technische universität dortmund

computer science 12

Bachelor Thesis

ROS2-Based Framework for Real-Time PTZ Camera Control Using VR Headsets

Dr. Ching-Chi Lin
Prof. Dr. Jian-Jia Chen

Otto-Hahn Str. 16
Technische Universität Dortmund
Email: chingchi.lin@tu-dortmund.de
September 26, 2024

Pan-Tilt-Zoom (PTZ) cameras are widely used in surveillance, remote monitoring, and robotics due to their ability to provide dynamic and flexible views of environments. Traditionally, these cameras are controlled remotely using joysticks or graphical interfaces. However, emerging technologies like Virtual Reality (VR) offer a more immersive and intuitive alternative, allowing the camera's orientation to be directly mapped to the user's head movements.

Integrating VR for PTZ camera control has the potential to revolutionize remote monitoring by creating a more natural and engaging user experience. Instead of relying on expensive 360-degree cameras to achieve an immersive effect, using a PTZ camera whose orientation adjusts based on the user's head movement offers a cost-effective solution. This approach not only reduces hardware costs but also significantly lowers the amount of network traffic needed for remote monitoring.

For real-world applications, such as security surveillance or robotic teleoperation, *reaction time* is a critical factor in determining system effectiveness. Specifically, we focus on *Motion-to-Photon* (MoP) latency, which refers to the delay between the user's head movement and the corresponding change in the VR device's display. MoP latency is a key metric for assessing the system's performance, as high latency can degrade the user experience, cause disorientation, and reduce the responsiveness of the camera system, leading to potential lapses in high-stakes environments.

Robot Operating System 2 (ROS2) [1] provides a software framework with real-time capabilities for developing robotic applications. In this project, ROS2 will act as middleware for communication between the VR headset and the PTZ camera. A custom ROS2 node will process the VR headset's head orientation data and translate it into control commands for the PTZ camera (pan, tilt, and zoom). These commands will be sent to the camera using the ONVIF protocol or a custom API, ensuring seamless control.

In this thesis[1], the objective is to build a ROS2-based system that allows users to control a PTZ camera's orientation via head movements tracked by a VR headset, and to evaluate the system's performance in terms of MoP latency. The student is expected to begin by developing a ROS2 node on a development platform such as a Raspberry Pi to handle the communication and control of the PTZ camera. After that, the student should test the ROS2 node with a VR headset, integrating the orientation data from the headset with the PTZ camera control system. Finally, the student should measure the MoP latency, identify performance bottlenecks within the system and attempt to optimize for lower latency and smoother operation. Students should note that, the involved source code in this thesis will be publicly released and should be fully documented to comply the rationale of open-source software development.

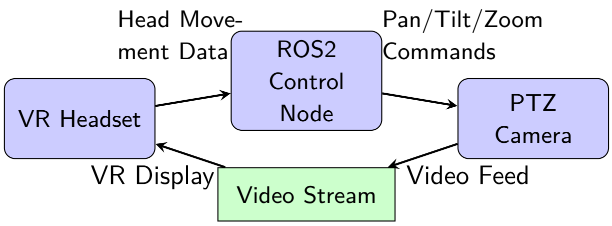

Figure 1: System Architecture

Required Skills:

- Knowledgeable of ROS2
- Knowledgeable of Python programming
- Knowledgeable of development boards

Acquired Skills after the thesis:

- Knowledge about real-time system design
- Knowledge about VR and camera integration
- Knowledge about optimizing for latency in a practical remote monitoring application.

References:

[1] S. Macenski, T. Foote, B. Gerkey, C. Lalancette, W. Woodall, "Robot Operating System 2: Design, architecture, and uses in the wild," Science Robotics vol. 7, May 2022.

[1] Other suggestions and related topics are also welcome. Please do not hesitate to make an appointment.