

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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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 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 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 **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 Rehabilitation Biomedical Devices and Instrumentation Biomedical Robotics Assistive

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