Enabling codesharing in Rescue Simulation with USARSim/ROS

Zeid Kootbally[1], Stephen Balakirsky[2], and Arnoud Visser[3]

[1] Department of Mechanical Engineering, University of Maryland
[2] Georgia Tech Research Institute, Atlanta, Georgia
[3] Intelligent Systems Laboratory Amsterdam, Universiteit van Amsterdam

Abstract. *The Robot Operating System (ROS) has been steadily gaining popularity among robotics researchers as an open source framework for robot control. The Unified System for Automation and Robot Simulation (USARSim) has been used for many years by robotics researchers and developers as a validated framework for simulation. This paper presents a new ROS node that is designed to seamlessly interface between ROS and USARSim. It provides for automatic configuration of ROS transforms and topics to allow for full utilization of the simulated hardware. The design of the new node as well as examples of its use for mobile robot inside the RoboCup Rescue Simulation League are presented.*

1 Introduction

With the development of advanced but also more complex algorithms one cannot expect that a robotic control system will be developed from scratch. With the aid of open source projects such as the Robot Operating System (ROS) [17] allow anyone with a Linux computer to download and run some of the most advanced robotic algorithms that exist. This is essential for the RoboCup mission; to accelerate the developments of intelligent and dexterous robots. With working modules that cover all basic capabilities needed for a functional robot, developers can concentrate on improving the aspects needed for their application.

Most programmers have access to a single robot or small sensor suite, but are missing access to some of the robotic hardware needed for the job. Simulators exist to fill this void and allow both experts and novices to experiment with robotic algorithms in a safe, low-cost environment. However, to truly provide valid simulation, the simulator must provide noise models for sensors and must be validated [2, 13–15, 21]. One modern robotic simulator, known as the Unified System for Automation and Robot Simulation (USARSim) [2] provides such a simulation platform. This simulator has been used by the expert robotics community for several years and has played an important role in developing robotics applications [3].

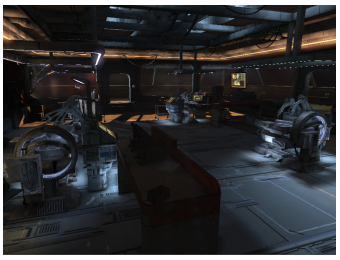
This paper examines how a new interface to the ROS control framework (introduced by [5]) can be used inside the RoboCup Rescue Simulation League [1]. The ROS framework allows for easy sharing of modules [9], allowing fast progress.

BACKGROUND

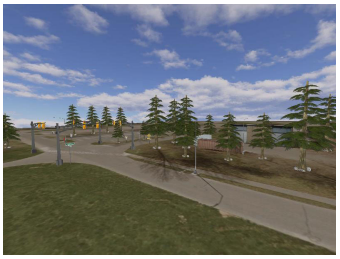
The USARSim Framework

USARSim [7] is a high-fidelity physics-based simulation system based on the Unreal Developers Kit (UDK)[4] from Epic Games. Through its usage of UDK, USARSim utilizes the PhysX physics engine [6] and high-quality 3D rendering facilities to create a realistic simulation environment that provides the embodiment of, and environment for a robotic system. The current release of USARSim consists of various environmental models, models of commercial and experimental robots, and sensor models. High fidelity at low cost is made possible by building the simulation on top of a game engine. By loading the most difficult aspects of simulation to a high volume commercial platform (available for free to academic users) which provides superior visual rendering and physical modeling, full user effort can be devoted to the robotics-specific tasks of modeling platforms, control systems, sensors, interface tools and environments. These tasks are in turn accelerated by the advanced editing and development tools integrated with the game engine. This leads to a virtuous spiral in which a wide range of platforms can be modeled with greater fidelity in a short period of time.

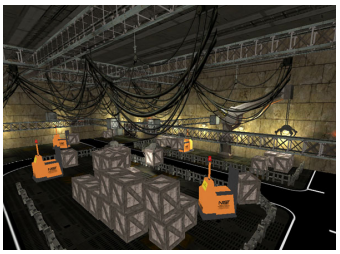
(a) Dutch Open final,



(b) RoboCup 2012 preliminary,



(c) NIST main campus,



(d) Factory.

