VRViz: Native VR Visualization of ROS Topics

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INTRODUCTION

With Virtual Reality (VR) hardware becoming readily available, the promise of unparalleled data visualization and immersion using VR is coming within reach. Further, the Robot Operating System, or ROS [1], has matured to a point where it is considered key to the development of robotic systems, including simulation and sensor processing. In this paper we present our openly accessible framework to introduce the ROS-based 3D models of a robot into an active VR environment, therefore merging the advantages of the breadth of tools that ROS offers on kinematics and simulation with the immersion that VR offers. We anticipate that our tool can offer key insights during the robot design evaluation stage, as it provides the possibility for the robot to interact with its surroundings, while providing the operator with a realistic overview of its visual or ergonomic considerations. There have been several attempts to bring the benefits of virtual reality to the ROS framework, however these either depend on obsolete hardware [2] or require the use of a separate PC running Windows [3] in order to use the Oculus drivers on the Windows computer. We present here an open source ROS node which provides visualization of ROS topics in virtual environment, with similar functionality to RViz while running natively on Ubuntu.

MATERIALS AND METHODS

The software is written in C++ using OpenGL. VRViz depends on Steam & SteamVR being installed, which are freely available from Valve Corporation. Linked dependencies include OpenVR and SDL2, which are included in the repository as catkin libraries to match the ROS catkin ecosystem. The VRViz Node itself extends an example class in order to ease integration of updates to the OpenVR SDK, which is useful as the OpenVR SDK is still under active development. The software is available open sorce on GitHub at https://github.com/RViMLab/vrviz.

VRViz is under active development, and currently supports the following message types:

- **Image:** Stereo or normal image;
- **Point Cloud:** Colored points in 3D space;
- **Robot Description:** URDF description, including 3D meshes;
- **Transforms**: Display axes for transformations;
- **Visualization Markers:** shapes, text & meshes.

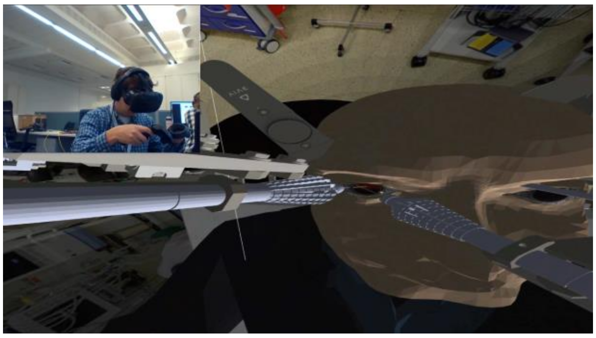

Figure. 1. Preliminary design-stage retinal surgery robot being manipulated and visualized in virtual reality. The inset shows the user, and the large view shows the left eye image sent to the headset.

For the 3D interaction in the virtual world, the "Ground" of VR space is set to a user chosen transformation frame. This world coordinate frame can be manipulated with buttons on the Steam-VR wand; this capability has proved helpful in cases with large scenes or when operating in seated mode, but can cause some disorientation. The button events are published back to ROS as messages. The user can also walk around the scene, and the position and orientation of the VR-headset and VR-wands poses are published back to ROS as transform messages to be used for control, with millimeter-level accuracy. The size of the 3D world is scalable from ROS→VR, to allow both large or small scenes to be comfortably explored.

As a test case, the authors used a model of a retinal surgical system currently being designed by the Robotics and Vision in Medicine Lab and Moorfields Eye Hospital [4]. This model was converted from SolidWorks into ROS using the standard URDF format. Further context, such as the surrounding surgical suite and the operating table, was also added. Kinematics nodes were created for every robot joint, enabling the manipulation of a robot designed in Solidworks via ROS in VR. Once in ROS, the robotic system was evaluated in 3D by both the engineers designing the system and the clinicians who will ultimately use the system.

The virtual reality system was then further extended by adding a simple retinal surgery game and used for outreach events. The system was shown to the general public at New Scientist Live, a science exposition in London. The system was also demonstrated to potential patients at the UK Macular Society's London

Conference, providing an opportunity for the patient community to get a first understanding of scientific research and development in robotics.

