Field Robotics and Learning Group, Mechanical Engineering, University College London

Yanchao Wang, Song Ma, Xu You, Zaopeng Dong, Qianqian Yang, Yongchang Xie, Yuanchang Liu
yanchao.wang.20@ucl.ac.uk, song.ma.18@ucl.ac.uk, yuanchang.liu@ucl.ac.uk

UCL

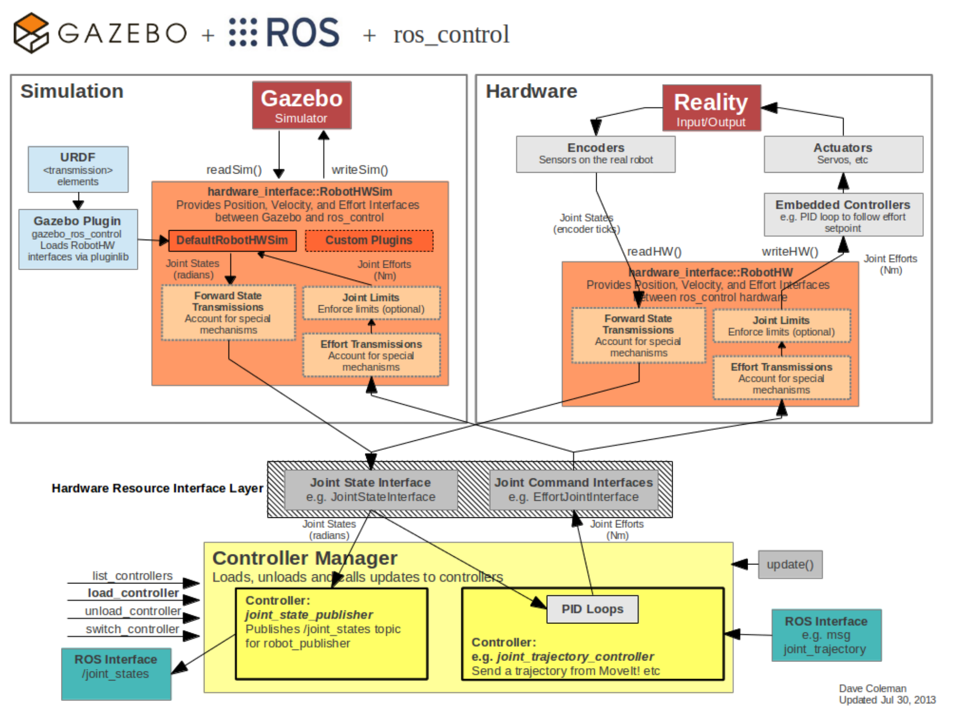
Fostering Skills and Expertise in Marine Robotics at UCL: Virtual RobotX 2023

Team FRL

ROBOTICS
Innovation + Application

Robot Operating System (ROS) and Gazebo

- Hardware-in-the-loop (HIL) is a testing technique used in the development of complex systems, particularly in engineering disciplines like robotics and control systems. In HIL testing, the physical hardware components of a system, such as sensors, actuators, and controllers, are integrated into a simulation environment.



About Virtual RobotX 2023

Individual Tasks

The following quick start instructions walk you through th
available task-specific messages.