Fig. 1. Sample of 3D environments in USARSim.

USARSim was originally based upon simulated environments in the USAR domain [20]. Realistic disaster scenarios as well as robot test methods were cre-

[4] http://www.unrealengine.com/udk

ated (Figure 1(a) and 1(b)). Since then, USARSim has been used worldwide and more environments have been developed for different purposes, including human robot interaction and educational games [3]. Other environments such as the NIST campus (Figure 1(c)) and factories (Figure 1(d)) have been used to test the performance of robotic algorithms in different circumstances [2, 21]. The simulation is also widely used for the RoboCup Virtual Robot Rescue Competition [1], the IEEE Virtual Manufacturing and Automation Challenge [4].

The ROS Framework

ROS [17] is an open source framework designed to provide an abstraction layer to complex robotic hardware and software configurations. It provides libraries and tools to help software developers create robot applications and has found wide use in both industry and academia [8]. Examples of ROS applications include Willow Garage's Personal Robots Program [22], the Stanford University STAIR project [16] and the European Nifti project [11]. Developers of ROS code are encouraged to contribute their code back to the community and to provide documentation and maintenance of their algorithms.

ROS consists of a large range of tools and services that both users and developers alike can benefit from. The philosophical goals of ROS include an advanced set of criteria and can be summarized as: peer-to-peer, tools-based, multi-lingual, thin, and free and open-source [17]. Furthermore, debugging at all levels of the software is made possible with the full source code of ROS being publicly available. Thus, the main developers of a project can benefit from the community and vice-versa.

THE ROS/USARSIM INTERFACE

USARSim is designed to communicate over a TCP/IP socket with a computer hosting the controller of the robot. The robot is "spawned" into the simulated world running on the game server. A robot's configuration is controlled by an initialization file that resides on the simulation system's computer, comparable with the launch file from Gazebo. This file controls aspects such as sensor configuration, battery life, and simulated noise models. One socket connection is established per simulated robot, with both commands and sensor data being transmitted over the socket. An additional separate socket is established for high-volume sensors such as camera systems.

ROS stacks are designed to "bottom out" at a hardware abstraction layer that provides the interface to sensors and the motors of the robot; publishing and subscribing to the basic topics of the robot. For example, the mobility stack expects to be able to control a platform by writing commands to low-level topics that control items such as the velocity. In addition, the mobility stack expects feedback from sensors, such as the movement detected by the inertia sensor. In order to close this low-level loop between ROS and USARSim, a USARSim

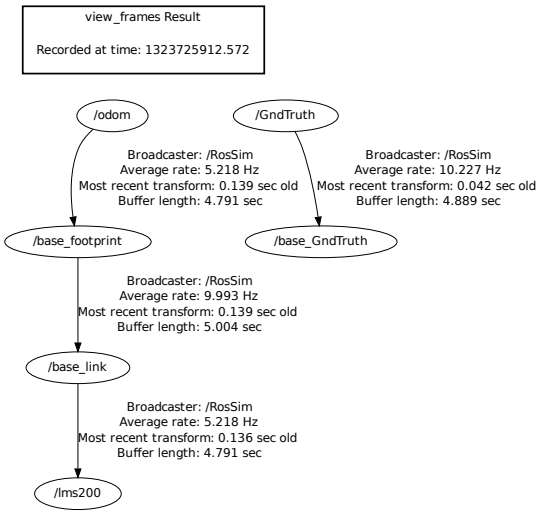


Fig. 2. Auto-generated `tf` transform tree for P3AT robot.

package was created inside ROS[5]. This package contains a node called *RosSim* that publishes a ROS transform tree `tf` and sensor messages, and also accepts platform and actuator motion commands. When run, it provides a mechanism for spawning a robot in USARSim, and then auto-discovering the robot's sensors, actuators, and drive configuration in order to provide the necessary ROS topics.

