Digital Twin Model of Underwater Construction Robot for Real-Time Grinding Simulation

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Abstract

Marin robots are used in the construction and maintenance of underwater structures. Since these robots are operated in a harsh environment, they are usually driven by remote operations. However, remote operations are difficult due to the limitations of sensors. In order to overcome these difficulties, research is being conducted on enhancing remote operation using a digital twin corresponding to an actual underwater construction robot [1]. The digital twin of the underwater construction robot in the virtual environment must be able to accurately predict the behavior of the physical twin, and at the same time, perform in real-time due to the remote operation by human operators. A digital twin model of the underwater construction robot was developed by applying the recursive subsystem synthesis method [2]. Grinding and drilling tasks are common tasks for a construction robot. However, real-time simulation of such tasks is extremely difficult due to high-frequency contact forces. In order to overcome such difficulty, a meta-model based on deep neural network (DNN) technology has been under development for estimating tool force of grinding tasks [3]. In this paper, we explain an integrated model, which combines a virtual tool force estimation model and a virtual underwater construction robot model for real-time simulation.

The underwater construction robot is shown in Fig. 1. It consists of a manipulator arm with a tool plate, a cabin, a base frame, four suspension linkage subsystems, and four track subsystems. The manipulator is driven with four hydraulic motors and two hydraulic cylinder units. The tool plate which is located at the end of the manipulator is also operated by a hydraulic motor. The cabin can swivel with respect to the base frame. Four suspension linkage subsystems are attached to the base frame and each of them is actuated by two hydraulic cylinders. The track subsystem which is composed of a sprocket, a pulley, and a rubber track, can be rotated relative to the suspension link to make the track negotiate rough terrain. The track sprocket is also driven by a hydraulic motor.

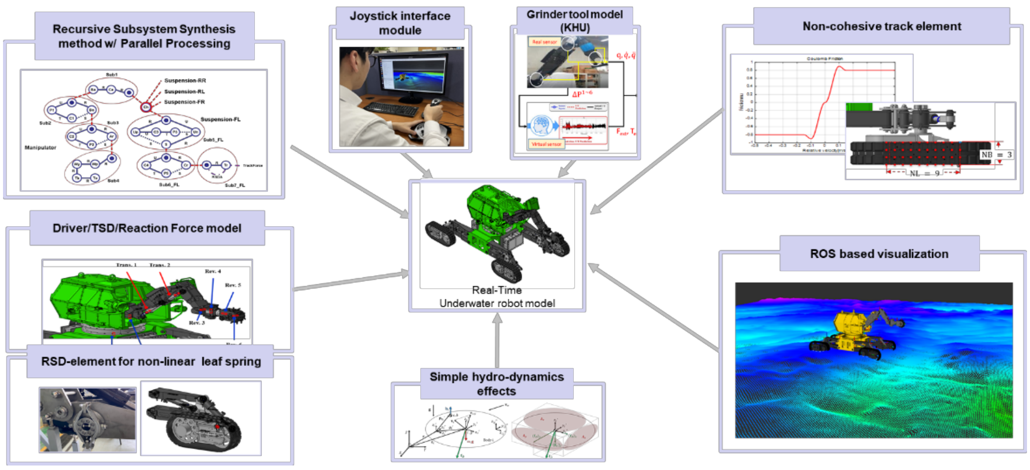

Figure 1: A digital twin model of the underwater construction robot

In order to construct the meta-model for the tool force estimation, data collections were made using actual experimental tests as shown in Fig. 2. The input data for meta-model are tool penetration, tool position and orientation, tool hydraulic actuator pressure, the pressure differences of the hydraulic motors in the manipulator arm, and IMU information of the cabin.

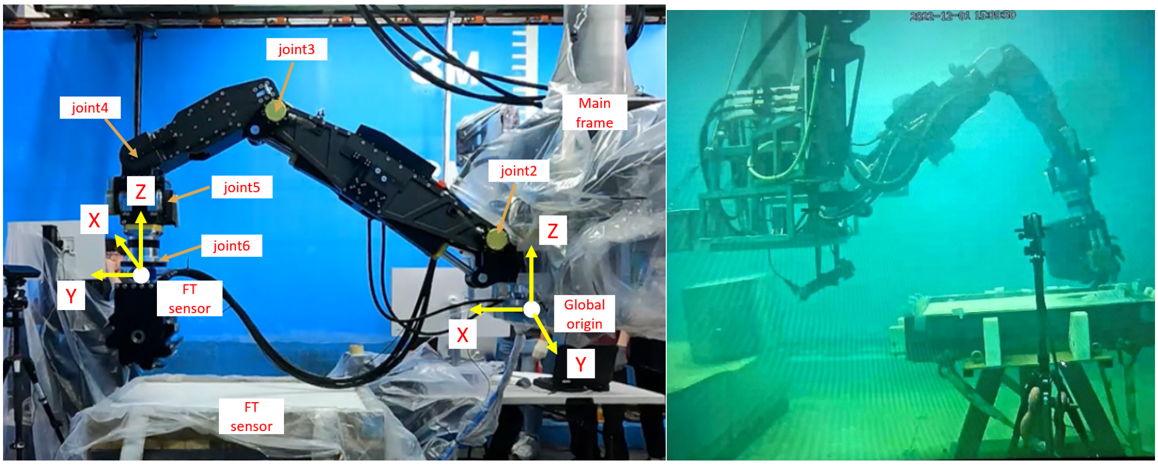

Figure 2: Experimental test for tool estimation meta model data collection

To integrate the tool force estimation module, the underwater construction robot model must produce the above-described input data. Thus, basic hydraulic motor models have been developed for the manipulator arm. The grinding simulations are carried out and the performance of the digital twin model is under investigation, as shown in Figure 3.

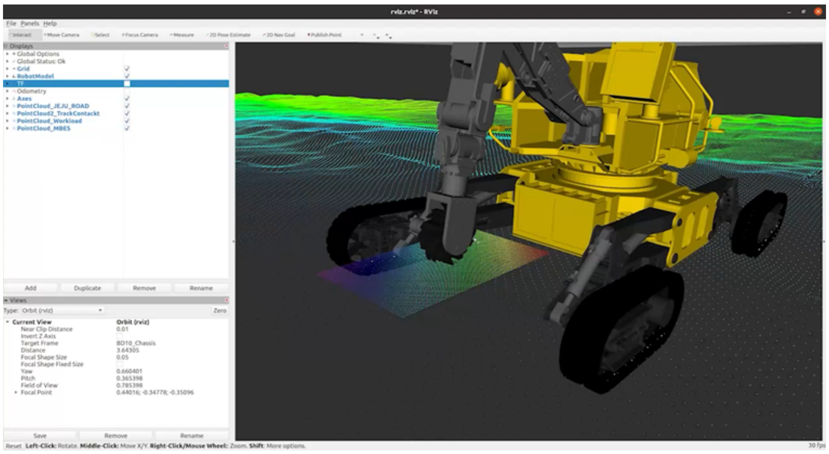
Figure 3: Grinding simulation using digital twin model

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