Studies in Computational Intelligence

Volume 772

Series editor

Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland
e-mail: kacprzyk@ibspan.waw.pl

The series "Studies in Computational Intelligence" (SCI) publishes new developments and advances in the various areas of computational intelligence—quickly and with a high quality. The intent is to cover the theory, applications, and design methods of computational intelligence, as embedded in the fields of engineering, computer science, physics and life sciences, as well as the methodologies behind them. The series contains monographs, lecture notes and edited volumes in computational intelligence spanning the areas of neural networks, connectionist systems, genetic algorithms, evolutionary computation, artificial intelligence, cellular automata, self-organizing systems, soft computing, fuzzy systems, and hybrid intelligent systems. Of particular value to both the contributors and the readership are the short publication timeframe and the world-wide distribution, which enable both wide and rapid dissemination of research output.

More information about this series at http://www.springer.com/series/7092

Anis Koubaa · Hachemi Bennaceur
Imen Chaari · Sahar Trigui
Adel Ammar · Mohamed-Foued Sriti
Maram Alajlan · Omar Cheikhrouhou
Yasir Javed

Robot Path Planning and Cooperation

Foundations, Algorithms and Experimentations

Springer

Anis Koubaa
Prince Sultan University
Riyadh
Saudi Arabia

Hachemi Bennaceur
College of Computer and Information Sciences
Al Imam Mohammad Ibn Saud Islamic University
Riyadh
Saudi Arabia

Imen Chaari
University Campus of Manouba
Manouba
Tunisia

Sahar Trigui
University Campus of Manouba
Manouba
Tunisia

Adel Ammar
College of Computer and Information Sciences
Al Imam Mohammad Ibn Saud Islamic University
Riyadh
Saudi Arabia

Mohamed-Foued Sriti
College of Computer and Information Sciences
Al Imam Mohammad Ibn Saud Islamic University
Riyadh
Saudi Arabia

Maram Alajlan
College of Computer and Information Sciences
Al Imam Mohammad Ibn Saud Islamic University
Riyadh
Saudi Arabia

Omar Cheikhrouhou
College of Computers and Information Technology
Taif University
Taif
Saudi Arabia

Yasir Javed
College of Computer and Information Sciences
Prince Sultan University
Riyadh
Saudi Arabia

ISSN 1860-949X ISSN 1860-9503 (electronic)
Studies in Computational Intelligence
ISBN 978-3-319-77040-6 ISBN 978-3-319-77042-0 (eBook)
https://doi.org/10.1007/978-3-319-77042-0

Library of Congress Control Number: 2018934389

Printed on acid-free paper

This Springer imprint is published by the registered company Springer International Publishing AG part of Springer Nature
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The objective of the book is to provide the reader with a comprehensive coverage of two important research problems in mobile robots, namely global path planning and cooperative multi-robots applications with a focus on multi-robot task allocation (MRTA) problem. As such, this book is organized in two major parts: Global Path Planning, and Multi-Robot Task Allocation. The objective of the first part of the book is to respond to a research question that we have been investigating along the two-year period of the iroboapp project: considering the vast array of AI techniques used to solve the robot path planning problem ranging from evolutionary computation techniques (e.g. GA, ACO) to meta-heuristic methods (e.g. A*), which technique is the best? In this part, we first revisit the foundations and present a background of the global path planning problem, and the underlying intelligent techniques used to solve it. Then, we present our new intelligent algorithms to solve these problems, based on common artificial intelligence approaches, and we analyze their complexities. Different simulation models using C++, MATLAB and others have been devised. An extensive comparative performance evaluation study between the path planning algorithms is presented. In addition, we validate our results through real-world implementation of these algorithms on real robots using the Robot Operation System (ROS). The second part of the book deals with cooperative mobile robots. We focus on the multi-robot task allocation (MRTA) problem and we present a comprehensive overview on this problem. Then, we present a distributed market-based mechanism for solving the multiple depot, multiple travel salesman problem which is a typical problem for several robotics applications. A major contribution of this book is that it bridges the gap between theory and practice as it shows how to integrate the global path planning algorithms in the ROS environment and it proves their efficiency in real scenarios. We believe that this handbook will provide the readers with a comprehensive reference on the global path planning and MRTA problems starting from foundations and modeling, going through simulations and real-world deployments. Links to videos and demonstrations will be included in the book.

