

From ROS to Unity: leveraging robot and virtual environment middleware for immersive teleoperation*

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Abstract—Virtual reality systems are often proposed as an appropriate technology for the development of teleoperational interfaces for autonomous and semi-autonomous systems. In the past such systems have typically been developed as “one off” experimental systems in part due to a lack of common software systems for both robot software development and virtual environment infrastructure. More recently, common frameworks have begun to emerge for both robot control (e.g., ROS) and virtual environment display and interaction (e.g., Unity). Here we consider the task of developing systems that integrate these two environments. A yaml-based communications protocol over web sockets is used to glue the two software environments together. This allows each system to be controlled using standard software toolkits independently while providing a flexible interface between these two infrastructures.

Index Terms—robotics, teleoperation, virtual reality.

I. INTRODUCTION

There has long been an interest in developing virtual environment-based interface technologies for the control and supervision of autonomous and semi-autonomous devices. The basic concept can be traced back to early work in telepresence (see [1]): By providing an operator with a perceptual environment that is consistent with the experience that they would have experienced had they been co-located with the remote device then operator performance would be improved. Virtual reality would seem an appropriate technology to provide these essential perceptual cues. Given the potential such an interface might provide, a number of different experimental and operational systems have been developed. For example, systems have been developed for space operations (e.g., [2]), off-road vehicles (e.g., [3]) and unmanned aerovehicles (e.g., [4]), to name but a few. Although these and other systems have had their successes, one aspect that has limited the adoption more generally of the concept has been the lack of a common and easily accessible software infrastructure for both robot control and virtual reality systems. Fortunately, the last few years have seen the development and adoption of a number of standard software systems for both robot control and virtual reality infrastructure. Here we explore how these advances can be exploited in the development of a virtual reality-based teleoperational interface for autonomous robots.

A. Autonomous robot middleware

There have been a number of attempts to develop a standard robot middleware. Early efforts at developing such software infrastructures for robot control include Ayllo [5], Player [6] and COLBERT/Saphira [7]. Although these efforts advanced our understanding of the requirements for autonomous robot middleware, for a number of reasons these systems did not find wide-spread adoption in the academic and industrial communities. Different systems had different detractions, but often systems were targeted at specific hardware platforms/sensor platforms, or had limited computing hardware/operating system or language support. Over the last decade the ROS (Robot Operating System) [8] has emerged as a standard software middleware for the development of autonomous systems. Within ROS, overall robot control is modelled as a collection of asynchronous processes (known as nodes) that communicate via message passing. Although ROS has been ported to a number of different hardware platforms and bindings exist for a number of different languages, support is primarily targeted towards Ubuntu, with software libraries targeted at C++ and Python. A very limited level of support exists for lower performance devices (e.g., Android platforms) but the limited memory footprint on such devices makes development and deployment more complex.

There are a number of reasons why ROS has emerged as a standard software middleware for robot software. First, the software makes few assumptions about hardware or networking – although it does rely on reliable TCP/IP communication. Second, the software model of independent communicating agents allows for great modularity, including the integration of software across multiple hardware sites – including remote sites. Third, there is support for a large number of robots and sensors. Finally, there exists a large number of software tools and libraries for common robot tasks.

Figure 1 illustrates a ROS-based robot system. Figure 1(a) shows a robot based on the P3-AT platform developed by Mobile Robots. The robot relies on skid-steering, and is controlled by a PC104 computer mounted inside the robot proper. The robot exposes the sensors/locomotion system in terms of a small number of ROS nodes. A standard laptop mounted on top of the robot runs Ubuntu, and hosts two laser scanners one mounted in the horizontal plane, the other in the vertical, and communicates with the ROS environment

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From Ros To Unity Leveraging Robot And Virtual

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From Ros To Unity Leveraging Robot And Virtual:

Modelling and Simulation for Autonomous Systems Jan Mazal,Adriano Fagiolini,Petr Vasik,Michele Turi,Agostino Bruzzone,Stefan Pickl,Vlastimil Neumann,Petr Stodola,2022-04-01 This book constitutes the thoroughly refereed post conference proceedings of the 8th International Conference on Modelling and Simulation for Autonomous Systems MESAS 2021 held as a virtual event due COVID 19 in October 2021 The 30 full papers together with 2 short papers included in the volume were carefully reviewed and selected from 50 submissions They are organized in the following topical sections M and AxS AI in context of future warfare and security environment and future challenges of Advance M S Technology