Task 1: Stationkeeping

Task 2: Wayfinding

Task 3: Perception

Task 4: Acoustic Perception

Task 5: Wildlife Encounter and Avoid

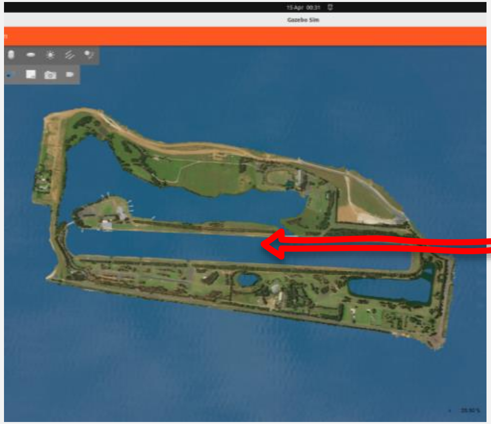
Task 6: Follow the Path

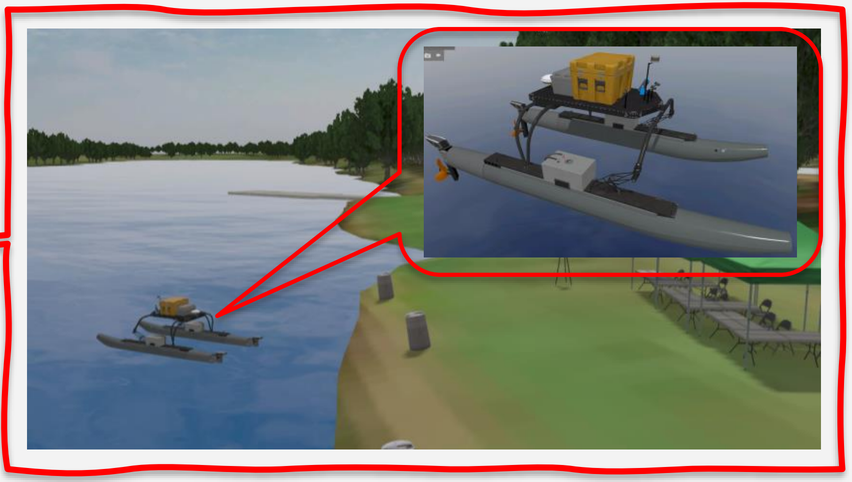
Task 7: Acoustic Tracking

Task 8: Scan and Dock and Deliver

Top: VRX Tutorials	**Next:** Stationkeeping

The VRX simulation environment has been embraced by the maritime robotics research and development community, evolving to accommodate advancements in perception, learning, and control, along with exploring novel applications for USV capabilities.





https://robotx.org/programs/vrx-2023/

Customizing WAM-V

- The WAM-V thruster and component configuration can be customized. This involves writing a user-generated thruster YAML file and a user-generated component YAML file, and then running a script that will generate a custom WAM-V URDF file with the specified thrusters and components.

Station Keeping

- **NMPC:**
- The USV model can be denoted as:

$$\begin{bmatrix} \mathrm{m} & 0 \\ 0 & I \end{bmatrix} \begin{bmatrix} \dot{v}_W \\ \dot{\omega}_B \end{bmatrix} = \begin{bmatrix} \dot{F}_W \\ \dot{\tau}_B \end{bmatrix} - \begin{bmatrix} \omega_B \times m v_B \\ \omega_B \times I \omega_B \end{bmatrix} + \begin{bmatrix} m g_W \\ 0 \end{bmatrix}$$

- The cost function to minimize the control effort:

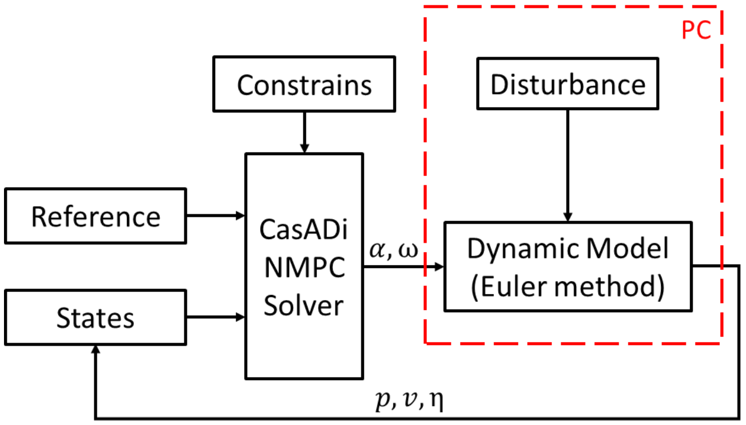
$$J(x_t, u_t) = \sum_{t=k}^{k+N-1} [(x_t - x_t^r)^\top Q (x_t - x_t^r) + u_t^\top R u_t] + (x_{k+N} - x_{k+N}^r)^\top F (x_{k+N} - x_{k+N}^r)$$

- The constrained optimal control problem in the prediction horizon is sampled in N steps. At each time t, the problem can be denoted as:

$$\min_{x_0 \ldots x_N, u_0 \ldots u_{N-1}} J$$

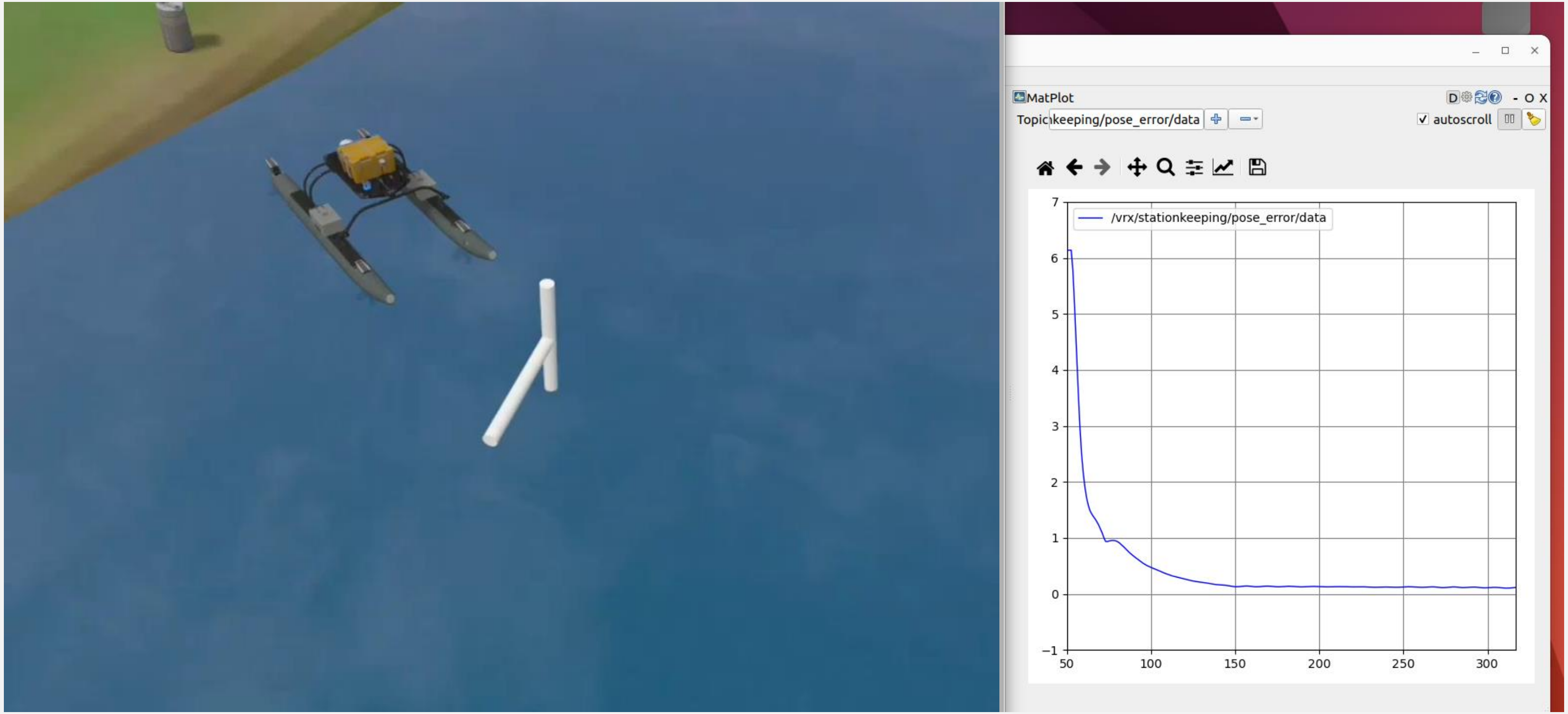
subject to

$$x_{k+1} = f(x_k, u_k)$$
$$x_k \in \mathbb{X}$$
$$u_k \in \mathbb{U}$$



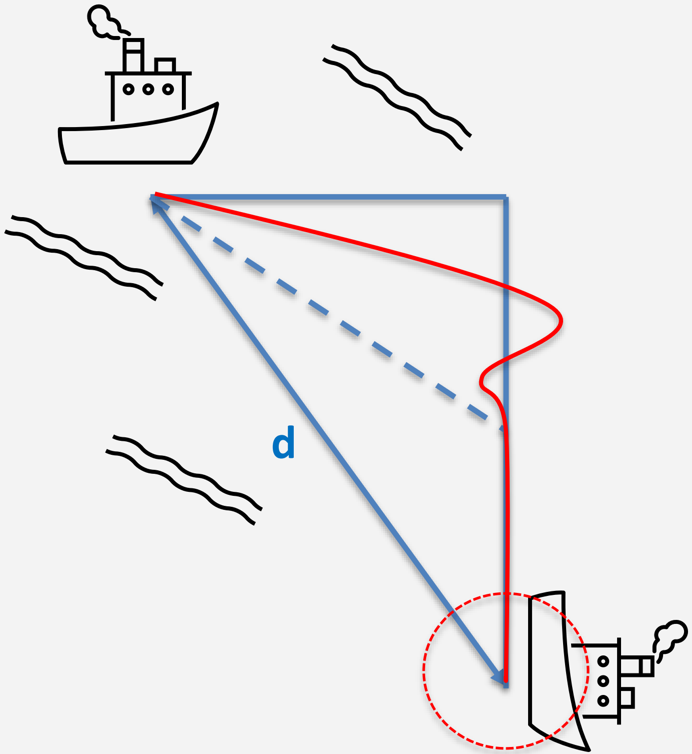
Task Summary: Navigate to the goal pose and hold station. The best solutions will minimize the difference between the goal pose and the actual pose of the vehicle over the duration of the task.