Riyadh, Saudi Arabia	Anis Koubaa
Riyadh, Saudi Arabia	Hachemi Bennaceur
Manouba, Tunisia	Imen Chaari
Manouba, Tunisia	Sahar Trigui
Riyadh, Saudi Arabia	Adel Ammar
Riyadh, Saudi Arabia	Mohamed-Foued Sriti
Riyadh, Saudi Arabia	Maram Alajlan
Taif, Saudi Arabia	Omar Cheikhrouhou
Riyadh, Saudi Arabia	Yasir Javed

Acknowledgements

The work is supported by the Robotics and Internet-of-Things (RIOTU) Lab and Research and Initiative Center (RIC) of Prince Sultan University, Saudi Arabia. It also supported by Gaitech Robotics in China. Part of this work was previously supported by the iroboapp project "Design and Analysis of Intelligent Algorithms for Robotic Problems and Applications" under the grant of the National Plan for Sciences, Technology and Innovation (NPSTI), managed by the Science and Technology Unit of Al-Imam Mohamed bin Saud University and by King Abdulaziz Center for Science and Technology (KACST).

Contents

Acronyms

2PPLS	Two-phase Pareto local search
A*	The Astar algorithm
ABC	Artificial bee colony
ACO	Ant Colony Optimization
AD*	Anytime Dynamic A*
AM	Application Master
ANA*	Anytime Nonparametric A*
APF	Artificial Potential Field
ARA*	Anytime Repairing A*
BLE	Broadcast of Local Eligibility
BSP	Bulk Synchronous Parallel
CACO	Conventional ACO
CFor	A set of forbidden configuration
CFree	A set of free configuration
CPD	Compressed path databases technique
CYX	Cycle crossover operator
DWA	Dynamic Window Approach
E*	The E Star algorithm
EDA	Estimation of distribution algorithm
FCE	Free configuration eigen-spaces
FIS	Fuzzy Inference System
FMM	Fast marching method
FOD	Front obstacle distance
GA	Genetic Algorithm
GGA	Grouping genetic algorithms
GGA-SS	Steady-state grouping genetic algorithm
GRASP	Greedy Randomized Adaptive Search Procedure
HACO	Heterogeneous ACO
HDFS	Hadoop Distributed File System
IDPGA	Improved dual-population GA

ILS	Iterated Local Search
IWO	Invasive weed optimization
JPS	Jump point search
LOD	Left obstacle distance
MACO	Modified ACO
MD-MTSP	Multiple Depots MTSP
MLP	Multi-Layer Perceptron
MOKPs	Multi-objective Knapsack problems
MOP	Multi-Objective Optimization
MPCNN	Modified pulsecoupled neural network
MRS	Multi-Robot System
MRTA	Multi-Robot Task Allocation
MTD	Maximum Traveled Distance
MT	Maximum tour
MTSP	Multiple Traveling Salesmen Problem
NM	Node Manager
NN	Neural Networks
ORX	Ordered crossover operator
PFM	The Artificial potential field approach
PFM	Potential field method
PMX	Partially-matched crossover operator
PPaaS	Path Planning as a Service
PRM	The probabilistic roadmap method
PSO	Particle Swarm Optimization
QHS	Quad Harmony Search
RA*	Relaxed AStar
RM	Global Resource Manager
ROD	Right obstacle distance
ROS	Robot Operating System
RRT	Rapidly-exploring random tree
RTMA	Robot and Task Mean Allocation Algorithm
S+T	Services and Tasks
SA	Simulated Annealing
SOM	Self Organizing Maps
SP-CNN	Shortest path cellular neural network
SSSP	Single source shortest path algorithm
TSP	Traveling Salesmen Problem
TS	Tabu Search
TTD	Total Traveled Distance
TWD*	Two Way D*
UAV	Unmanned Air Vehicle
VNS	Variable Neighborhood Search
VRP	Vehicle routing problem
YARN	Yet Another Resource Negotiator

List of Figures

List of Tables