A Generic Force Field Method for Robot Real-time Motion Planning and Coordination

Dalong Wang

A thesis submitted in fulfilment
of the degree of
DOCTOR OF PHILOSOPHY

Faculty of Engineering and Information Technology
University of Technology, Sydney

October 2009

CERTIFICATE OF AUTHORSHIP / ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

(DALONG WANG)

Sydney, October 2009

Abstract

This thesis presents a systematic study on a novel force field method (F^2) for robot motion planning and multi-robot motion coordination. In this F^2 method, a force field is generated for each robot based on its status: location, orientation, travel speed, priority, size, and the robot's environment. A robot with larger volume, travelling at higher speed or with higher task priority than other robots, will have a larger force field, and consequently has priority in collision avoidance. The interaction of a robot's force field with its environment provides a natural way for real-time motion planning and multi-robot coordination.

Four novel F^2 based methods have been investigated for applications in different cases. The Canonical Force Field method (CF^2) is first designed based on the concept of the F^2 method, in which a robot is assumed to be travelling with constant speed and its moving direction is determined by the resultant forces acting on it. This CF^2 method has proved to be very efficient in applications in simple and structured environments. A Variable Speed Force Field method (VSF^2) which takes a robot's kinematic and dynamic constraints into consideration is further investigated. The VSF^2 method allows a robot to change its speed based on environmental information and the status of obstacles and other robots in the same environment. A Subgoal-Guided Force Field method (SGF^2) is developed to enhance the F^2 method by generating subgoals based on updated sensor data. A robot using the SGF^2 method will then move towards a subgoal instead of the global goal, which greatly broadens the applicability of the F^2 method in more complex environments. Finally, a Dynamic Variable Speed Force Field method ($DVSF^2$) is designed for applications in partially known and dynamically changing environments. In this method, subgoals are selected on a pre-planned global path.

In order to investigate the effect of parameters on the performance of the proposed F^2 methods, two optimization algorithms have been proposed in this research for optimal design of the parameters in F^2 methods: the Particle Swarm Optimization-tuned Force Field method (PSO-tuned F^2) for single objective parameter optimization and the Ranked Pareto Particle Swarm Optimization approach for multiobjective parameter optimization.

Extensive simulations and experiments with real robots in an indoor environment have been carried out to verify these methods. The results have demonstrated the feasibility and efficiency of the F^2 methods in real-time robot motion planning and multi-robot coordination in various environments.

Acknowledgements

I would like to express my deepest gratitude to the following people for helping me during my study in the ARC Centre of Excellence for Autonomous Systems (CAS), Faculty of Engineering and Information Technology, University of Technology, Sydney. First of all, I would like to thank my principal supervisor Associate Professor Dikai Liu for his advice and guidance throughout these years. Without his support the completion of this thesis would not have been possible. I would also like to thank Professor Gamini Dissanayake for advising me on my research. His expert knowledge and deep insight provide invaluable help to my research.

I would like to thank all friends and colleagues in CAS, especially Gavin Paul, Nathan Kirchner, Zhengzhi Zhang, Pholchai Chotiprayanakul, Tianran Ren, Tarek Taha, and Stephen Webb for their friendship and help. I would like to thank Mr. Tarek Taha and Dr. Jaime Valls Miro for their great support in experiments with robots. A special thank goes to Dr. Ngai Ming Kwok, who helped a lot in my research on parameter optimization of the force field methods and gave me many helpful suggestions on the writing of my thesis.

Finally, I would like to thank my family who has always supported me and my wife Danna for always being by my side. You are the source of my inspiration, courage and happiness.

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