The *RosSim* node relies on several parameters for its configuration. These are necessary for the creation of a robot in USARSim and a transform tree `tf` in ROS. A transform tree for the P3AT robot is shown in Figure 2. This transform tree is built automatically from data obtained from the USARSim GEO and CONF messages. Since USARSim supports multiple sensors on a robot, it should be specified which sensor should be preferred for an initial localization estimation (later updated in a SLAM algorithm). That sensor's name is automatically changed to *odom*. The *base_footprint*, representing the robot platform and the *base_link* representing robot sensor mounting points are also automatically generated.

Vehicle movement commands into USARSim vary depending on the robot type. For example, skid-steered vehicles require left and right wheel velocities while Ackerman steered vehicles require steering angle and linear velocity. ROS provides a *cmd_vel* topic that includes both linear and angular velocities. The *RosSim* node automatically converts these velocities into the appropriate commands and values for the USARSim simulator based on the robots steering type,

[5] http://sourceforge.net/projects/usarsimros/

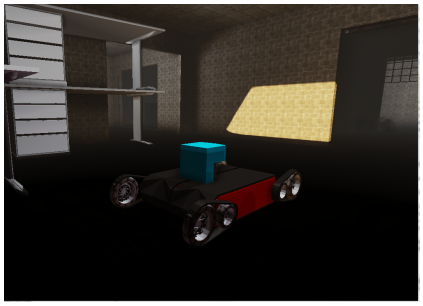


Fig. 3. Kenaf in RoboCup 2012 final environment.

wheelbase, and wheel separation. Vehicle speeds are also clamped to not exceed maximum velocities that are set in the simulation.

Sensor Interface

ROS provides a rich vocabulary of sensor interface messages. The *RosSim* node strives to automatically match simulated sensors to the appropriate ROS topic. Currently, a wide variety of sensors are supported; ground truth, inertial navigation, GPS, range-scanners, sonar, CO2 and acoustic sensors are supported. It is our ambition to support all sensors which are used in the RoboCup Rescue competition [1]. This presence of sensors is queried via USARSim's CONF and GEO messages and automatically included the robot transform tree used by ROS. The corresponding sensor messages are published at the rate that the *RosSim* node receives the sensor output.

Mobile Robot Control with the ROS Navigation Stack

Control of mobile robots through the ROS/USARSim interface is performed with the ROS navigation stack[6]. The navigation stack provides for 2D navigation and takes in information from odometry, sensor streams, and a goal pose to plan the velocity commands that does not lead to collisions. The planning for collision free paths is performed on two levels: one on a local costmap and a global costmap.

Although different models of mobile robot are developed in USARSim, the Kenaf has proven its worth in the Rescue League [14]. The Kenaf robot (see Figure 3) is a challenge to be used the navigation stack with its elongated rectangular form (so not square or circular) and its flippers. As configured in our experiments, it includes a laser scanner mounted on his base.

Low-level Navigation The ROS/USARSim interface allows for the start-up and control of the default robot base controllers by directly sending velocity commands to the base. This task was performed using the following commands:

[6] {http://www.ros.org/wiki/navigation}

1. Bring up an environment in USARSim.
2. $roscore
3. $roslaunch usarsim usarsim.launch
4. $rosrun teleop_twist_keyboard teleop_twist_keyboard.py
5. $rosrun gmapping slam_gmapping scan:=lms200 _odom_frame:=odom

In step 1. an environment is started on the server side (USARSim). If an environment is not up and running, passing messages between ROS and USARSim will fail. Step 2. starts *roscore*, a collection of nodes and programs that are pre-requisites of a ROS-based system for ROS nodes to communicate. Step 3. launches the *usarsim.launch* file. This launch file contains the parameters to connect the game server and starts the *RosSim* node that provides a connection between ROS and USARSim. Step 4. starts the *teleop_twist_keyboard* node which sends velocity commands to the *RosSim* node through the computer keyboard. At this point, the Kenaf can be controlled by keyboard teleop in the USARSim environment. Step 5. starts the node *slam_gmapping* which transforms each incoming scan from the laser into the odometry tf frame to build a map. Here, the topic *scan* is used to create the map with the parameter *_odom_frame*, the frame attached to the odometry system.