Robot Operating System (ROS) Anis Koubaa,2018-07-05 Building on the successful first and second volumes this book is the third volume of the Springer book on the Robot Operating System ROS The Complete Reference The Robot Operating System is evolving from year to year with a wealth of new contributed packages and enhanced capabilities Further the ROS is being integrated into various robots and systems and is becoming an embedded technology in emerging robotics platforms The objective of this third volume is to provide readers with additional and comprehensive coverage of the ROS and an overview of the latest achievements trends and packages developed with and for it Combining tutorials case studies and research papers the book consists of sixteen chapters and is divided into five parts Part 1 presents multi robot systems with the ROS In Part 2 four chapters deal with the development of unmanned aerial systems and their applications In turn Part 3 highlights recent work related to navigation motion planning and control Part 4 discusses recently contributed ROS packages for security ROS2 GPU usage and real time processing Lastly Part 5 deals with new interfaces allowing users to interact with robots Taken together the three volumes of this book offer a valuable reference guide for ROS users researchers learners and developers alike Its breadth of coverage makes it a unique resource

Virtual, Augmented and Mixed Reality. Applications and Case Studies Jessie Y.C. Chen,Gino Fragomeni,2019-07-10 This two volume set LNCS 11574 and 11575 constitutes the refereed proceedings of the 11th International Conference on Virtual Augmented and Mixed Reality VAMR 2019 held in July 2019 as part of HCI International 2019 in Orlando FL USA HCII 2019 received a total of 5029 submissions of which 1275 papers and 209 posters were accepted for publication after a careful reviewing process The 80 papers presented in this volume were organized in topical sections named multimodal interaction in VR rendering layout visualization and navigation avatars embodiment and empathy in VAMR cognitive and health issues in VAMR VAMR and robots VAMR in learning training and entertainment VAMR in aviation industry and the military

Advances in Simulation and Digital Human Modeling Daniel N Cassenti,Sofia Scataglini,Sudhakar L. Rajulu,Julia L. Wright,2020-06-27 This book presents the latest advances in modeling and simulation for human factors research It reports on cutting edge simulators such as virtual and augmented reality multisensory environments and modeling and simulation methods used in various applications including surgery military operations occupational safety sports training education transportation and robotics

Based on two AHFE 2020 Virtual Conferences such as the AHFE 2020 Virtual Conference on Human Factors and Simulation and the AHFE 2020 Virtual Conference on Digital Human Modeling and Applied Optimization held on July 16 20 2020 the book serves as a timely reference guide for researchers and practitioners developing new modeling and simulation tools for analyzing or improving human performance It also offers a unique resource for modelers seeking insights into human factors research and more feasible and reliable computational tools to foster advances in this exciting field

ROBOT 2017: Third Iberian Robotics Conference Anibal Ollero,Alberto Sanfeliu,Luis Montano,Nuno Lau,Carlos Cardeira,2017-12-21 These volumes of Advances in Intelligent Systems and Computing highlight papers presented at the Third Iberian Robotics Conference ROBOT 2017 Held from 22 to 24 November 2017 in Seville Spain the conference is a part of a series of conferences co organized by SEIDROB Spanish Society for Research and Development in Robotics and SPR Portuguese Society for Robotics The conference is focused on Robotics scientific and technological activities in the Iberian Peninsula although open to research and delegates from other countries Thus it has more than 500 authors from 21 countries The volumes present scientific advances but also robotic industrial applications looking to promote new collaborations between industry and academia

Human-centric Robotics - Proceedings Of The 20th International Conference Clawar 2017 Manuel F Silva,Gurvinder S Virk,Mohammad Osman Tokhi,Benedita Malheiro,Paulo Ferreira,Pedro Guedes,2017-08-23 This book provides state of the art scientific and engineering research findings and developments in the area of service robotics and associated support technologies around the theme of human centric robotics The book contains peer reviewed articles presented at the CLAWAR 2017 conference The book contains a strong stream of papers on robotic locomotion strategies and wearable robotics for assistance and rehabilitation There is also a strong collection of papers on non destructive inspection underwater and UAV robotics to meet the growing emerging needs in various sectors of the society Robot designs based on biological inspirations are also strongly featured

Special Topics in Structural Dynamics & Experimental Techniques, Volume 5 Nikolaos Dervilis,2025-08-07 *Special Topics in Structural Dynamics Experimental Techniques Volume 5* Proceedings of the 37th IMAC A Conference and Exposition on Structural Dynamics 2019 the fifth volume of eight from the Conference brings together contributions to this important area of research and engineering The collection presents early findings and case studies on fundamental and applied aspects of Structural Dynamics including papers on Analytical Methods Emerging Technologies for Structural Dynamics Engineering Extremes Experimental Techniques Finite Element Techniques General Topics