Station Keeping

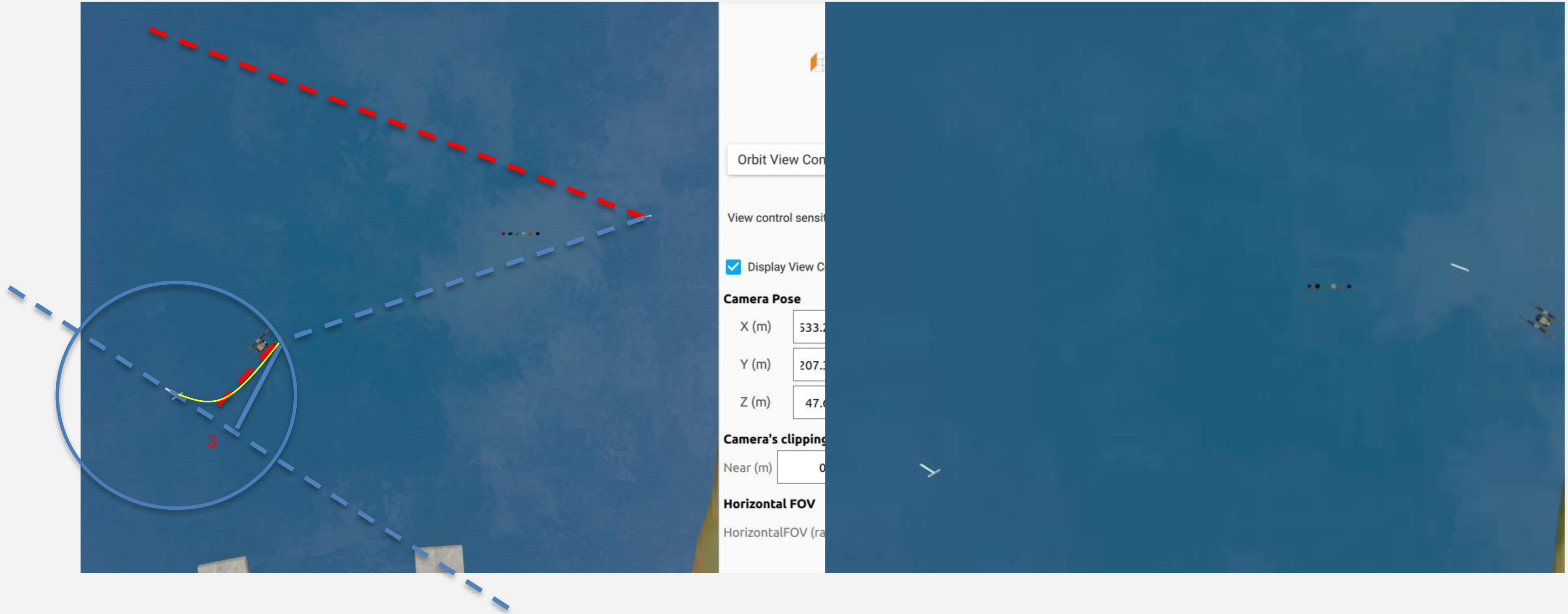


Waypoint Tracking

- **Task Summary:** Navigate through each of the published waypoints, such that vehicle achieves, as closely as possible, the positions and orientations specified.
- **Solution:**
    - When the distance is longer than the desired threshold, the WAM-V will following a desired trajectory.
    - When the distance is shorter than the desired threshold, the WAM-V will start the station keeping procedure.
- **Benefits:**
    - Gazebo provides users with a convenient testing method when their models are difficult to manipulate or have safety risks.