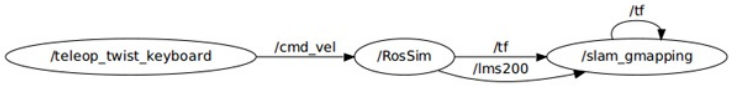


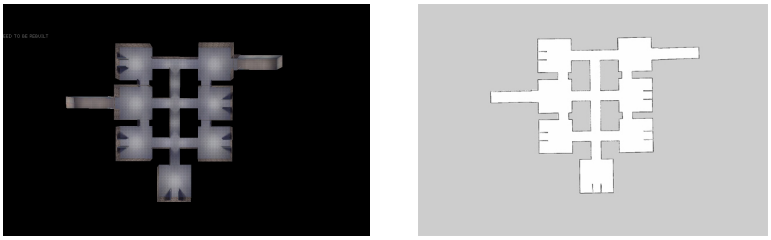
Fig. 4. Mobile robot control using *teleop*

Figure 4 is a graph generated by `rxgraph` with the option "quiet". The graph illustrates the communication between the nodes *RosSim*, *teleop_twist_keyboard*, and *slam_gmapping*. The keyboard inputs are converted in velocity commands and then communicated to the *RosSim* node on the topic *cmd_vel*. *slam_gmapping* uses the topics (*lms200*) and (*tf*) as inputs to build the map. To save the generated map, the following command is used:

$rosrun map_server map_saver

Figure 5(a) is a bird's eye view of the environment used to run the `teleop` command to steer a robot through the environment and Figure 5(b) is the map generated by the *map_saver* utility-command.

High-level Navigation Several teams [18, 19] are currently building high-level navigation software by combining existing ROS algorithms with algorithms from



(a) USARSim environment. (b) Map of the environment.

Fig. 5. Environment in USARSim and the corresponding map.

their institutes. Those teams perform simultaneous localization and mapping to generate online maps, and use those maps to plan path (for instance with the RRT algorithm [19]) to replace `teleop` with autonomous navigation.

CONCLUSION AND FUTURE WORK

This paper has presented a new ROS package that allows for the seamless interface of USARSim with ROS. The package provides for auto-discovery of robots and sensors, and produces the standard ROS topics that one would expect from a physical platform. Several researchers from outside the RoboCup community [10, 12] have already tried this interface. Still, further work is needed to provide the control interface for legged robots (as the Nao robot) and flying robots (such as the AirRobot and the AR.Drone). In addition, the whole sensor suite must have their USARSim interfaces wrapped to be supported in the ROS environment. On the positive site, as the Darpa Robotics Challenge is based on the ROS framework, progress in this competition could be an advance for the RoboCup, and vice versa.

References

1. Akin, H., Ito, N., Kleiner, A., Pellenz, J., Visser, A.: Robocup rescue robot and simulation leagues. AI Magazine 34(1), 78–86 (2013)
2. Balaguer, B., Balakirsky, S., Carpin, S., Lewis, M., Scrapper, C.: USARSim: a Validated Simulator for Research in Robotics and Automation. In: IEEE/RSJ IROS 2008 Workshop on Robot Simulators: Available Software, Scientific Applications and Future Trends (2008)
3. Balakirky, S., Carpin, S., Lewis, M.: Workshop on robots, games, and research: Success stories in usarsim. In: Proceedings of the International Conference on Intelligent Robots and Systems (IROS 2009) (October 2009)
4. Balakirsky, S., Chitta, S., Dimitoglou, G., Gorman, J., Kim, K., Yim, M.: Robot challenge. IEEE Robotics Automation Magazine 19(4), 9–11 (2012)
5. Balakirsky, S., Kootbally, Z.: USARSim/ROS: a combined framework for robot control and simulation. In: Proceedings of the ASME 2012 International Symposium On Flexible Automation (ISFA 2012) (June 2012)

