

Development of the Saemangeum Digital Test-bed (K-URSim) for Unmanned Underwater Vehicles

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Abstract—This paper presents K-URSim (KRISO Underwater Robot Simulator), a ROS2-based modular simulation platform that serves as the backbone of the Saemangeum Digital Marine Testbed for unmanned marine systems (UMS). Unlike conventional simulators, K-URSim is tightly coupled with the real inshore test site, integrating in-situ ocean data such as currents, waves, and bathymetry into the simulation loop for realistic environment reproduction and data-driven validation. The platform adopts a modular architecture (KRISO Extensions) supporting vehicle modeling, physics-based dynamics, sensing, planning, control, and external interfaces within a unified ROS2 framework. By bridging simulation and real-world experiments, K-URSim enables pre-validation of control algorithms and mission scenarios prior to deployment, reducing cost and risk. It also supports reinforcement learning-based autonomy and synthetic data generation for sim-to-real transfer. The system can also integrate with NVIDIA Omniverse for digital-physical hybrid testing and sim-to-real validation.

I. INTRODUCTION

Unmanned marine systems (UMS), including autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), and unmanned surface vehicles (USVs), are increasingly utilized in applications such as ocean exploration, infrastructure inspection, and maritime monitoring. However, validation of these systems in real ocean environments remains costly, risky, and difficult to repeat due to dynamic and uncertain environmental conditions.

Recent advances in simulation technologies, including physics-based modeling and ROS2-based system integration, have enabled simulation-driven development of marine robotic systems. Nevertheless, most existing simulators rely on synthetic environments and are often designed for specific platforms or tasks, limiting their ability to represent real-world marine conditions and support reliable sim-to-real validation.

To enable realistic field experimentation, the Korea Research Institute of Ships and Ocean Engineering (KRISO) is establishing an inshore test site within the Saemangeum seawall in the Republic of Korea. This site forms an enclosed-sea environment, providing controlled yet realistic marine conditions for system testing. While such infrastructure enables practical validation, effective utilization of the test site requires a complementary simulation framework capable of reproducing and extending real-world conditions

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Fig. 1. Conceptual illustration of the Saemangeum enclosed-sea test site. The testbed supports multi-domain unmanned systems including USVs, AUVs, and UAVs, along with measurement infrastructure and integrated control systems.

for pre-validation and scenario design. Fig. 1 shows the Saemangeum enclosed-sea test site and its infrastructure.

To address this need, we present **K-URSim** (KRISO Underwater Robot Simulator), a ROS2-based modular simulation platform that serves as the backbone of a Digital Marine Testbed integrated with the Saemangeum enclosed-sea test site. By incorporating in-situ measured ocean data, including currents, waves, bathymetry, and environmental properties, K-URSim enables realistic environment reproduction and data-driven validation under actual operating conditions.

By bridging simulation and physical experiments, the proposed framework enables pre-validation of control algorithms and mission scenarios prior to deployment, reducing cost and risk. K-URSim also supports reinforcement learning-based autonomy and synthetic data generation for sim-to-real transfer. This integration enables an efficient development cycle and direct coupling with real-world test environments.

II. K-URSIM

K-URSim is a ROS2-based modular platform for autonomous marine robotic systems. It serves as the backbone of a Digital Marine Testbed integrated with the Saemangeum enclosed-sea test site, enabling simulation-based pre-validation under realistic conditions.

The platform adopts a modular extension framework, referred to as *KRISO Extensions*, which organizes key functionalities into interoperable software modules for flexible