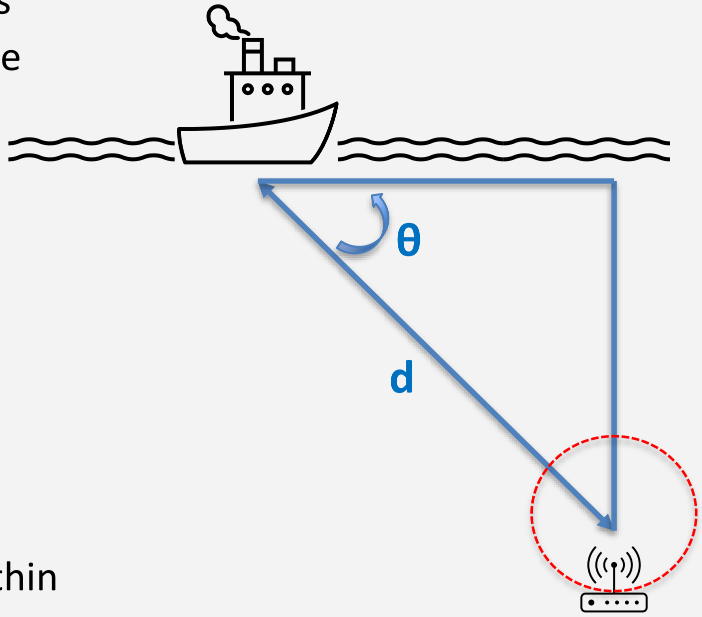


Waypoint Tracking

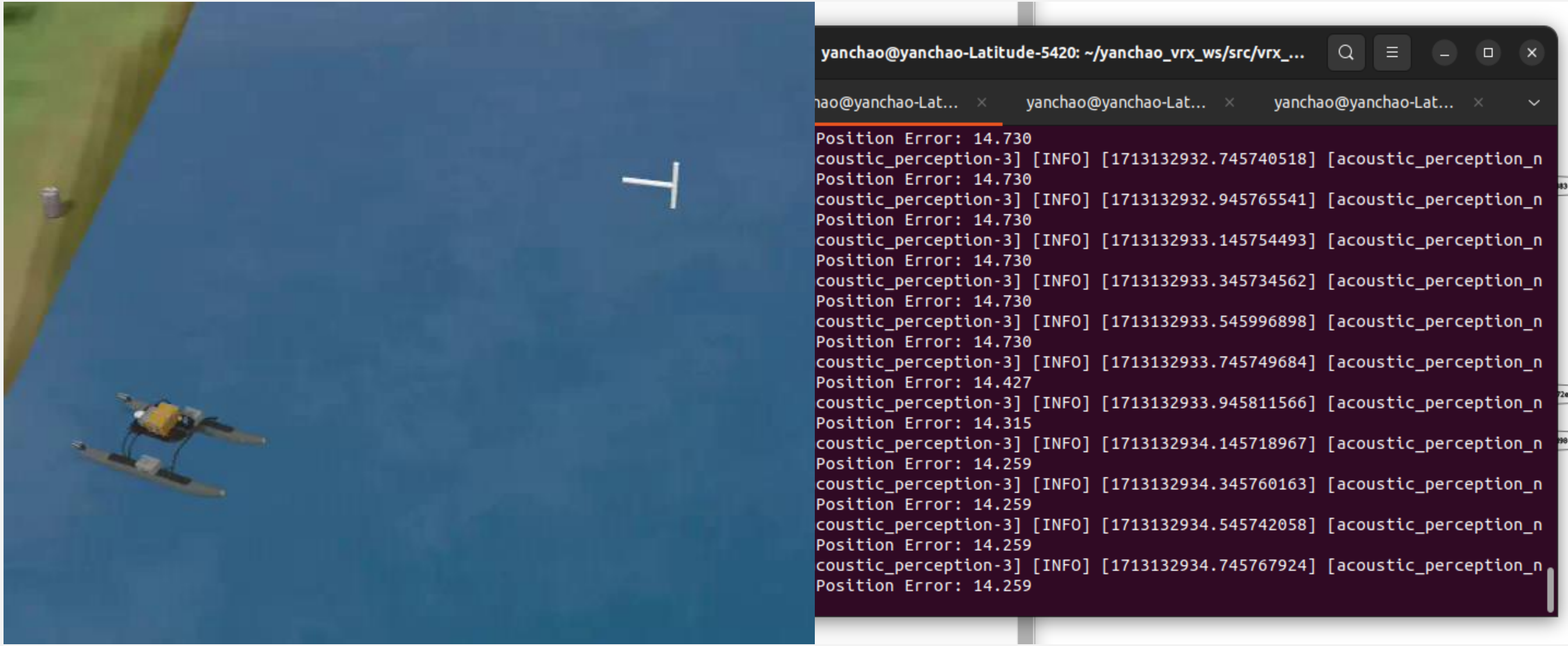


Acoustic Perception

- **Task Summary:** An underwater acoustic beacon emits noisy signals representing its position relative to the USV. The objective is for the USV to locate and navigate towards.
- **Solution:**
  - Use a Butterworth lowpass filter to process the noisy signals broadcasted by the beacon.
  - Calculate desired heading and speed for the USV to navigate towards the beacon dynamically
- **Benefits:**
  - Gazebo can simulate a variety of disturbances and noises within the open-source environment, enhancing the realism of sensor noise in real-world scenarios.

