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Evolution of High Level Motion Control for Autonomous Ground Vehicles

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Contents

List of Figures

List of Tables

Abstract

Autonomous robotic exploration is the task of building models of an environment. This task requires robots to rapidly plan, re-plan and execute their motion trajectories using sensory data that is provisional, uncertain and noisy. To navigate successfully under these conditions, robots require carefully designed motion controller software to guide the robot safely, quickly, reliably and efficiently to intermediate exploration objectives. Conventionally, the basic design of a motion controller is derived from first principles using simplified models of motion control and then refined by hand in response to observed performance. While this approach works in simpler applications, it becomes more challenging and less effective as applications become more complex and the number of variables to consider increases. Moreover, changes in robot configuration and environment can entail costly redesign of the controller. As such, we argue that this manual approach will become increasingly impractical as our exploration tasks become more ambitious. In this thesis, we address the development of motion control using techniques from Evolutionary Computation (EC). Our approach is to view the motion control design as a search problem, that can be subject to automation. In this work we present a novel framework for evolving the core component of motion control based on a form of EC called Grammatical Evolution (GE). GE systematically refines populations of potential programatic solutions for a given problem, until an effective solution is found. In our approach, we use GE to search automatically for the best motion control for a given set of exploration tasks. GE allows the user to constrain the search space for programs using Backus-Naur Form (BNF) grammar specifications. We use these grammars to define the search space for controllers for each exploration application. We conducted four experiments to evaluate our proposed approach. Each experiment demonstrates the framework in different exploration configurations and different requirements. All of our experiments evolved controller code for unmanned ground vehicles (UGV's). Our first experiment evolved numerical parameters for the control of small teams of UGV's. Our second experiment evolved control for a single UGV to optimise exploration performance and energy consumption. Our third experiment evolved both the structure and parameters of the core control function. Our fourth experiment evolved the input factor selection and numerical constants for well-established navigation approach in progressively

more realistic situations - culminating in deployment on real platforms. In each of our experiments we found that the automated search approach outperformed carefully designed handwritten control. Moreover the structure of the evolved equation helped to reveal the nature of the trade-offs inherent in the exploration task and what factors appear to be most relevant to informing effective control.

Thesis Declaration

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MOHD FAISAL IBRAHIM
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Abbreviations

APF	Artificial Potential Field
BNF	Backus-Naur Form
CFG	Context-Free Grammar
CMA-ES	Covariance Matrix Adaptation Evolutionary Strategy
DTC	Decision-Theoretic based Motion Control
DWA	Dynamic Window Approach
EC	Evolutionary Computation
ER	Evolutionary Robotics
ES	Evolutionary Strategy
FLC	Fuzzy Logic Controller
GA	Genetic Algorithm
GE	Grammatical Evolution
GP	Genetic Programming
GS	Ground Station
GPS	Global Positioning System
HRL	Hierarchical Reinforcement Learning
IMU	Inertia Measurement Unit
LE	Layered Evolution
LIDAR	Light Detection and Ranging Sensor
MPC	Model Predictive Control
ND	Nearness Diagram
NN	Neural Network
POMDM	Partially Observable Markov Decision Model
PSDP	Policy Search Dynamic Programming
RL	Reinforcement Learning
SGHC	Simple Genetic Hill Climbing
SLAM	Simultaneous Localisation and Mapping
SVM	Support Vector Machine
UGV	Unmanned Ground Vehicle
VFH	Vector Field Histogram