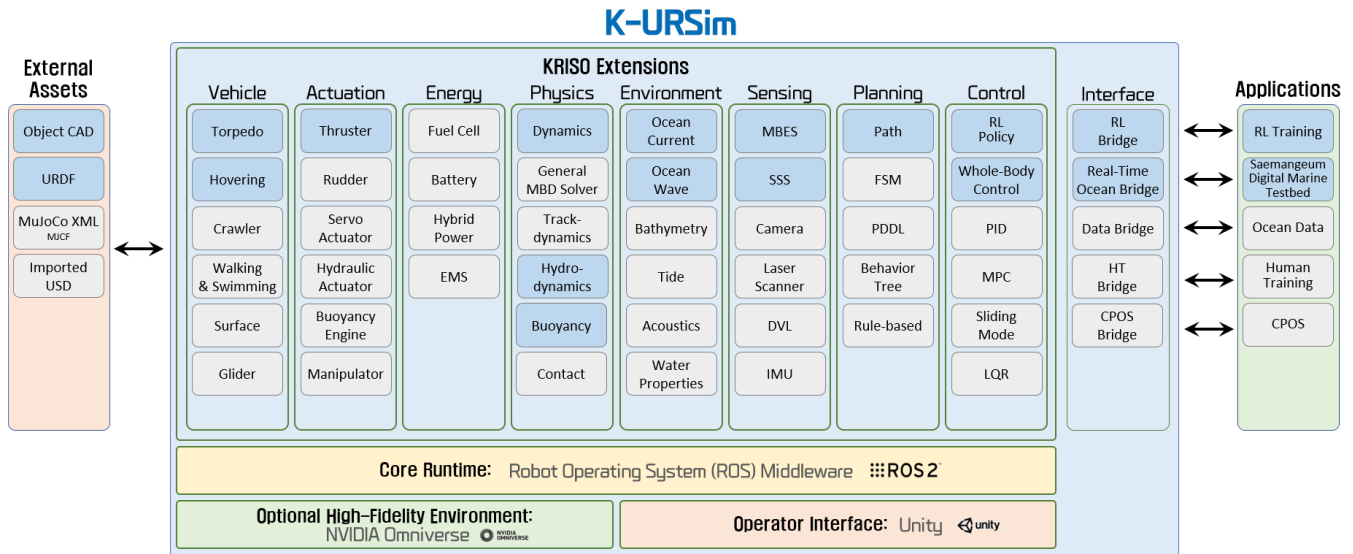


Fig. 2. Software architecture of K-URSim. A ROS-based modular framework (KRISO Extensions) supporting vehicle, environment, sensing, planning, control, and real-data-driven simulation.

integration of robot models, environments, and autonomy algorithms.

A. Software Architecture

Fig. 2 illustrates the software architecture of the K-URSim platform. The system is built on ROS middleware and organized through KRISO Extensions, which provide modular components for *Vehicle*, *Actuation*, *Energy*, *Physics*, *Environment*, *Sensing*, *Planning*, *Control*, and *Interface*.

K-URSim supports integration of external assets through standard formats such as CAD, URDF, MJCF, and USD. It can be coupled with NVIDIA Omniverse and Unity-based interfaces for visualization and interaction, while connecting with real ocean data for simulation-driven validation and sim-to-real experimentation.

B. Extensibility

K-URSim enables flexible configuration of marine robotic systems, environments, and autonomy algorithms within a unified framework. The KRISO Extensions architecture allows independent development and integration of modular components, facilitating adaptation to diverse robot types and mission scenarios.

The platform supports external assets (CAD, URDF, MJCF, USD) and interfaces for reinforcement learning and data generation, enabling scalable experimentation. Optional integration with NVIDIA Omniverse further extends the platform toward photorealistic rendering and advanced sensor simulation.

C. Functionality

K-URSim provides a framework for simulation-driven validation and digital-physical hybrid testing. By integrating in-situ ocean data from the Saemangeum enclosed-sea test site, the platform enables realistic environment reproduction

and simulation-based pre-validation, reducing the cost and risk of field experiments.

It also supports repeatable evaluation and reinforcement learning-based autonomy through diverse environments, robot configurations, and sensor simulations. Through its interface modules, K-URSim enables synthetic data generation and real-data validation, facilitating sim-to-real transfer. These capabilities enable reliable validation of autonomous systems under realistic conditions.

III. CONCLUSION

This paper presented K-URSim, a modular simulation platform serving as the backbone of a Digital Marine Testbed for unmanned marine systems. By coupling simulation with the Saemangeum enclosed-sea test site, the platform enables simulation-based pre-validation and digital-physical hybrid testing, significantly reducing cost and improving reliability. In addition, K-URSim supports reinforcement learning-based autonomy development and sim-to-real transfer through realistic environment modeling and data-driven validation. The proposed framework demonstrates the potential of integrating simulation and real-world testing for efficient development of marine robotic systems.

Future work will focus on extending the platform toward multi-vehicle and aerial-marine cooperative operations, as well as enhancing AI-driven autonomy and large-scale data generation.

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