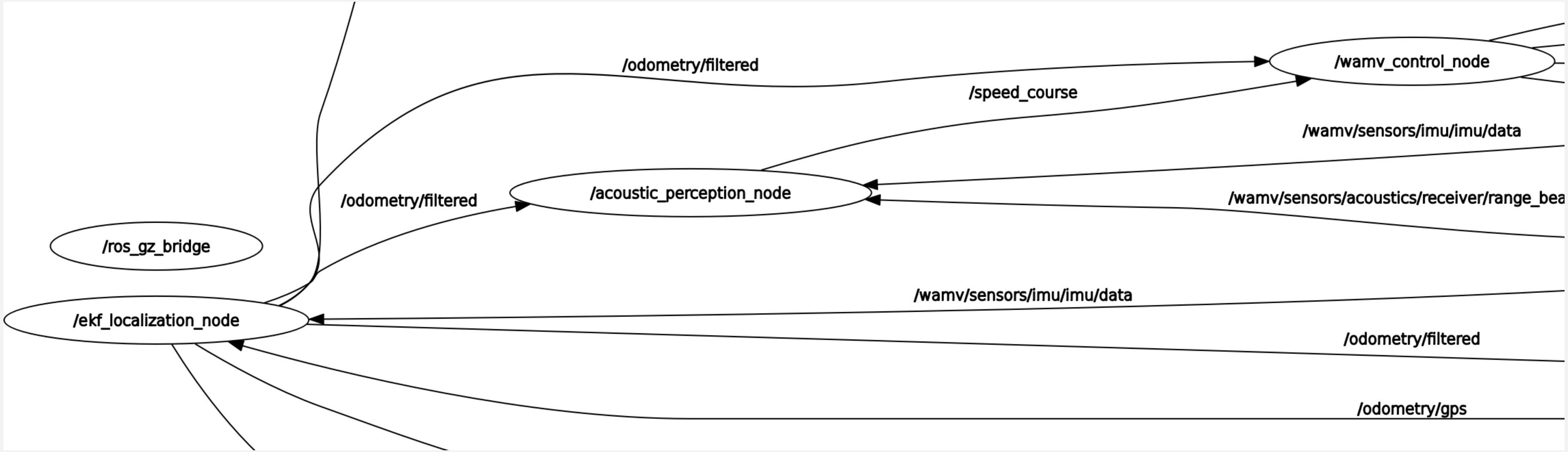


Acoustic Perception



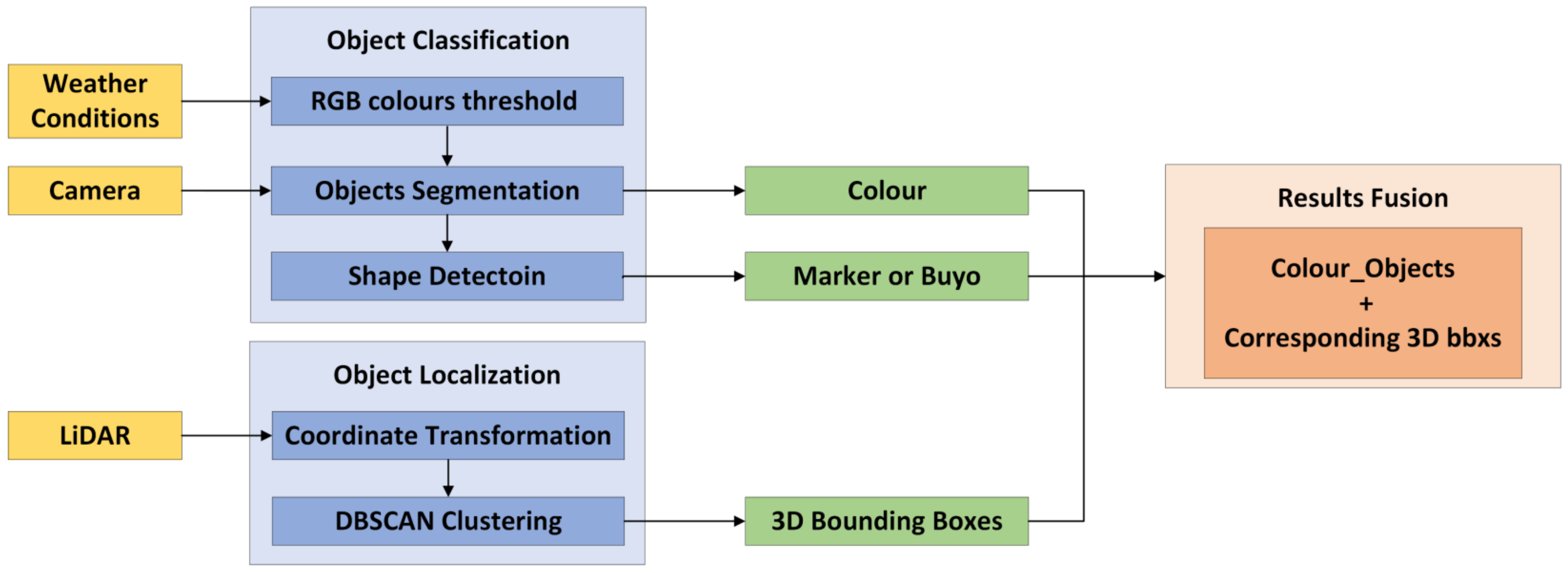
Acoustic Perception

Nodes are typically used for various tasks such as controlling hardware, processing sensor data, performing calculations, or implementing algorithms. Nodes communicate with each other by publishing and subscribing to topics, which allows them to exchange data and coordinate their actions within a ROS system.

