free, and searches the roadmap for the shortest path between start and goal nodes. If a collision with the obstacles occurs, the corresponding nodes and edges are removed from the roadmap or the planner updates the roadmap with new nodes and edges, and then searches for a shortest path. The procedure is repeated until a collision-free path is found. The goal of our approach is to minimize the number of collision checks and calls to the local method. Experimental results presented in this paper show that our approach is very efficient in practice.

1 Introduction and Motivation

We consider the basic problem, where there is one robot present in a static and known environment, and the task is to compute a collision-free path describing a motion that brings the robot from its current position to some desired goal position. The space where the robot and the obstacles are physically present is called the *workspace* $\mathcal{W}$. The planning is mostly performed in another space, the *configuration space* $\mathcal{CS}$. Each placement of the robot in $\mathcal{W}$ is mapped to a point in $\mathcal{CS}$. The portion of $\mathcal{CS}$ corresponding to collision-free placements of the robot is referred to as the *free-configuration space* $\mathcal{CS}_f$.

Automatic motion planning has applications in many areas such as robotics, virtual prototyping, graphic animation, medical surgery, and computational chemistry. Although many different motion planning methods have been proposed, most are not used in practice since they are computationally infeasible except for some restricted cases. Indeed, there is strong evidence that any complete planner requires time exponential in the number of degrees of freedom (dofs) of the robot. For this reason, attention has focused on randomized or probabilistic motion planning methods.

Probabilistic roadmap method (PRM) is a general planning scheme building probabilistic roadmaps by randomly selecting configurations from the free-configuration space and interconnecting certain pairs by simple feasible paths.

C.A. Coello Coello et al. (Eds.): MICAI 2002, LNAI 2313, pp. 1–10, 2002.

The method has been applied to a wide variety of robot motion planning problems with remarkable success [1], [2], [3], [4], [5].

There are two main classes of PRM planners [6]: *multi-query* and *single-query* planners. A multi-query planner pre-computes a roadmap and then uses it to process multiple queries [2], [3], [4], [5]. In general, the query configurations are not known in advance, so the roadmap must be distributed over the entire $\mathcal{CS}_f$. On the other hand, a single-query planner computes a new roadmap for each query [1], [6], [7]. Its only goal is to find a collision-free path between two query configurations. The less free space it explores before finding such a path, the better. Single query planners are more suitable in environments with frequent changes.

Since PRM planners perform relatively expensive pre-computation, they are most suitable for processing multiple queries in a static environment. However, of particular interest are planners that with little preprocessing can answer single queries very quickly. Such planners can be used to re-plan paths in applications where the configuration space obstacles could change. This occurs, for instance, when the robot changes tools, grasps an object, or a new obstacle enters the workspace.

In this paper we further develop probabilistic planning techniques in direction of achieving general and practical useful single query planners. We present a extended approach based upon a general scheme for lazy evaluation of the feasibility of the roadmap. Original version of lazy PRM was presented by Bohlin and Kavraki [8]. The scheme suggested for lazy evaluation of roadmaps is general and can be applied to any graph that needs to be explored. In addition to lazy PRM, other related algorithms, and variations of PRM, can benefit from this scheme and significantly increase performance.

This paper is organized as follows. Section 2 presents works related to nonholonomic motion planning. Section 3 deals with car-like robots and briefly presents the local method, Reeds & Shepp's paths. Our algorithm is described in detail in Section 4, and experimentally evaluated in Section 5. Section 6 discusses our results and presents future work.

2 Previous and Related Work

A first single-shot random planner for free-flying planar robots was described in [1] and subsequently expanded into a general learning approach for various robot types in [2]. Vallejo, Jones and Amato [7] propose an adaptive framework for single-shot motion planning. The author's strategy consists of adaptively select a planner whose strengths match the current situation, and then switch on-line to a different plannner. Experimental results show that this strategy solves queries that none of the planners could solve on their own; and is suitable for crowded environments in which the robot's free-configuration space has narrow corridors such as in maintainability studies in complex 3-D CAD models.

The lazy PRM presented by Bohlin and Kavraki [8] describes an algorithm, which minimize the number of collision checks performed during planning. In contrast with classic PRMs, the planner initially assumes that all nodes and edges in the roadmap are collision-free, and searches the roadmap at hand for a shortest path between the start and the goal node. The nodes and edges along the path are checked for collision. If a collision with the obstacles occurs, the corresponding nodes and edges are removed from the roadmap. Planner either finds a new shortest path, or first updates the roadmap with new nodes and edges, and searches for a shorter path. The process is repeated until a collision-free path is found. Experimental results show a six dof robot in a realistic industrial environment.

Another simple and efficient approach for solving single-query path planning problems is presented in [6] by Kuffner and Lavalle. The approach works by incrementally building two rapidly-exploring random trees (RRTs) rooted at the start and the goal configurations. The key idea is to bias the exploration towards unexplored portions of the space by sampling points in the state space, and incrementally "pulling" the search tree toward them. The drawbacks for this method are the choice of the a suitable metric, the construction of nearest-neighbors and the collision detection. Experimental results presented by the authors include planning problems that involve holonomic constraints for rigid and articulated bodies, manipulation, nonholonomic constraints, kinodynamic constraints, and kinematics closure constraints.

The planner presented by Sánchez and Latombe [9] uses a lazy collision-checking strategy (it postpones collision tests along connections in the roadmap until they are absolutely needed) with single-query bi-directional sampling techniques (it does not pre-compute a roadmap, but uses the two input query configurations to explore as little space as possible and searches the robot's free space by concurrently building a roadmap made of two trees rooted at the query configurations). Combining these techniques, the planner can solve path planning problems of practical interest (i.e. with realistic complexity) in times ranging from fractions of a second to a few seconds.

Planners based on lazy strategy [8] and [9] always use as local method the computing of the straight-line segment (Euclidean distance). Much research has been done on motion plannning for nonholonomic car-like robots (see [10] for a review). Švestka and Overmars [4] use the RTR paths as local method. An alternative is to use a local method that constructs the shortest path connecting the two configurations as was done in [11], [5], [12]. Another randomized strategy that has been used for non-holonomic planning is the RRT approach [6].

3 Model of a Car-Like Robot

With reference to Fig. 1, the coordinates x and y determine the position in the plane of the rear wheel axle mid-point of the car, while θ is the angle that the unit direction vector forms with the positive x axis. A *configuration* of the car is given by a triple $(x, y, \theta) \in \Re^2 \times S^1$, where S^1 is the unit circle in the plane. The point $(x, y) \in \Re^2$ will be referred to as the *position* of the car in the plane.