6. Boeing, A., Bräunl, T.: Evaluation of real-time physics simulation systems. In: Proceedings of the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia. pp. 281–288. ACM (2007)
7. Carpin, S., Wang, J., Lewis, M., Birk, A., Jacoff, A.: Robocup 2005: Robot Soccer World Cup IX, LNAI, vol. 4020, chap. High Fidelity Tools for Rescue Robotics: Results and Perspectives, pp. 301–311. Springer (2006)
8. Cousins, S.: Is ros good for robotics? IEEE Robotics Automation Magazine 19(2), 13–14 (2012)
9. Cousins, S., Gerkey, B., Conley, K., Garage, W.: Sharing software with ros. IEEE Robotics Automation Magazine 17(2), 12–14 (2010)
10. Haber, A., McGill, M., Sammut, C.: jmesim: An open source, multi platform robotics simulator. In: Proceedings of Australasian Conference on Robotics and Automation (December 2012)
11. Larochelle, B., Kruijff, G.J., Smets, N., Mioch, T., Groenewegen, P.: Establishing human situation awareness using a multi-modal operator control unit in an urban search & rescue human-robot team. In: 2011 IEEE RO-MAN. pp. 229–234 (2011)
12. Meyer, J., Sendobry, A., Kohlbrecher, S., Klingauf, U., von Stryk, O.: Comprehensive simulation of quadrotor uavs using ros and gazebo. In: Simulation, Modeling, and Programming for Autonomous Robots, Lecture Notes in Artificial Intelligence, vol. 7628, pp. 400–411. Springer, Heidelberg (2012)
13. van Noort, S., Visser, A.: Validation of the dynamics of an humanoid robot in usarsim. In: Proceedings of Performance Metrics for Intelligent Systems Workshop (PerMIS12) (March 2012)
14. Okamoto, S., Kurose, K., Saga, S., Ohno, K., Tadokoro, S.: Validation of simulated robots with realistically modeled dimensions and mass in usarsim. In: Safety, Security and Rescue Robotics, 2008. SSRR 2008. IEEE International Workshop on. pp. 77–82. IEEE (2008)
15. Pepper, C., Balakirsky, S., Scrapper, C.: Robot simulation physics validation. In: Proceedings of the 2007 Workshop on Performance Metrics for Intelligent Systems. pp. 97–104. PerMIS '07, New York, NY, USA (2007)
16. Quigley, M., Berger, E., Ng, A.Y., et al.: Stair: Hardware and software architecture. In: AAAI 2007 Robotics Workshop, Vancouver, BC. pp. 31–37 (2007)
17. Quigley, M., Conley, K., Gerkey, B.P., Faust, J., Foote, T., Leibs, J., Wheeler, R., Ng, A.Y.: Ros: an open-source robot operating system. In: ICRA Workshop on Open Source Software (2009)
18. Takahashi, T., Nishimura, H., Shimizu, M.: Hinomiyagura team description paper for robocup 2013 virtual robot league (February 2013)
19. Taleghani, S., Shayesteh, M.H., Samizade, S., Sistani, F., Hashemi, S., Hashemi, A., Najafi, J.: Mrl team description paper for virtual robots competition 2013 (February 2013)
20. Wang, J., Lewis, M., Gennari, J.: A Game Engine Based Simulation of the NIST Urban Search and Rescue Arenas. In: Proceedings of the 2003 Winter Simulation Conference. vol. 1, pp. 1039–1045 (2003)
21. Wang, J., Lewis, M., Hughes, S., Koes, M., Carpin, S.: Validating USARSim for use in HRI Research. In: Proceedings of the Human Factors and Ergonomics Society 49^{th} Annual Meeting. pp. 457–461 (2005)
22. Wyobek, K., Berger, E., der Loos, H.V., Salisbury, K.: Towards a Personal Robotics Development Platform: Rationale and Design of an Intrinsically Safe Personal Robot. In: Proceedings of the IEEE International Conference on Robotics and Automation (ICRA). pp. 2165–2170. Pasadena, CA (2008)