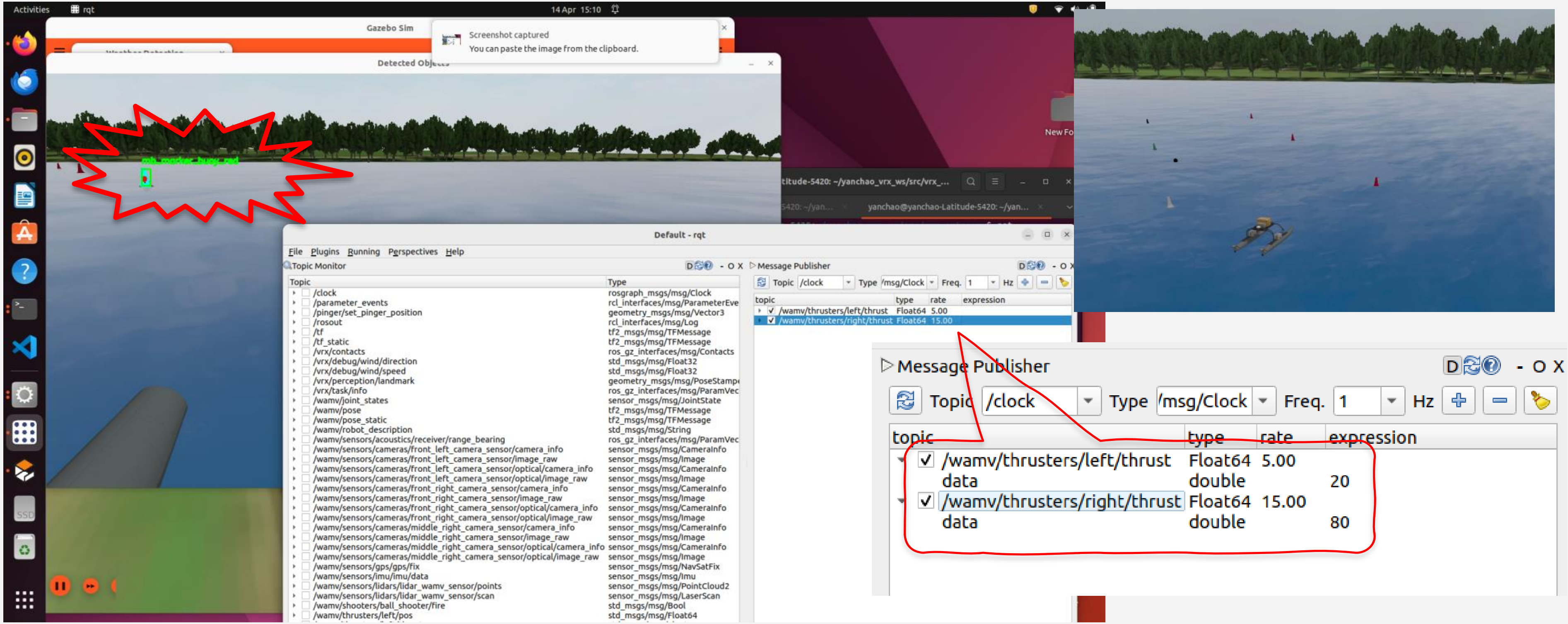


Perception

- **Task Summary:** The USV needs to utilize its sensors like cameras and LIDAR to identify, analyze, and pinpoint various objects in its surroundings. The perception process must be reliable enough to tackle uncertainties related to the vehicle's movement, sensor uncertainty, and environmental variations such as lighting changes and fog.