[XXVI Brazilian Congress on Biomedical Engineering](#) Rodrigo Costa-Felix,João Carlos Machado,André Victor Alvarenga,2019-06-03 This volume presents the proceedings of the Brazilian Congress on Biomedical Engineering CBEB 2018 The conference was organised by the Brazilian Society on Biomedical Engineering SBEB and held in Arma o de Buzios Rio de Janeiro Brazil from 21 25 October 2018 Topics of the proceedings include these 11 tracks Bioengineering Biomaterials Tissue Engineering and Artificial Organs Biomechanics and

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ROS Robotics Projects Ramkumar Gandhinathan, Lentin Joseph, 2019-12-18 Build exciting robotics projects such as mobile manipulators self driving cars and industrial robots powered by ROS machine learning and virtual reality Key Features Create and program cool robotic projects using powerful ROS libraries Build industrial robots like mobile manipulators to handle complex tasks Learn how reinforcement learning and deep learning are used with ROS Book Description Nowadays heavy industrial robots placed in workcells are being replaced by new age robots called cobots which don't need workcells They are used in manufacturing retail banks energy and healthcare among other domains One of the major reasons for this rapid growth in the robotics market is the introduction of an open source robotics framework called the Robot Operating System ROS This book covers projects in the latest ROS distribution ROS Melodic Morenia with Ubuntu Bionic 18.04 Starting with the fundamentals this updated edition of ROS Robotics Projects introduces you to ROS 2 and helps you understand how it is different from ROS 1 You'll be able to model and build an industrial mobile manipulator in ROS and simulate it in Gazebo 9 You'll then gain insights into handling complex robot applications using state machines and working with multiple robots at a time This ROS book also introduces you to new and popular hardware such as Nvidia's Jetson Nano Asus Tinker Board and Beaglebone Black and allows you to explore interfacing with ROS You'll learn as you build interesting ROS projects such as self driving cars making use of deep learning reinforcement learning and other key AI concepts By the end of the book you'll have gained the confidence to build interesting and intricate projects with ROS What you will learn Grasp the basics of ROS and understand ROS applications Uncover how ROS 2 is different from ROS 1 Handle complex robot tasks using state machines Communicate with multiple robots and collaborate to build apps with them Explore ROS capabilities with the latest embedded boards such as Tinker Board S and Jetson Nano Discover how machine learning and deep learning techniques are used with ROS Build a self driving car powered by ROS Teleoperate your robot using Leap Motion and a VR headset Who this book is for If you're a student hobbyist professional or anyone with a passion for learning robotics and interested in learning about algorithms motion control and perception capabilities from scratch this book is for you This book is also ideal for anyone who wants to build a new product and for researchers to make the most of what's already available to create something new and innovative in the field of robotics **Robot Operating System Cookbook** Kumar Bipin, 2018-06-29 Leverage the power of ROS to build exciting collaborative robots Key Features Delve into an open source meta operating system for your robot Get acquainted with tools and libraries for building and running code on multiple platforms Use Gazebo to model your robot and create a virtual environment Book Description This book will leverage the power of ROS with an introduction to its core and advanced concepts through exciting recipes You will get

acquainted with the use of different synchronous and asynchronous communication methods including messages services and actions You will learn how to use the various debugging and visualization tools used in development and how to interface sensors and actuators with the ROS framework Firstly you will get to grips with ROS simulation frameworks such as Gazebo and RotorS for modeling and simulating any physical robot and virtual environment You will also cover mobile robotics micro aerial vehicles and robotic arms which are the leading branches of robotic applications Robot Operating System Cookbook will also guide you in the development of an autonomous navigation framework for both mobile robots and micro aerial vehicles Finally you will explore ROS Industrial an open source project that extends the advanced capabilities of ROS software to manufacturing industries What you will learn Explore advanced concepts such as ROS pluginlib nodelets and actionlib Work with ROS visualization profiling and debugging tools Gain experience in robot modeling and simulation using Gazebo Understand the ROS Navigation Stack for mobile robots Configure a MoveIt package for a manipulator robot Develop an autonomous navigation framework for MAV using ORB SLAM and MoveIt Integrate sensors actuators and robots into the ROS ecosystem Get acquainted with the ROS Industrial package with hardware support capabilities and applications Who this book is for If you re a researcher or engineer with an interest in the problems solutions and future research issues that you may encounter in the development of robotic applications this book is for you Basic knowledge of C and Python programming with the GNU Linux environment is strongly recommended to assist with understanding the key concepts covered in the book

