

Chapter 6

Establishing A-Priori Performance Guarantees for Robot Missions that Include Localization Software

Damian Lyons

Fordham University, USA

Ronald C Arkin

Georgia Institute of Technology, USA

Shu Jiang

Georgia Institute of Technology, USA

Matthew J O'Brien

Georgia Institute of Technology, USA

Feng Tang

Fordham University, USA

Peng Tang

Fordham University, USA

ABSTRACT

One approach to determining whether an automated system is performing correctly is to monitor its performance, signaling when the performance is not acceptable; another approach is to automatically analyze the possible behaviors of the system a-priori and determine performance guarantees. The authors have applied this second approach to automatically derive performance guarantees for behavior-based, multi-robot critical mission software using an innovative approach to formal verification for robotic software. Localization and mapping algorithms can allow a robot to navigate well in an unknown environment. However, whether such algorithms enhance any specific robot mission is currently a matter for empirical validation. Several approaches to incorporating pre-existing software into the authors' probabilistic verification framework are presented, and one used to include Monte-Carlo based localization software. Verification and experimental validation results are discussed for real localization missions with this software, showing that the proposed approach accurately predicts performance.

DOI: 10.4018/978-1-7998-1754-3.ch006

1. INTRODUCTION

For systems that need to function in critical situations, such as in healthcare applications, search and rescue robotics, and automated counter weapons of mass destructions (CWMD) missions, it is crucially important that the system function as specified or the result might be loss of life, or property damage or both. One approach to this problem is to monitor the system in operation (Leucker & Schallhart, 2009) and to signal an alert to a supervisor of the system when the performance is going, or predicted to go, outside the necessary performance envelope. This monitoring approach can be very effective in cases where a supervisor can step in, or the system can be disabled without consequence, when a performance problem is observed. However, in the case that the system is autonomous, or the supervisor cannot interact sufficiently quickly and the system cannot simply be disabled, then an alternate approach is necessary. In previous work for the Defense Threat Reduction Agency (Lyons et al., 2015) we have developed an efficient approach to the automatic, a-priori determination of performance guarantees for behavior-based robot missions operating in uncertain environments.

This work is related to formal software verification (Jhala & Majumdar, 2009) (DeMoura & Bjorner, 2012): a design tool to determine whether a piece of software will function properly without having to execute the software. The field has progressed strongly in recent years with developments in model-checking (Jhala & Majumdar, 2009) and satisfiability (SMT) engines (DeMoura & Bjorner, 2012). However, all such methods can at best approximate real robot performance because of the undecidability of the underlying verification problem. Designing a verification approach for mission critical robot software requires understanding what aspects of the robot software are of most importance to the problem. Behavior-based robot programming (Arkin, 1998) is an important tool in autonomous robotics that yields robot programs that are robust to uncertainty about exactly what environment the robots will face during execution. For this reason, in recent work (Lyons et al., 2015), we addressed the problem of automatically verifying behavior-based robot programs by leveraging the structure of such programs. The approach employs a unique combination of static analysis techniques and probabilistic reasoning to provide performance guarantees for behavior-based robot programs operating in physical environments with uncertain knowledge about obstacles to motion. Rather than addressing computational verification problems such as absence of deadlock or absence of run-time errors (Trojanek & Eder, 2014) (Walter, Taubig, & Luth, 2010), or verifying software generated control signals without consideration of the physical platform (Kim, Kang, & Lee, 2005), our work focuses on establishing performance guarantees for the mission software with a model of an uncertainly-known physical environment.

A key robotics development in recent years has been the use of probabilistic mapping and localization algorithms that allow a robot to operate robustly in previously unseen areas by automatically building a map and continually localizing the robot with respect to the map (Thrun, Burgard, & Fox, 2005). Many such algorithms have been programmed and tested and made available in software libraries (Dellaert, Fox, Burgard, & Thrun, 1999). Our prior work in verifying the performance of behavior-based robot missions involved manual and autotranslation of missions (O'Brien M., Arkin, Harrington, Lyons, & Jiang, 2014) specified using Georgia Tech's MissionLab (MacKenzie, Arkin, & Cameron, 1997) robot mission development toolkit. Other approaches to the verification of behavior-based systems have also been based on specific programming toolkits (Kiebusch, Armbrust, & Berns, 2015). However, since there already exist software libraries for probabilistic mapping and localization, it would be advantageous to simply include one of these in a robot mission *if* it provided the necessary performance. In this paper, we address the problem of incorporating existing software into our novel approach to performance

23 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage:

www.igi-global.com/chapter/establishing-a-priori-performance-guarantees-for-robot-missions-that-include-localization-software/244002

Related Content

Theories and Practices Behind Educational Robotics for All

Amy Eguchi (2021). *Handbook of Research on Using Educational Robotics to Facilitate Student Learning* (pp. 68-106).

www.irma-international.org/chapter/theories-and-practices-behind-educational-robotics-for-all/267662

iParking: An Intelligent Android-Cloud Based Smart Parking Reservation System Using Smart Phones Supportive to Smart City

Ankita Khadsare, Gauri Jadhav, Sayali Maliand Shivani Nanaware (2017). *International Journal of Synthetic Emotions* (pp. 1-24).

www.irma-international.org/article/iparking/182698

Autonomous Systems in a Military Context (Part 2): A Survey of the Ethical Issues

Jai Galliotand Tim McFarland (2016). *International Journal of Robotics Applications and Technologies* (pp. 53-68).

www.irma-international.org/article/autonomous-systems-in-a-military-context-part-2/167679

Optimization of Focused Wave Front Algorithm in Unknown Dynamic Environment for Multi-Robot Navigation

Priyanka Meel, Ritu Tiwariand Anupam Shukla (2013). *International Journal of Intelligent Mechatronics and Robotics* (pp. 1-29).

www.irma-international.org/article/optimization-of-focused-wave-front-algorithm-in-unknown-dynamic-environment-for-multi-robot-navigation/113909

Digital Control Theory Application and Signal Processing in a Laser Scanning System Applied for Mobile Robotics

Miguel Reyes-Garcia, Cesar Sepulveda-Valdez, Oleg Sergiyenko, Moisés Rivas-López, Julio Cesar Rodríguez-Quíñonez, Wendy Flores-Fuentes, Daniel Hernandez-Balbuena, Juan-Ivan Nieto-Hipolito, Fabian N. Murrieta-Rico, Lars Lindnerand Mykhailo Ivanov (2020). *Control and Signal Processing Applications for Mobile and Aerial Robotic Systems* (pp. 215-265).

www.irma-international.org/chapter/digital-control-theory-application-and-signal-processing-in-a-laser-scanning-system-applied-for-mobile-robotics/243767