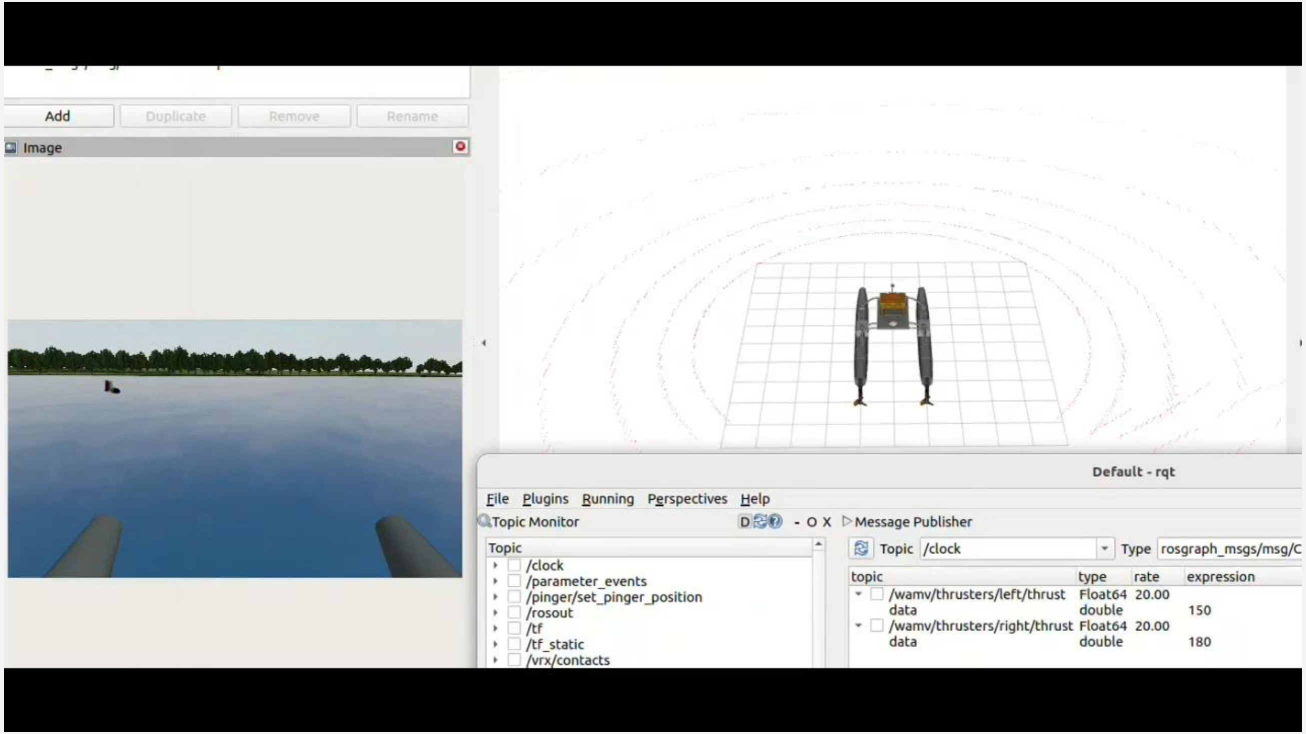


Perception


Gazebo Sim
Screenshot captured
You can paste the image from the clipboard.
Detected Objects
Default - rqt
File Plugins Running Perspectives Help
Topic Monitor
Message Publisher
Topic /clock Type /msg/Clock Freq. 1 Hz
topic type rate expression
/wamv/thrusters/left/thrust Float64 5.00
data double 20
/wamv/thrusters/right/thrust Float64 15.00
data double 80

Perception

- Use LiDAR to locate the target markers, employing DBSCAN to cluster the point cloud data.
- Fuse the camera and LiDAR outputs in the format, <Object_id, position_LiDAR_frame>.
- Convert the maker positions from the LiDAR coordinate frame to the geographic coordinate system and publish the final results.



More Challenges

Acoustic Tracking

Scan and Dock and Deliver

Field Robotics and Learning Group, Mechanical Engineering, University College London

Yanchao Wang, Song Ma, Xu You, Zaopeng Dong, Qianqian Yang, Yongchang Xie, Yuanchang Liu
yanchao.wang.20@ucl.ac.uk, song.ma.18@ucl.ac.uk, yuanchang.liu@ucl.ac.uk