ROS Robotics Projects Lentin Joseph,2017-03-31 Build a variety of awesome robots that can see sense move and do a lot more using the powerful Robot Operating SystemAbout This Book Create and program cool robotic projects using powerful ROS libraries Work through concrete examples that will help you build your own robotic systems of varying complexity levels This book provides relevant and fun filled examples so you can make your own robots that can run and workWho This Book Is ForThis book is for robotic enthusiasts and researchers who would like to build robot applications using ROS If you are looking to explore advanced ROS features in your projects then this book is for you Basic knowledge of ROS GNU Linux and programming concepts is assumed What You Will Learn Create your own self driving car using ROS Build an intelligent robotic application using deep learning and ROS Master 3D object recognition Control a robot using virtual reality and ROS Build your own AI chatter bot using ROS Get to know all about the autonomous navigation of robots using ROS Understand face detection and tracking using ROS Get to grips with teleoperating robots using hand gestures Build ROS based applications using Matlab and Android Build interactive applications using TurtleBotIn DetailRobot Operating System is one of the most widely used software frameworks for robotic research and for companies to model simulate and prototype robots Applying your knowledge of ROS to actual robotics is much more difficult than people realize but this title will give you what you need to create your own robotics in no time This book is packed with over 14 ROS robotics projects that can be prototyped without requiring a lot of hardware The book starts with an introduction of ROS and

its installation procedure After discussing the basics you ll be taken through great projects such as building a self driving car an autonomous mobile robot and image recognition using deep learning and ROS You can find ROS robotics applications for beginner intermediate and expert levels inside This book will be the perfect companion for a robotics enthusiast who really wants to do something big in the field Style and approach This book is packed with fun filled end to end projects on mobile armed and flying robots and describes the ROS implementation and execution of these models

Leveraging Program Synthesis for Robust Long-term Robot Autonomy Via Interactive Learning and Adaptation Jarrett Holtz, 2022

For autonomous robots to become as pervasive in uncontrolled human environments and our everyday lives as they are on campuses and in warehouses they need to be deployable by end users for various tasks End user deployment of autonomous robots over the long term requires robust behaviors that can leverage fundamental robot capabilities to achieve diverse goals while subject to various domains and user preferences Achieving this goal requires a system for designing and adapting behaviors that is intuitive data efficient easy to integrate and can handle changes in user imposed requirements over long deployments State of the art approaches to designing robot behaviors broadly fall into three categories reinforcement learning inverse reinforcement learning and learning from demonstration State of the art approaches for these techniques widely leverage deep neural networks DNNs as function approximators to represent either the complete behavior an optimal reward function or both a value function and the behavior in Actor Critic approaches DNNs are a powerful tool for function approximation that have been the catalyst for significant successes across a wide range of learning applications While DNN based approaches are broadly applicable they suffer from three key weaknesses when used for end user robot behavior design and adaptation

- 1 DNNs are black box behavior representations and thus are opaque to the user and difficult to understand or verify
- 2 learning with DNNs is extremely data intensive often requiring that data be collected in simulation and
- 3 DNN behaviors are difficult to adapt and sensitive to changing domains or user preferences such as when transferring from simulation to the real world

In this thesis we present approaches to leverage program synthesis as an alternative function approximator for learning from demonstration to approximate behaviors and reward functions respectively Program synthesis as a function approximator addresses some limitations of DNN based approaches by yielding human readable behavior representations that are amenable to program repair and parameter optimization for adaptation and that can leverage the well structured space of programs to learn behaviors in a data efficient manner However due to two primary factors existing state of the art synthesis approaches are insufficient to learn general robot programs First these approaches are not designed to handle non linear real arithmetic vector operations or dimensioned quantities all commonly found in robot programs Second synthesis techniques are primarily limited by their ability to scale with the search space of potential programs such that synthesis of many reasonably complex behaviors is intractable for existing approaches To address the goal of end user guided robot behavior learning and adaption We present Physics Informed Programs Synthesis PIPS as part

of a learning from demonstration and adaptation approach to lifelong robot learning Towards this goal this thesis presents the following contributions 1 An algorithm for PIPS that addresses limitations of program synthesis for robotics by reasoning about physical quantities 2 algorithms for LfD leveraging PIPS to learn robot behaviors as human readable programs 3 an approach to guiding lifelong robot learning by leveraging the structure of programmatic policies and demonstrations 4 program repair and synthesis techniques for adapting these learned policies from iterative user guidance and finally 5 extensive evaluation results in the social robot navigation domain across simulated and real world deployments that compare PIPS based learning to DNN based and traditional approaches

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