In order to demonstrate the adaptability of the system, two other robots were also tested with the system. The Turtlebot [5] is a widely used mobile robot which is well supported in ROS. This was used running in Gazebo, a physics simulator which works with ROS. A full body surgical robot which is still under development, CORVUS [6], was used with inverse kinematics to show the motion and dexterity of the robot with an operating table.

RESULTS

The virtual reality system with the retinal surgical robot, shown in Figure 1, received positive feedback both from the engineers designing the robot, as well as from the clinicians who were advising on the robot's design.

Figure. 2. Members of the public interacting with the VRViz demo at New Scientist Live.

The outreach event to the general public at New Scientist Live is shown in Figure 2. This event received positive feedback from most of the eventgoers. However, it should be noted that very young children found the virtual reality unsettling, and some users lacked good vision in both eyes due to medical issues which reduced the value in the 3D stereoscopic effect. This was also true among many members of the Macular Society, however the ability to move around in 3D still provided enough depth cues to those lacking stereo vision that they were able to get some value out of the demo.

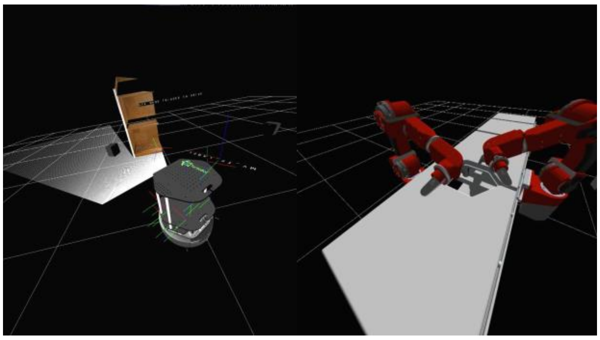

Figure. 3. Left: Turtlebot simulated in Gazebo, being visualized in virtual reality. **Right:** CORVUS full body surgical robot being controlled in virtual reality.

The additional robots tested can be seen in Figure 3. The Turtlebot and a point cloud it is scanning of a virtual environment are shown on the left, and the CORVUS robot can be seen on the right where the two arms are following the position of the wands.

CONCLUSION AND DISCUSSION

The VRViz node provides a significant benefit to engineers who are already using ROS for their development of robots for medical or other purposes. The ability to run natively in Ubuntu allows a lower barrier to entry than earlier systems, and the open source nature of the software means that additional or custom features can easily be added.

An additional benefit of the system is providing an entertaining and educational outreach tool with minimal additional effort once the system is set up. This can allow the valuable research into medical robotics to be shared with a wider audience to elicit feedback and keep target markets appraised of design progress prior to the construction of a physical prototype.

Future work planned for the system includes a more detailed user study, where the different features of the system are tested more rigorously in order to quantify the value they bring to a surgical robotics research platform.

The VRViz software should work with any headset supported by both OpenVR and Ubuntu, however the authors have only tested with a standard Vive headset and therefore cannot make any claims about compatibility beyond the Vive. As the software is still in development there are many opportunities for further work, including extending support for more ROS messages and testing the software with different robot designs. We welcome contributions from interested researchers in what we hope can become a useful platform for our community.

REFERENCES

[1] M. Quigley, et al. ROS: an open-source robot operating system. In *ICRA workshop on open source software*, volume 3, page 5. Kobe, 2009.

[2] oculus_rviz_plugins: Oculus plugins for RViz [online] Available: https://github.com/ros-visualization/oculus_rviz_plugins.

[3] D. Whitney, et al. "Comparing Robot Grasping Teleoperation across Desktop and Virtual Reality with ROS Reality." *Proceedings of the International Symposium on Robotics Research*. 2017.

[4] A. Mablekos-Alexiou, et al. "Requirements Based Design and End-to-End Dynamic Modeling of a Robotic Tool for Vitreoretinal Surgery." *ICRA*. IEEE, 2018.

[5] Garage, Willow. "Turtlebot." *Website: http://turtlebot.com* last visited 2018

[6] J. O'Neill and T. Kowalewski. Online free anatomy registration via non-contact skeletal tracking for collaborative human/robot interaction in surgical robotics. *ASME Journal of Medical Devices*, 8(3), 2014.