Development Report:

Development of a Teleoperation System for a Construction Robot

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[Received October 26, 2013; accepted December 3, 2013]

In this report, we introduce the development of a teleoperation system for a construction robot. The system is based on master-slave control, and consists of existing hardware, including hydraulic actuators. We propose presentation methods to provide a realistic presence at a real field, and confirm the validity of our system with experiments.

Keywords: construction robot, hydraulic actuator, master-slave control, teleoperation, virtual reality

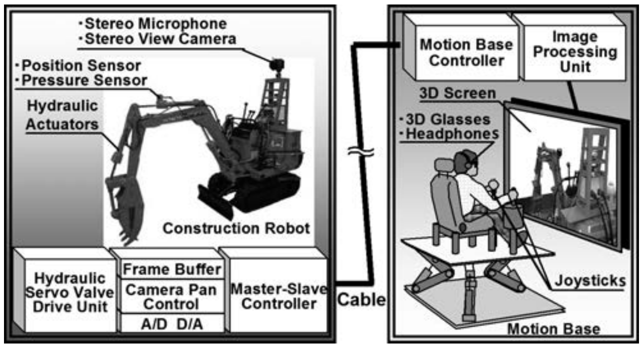

Fig. 1. System framework.

1. Introduction

A construction robot generally includes some actuators, and has sufficient power to carry out tasks that are difficult for humans. The application of such robots in environments that are dangerous for humans such as disaster scenes, space and the deep sea ground is becoming more and more important. Teleoperation is the most effective method of controlling these robots, and teleoperation systems are now developed at a variety of research institutes and companies. However, conventional teleoperation systems do not satisfy requirements of realistic presence and operability. Therefore, we have developed a new system based on hydraulic actuators that satisfies the requirements.

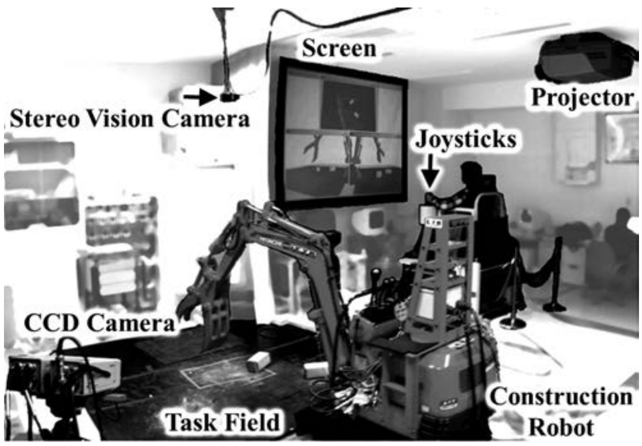

Fig. 2. Experimental facilities.

2. Teleoperation System

The system hardware consists primarily of a servo-controlled construction robot with hydraulic cylinders, two joysticks for operating the robot from a remote place, a 3-degree-of-freedom (3-DOF) motion base, and some type of visual sensor such as a charge-coupled device (CCD) camera or stereo vision camera (**Fig. 1**). The slave is the fork glove, and the master is the joysticks handled by the operator. The operator moves the joysticks while looking at visual information provided by the slave. Signals from the master then move hydraulic cylinders to drive the corresponding fork glove, arm, boom and swing. **Fig. 2** shows the present experimental facility.

3. Control of the Motion Base System

In order to simulate a kinematic presence in the work area, we developed a 3-DOF motion base, and propose a control method based on three acceleration sensors [1]. The motion base has a 3-axis parallel mechanism driven by a 3-part leg assembly, each leg of which consists of a pantographic link and a hydraulic cylinder servo system. It simulates the posture of the robot by controlling the link displacement according to acceleration data. This allows the operator to experience a highly realistic presence as if (s)he were sitting on the seat of the robot.

4. Master-Slave Control Method

We propose a master-slave control method [2] in order to create a realistic sense of force in the teleoperation. In our system, the joysticks have a DC servo motor, and the user experiences a reaction force via the joysticks when grasping an object with the fork glove. Each cylinder is subject to feedback control via a proportional control valve, and pressure sensors are attached to them. These sensors send signals to the master in real time, and the signals are then converted to force signals. We propose a variable-gain symmetric-position control in order to robustly obtain a reaction force when grasping objects of different hardnesses. We also propose control methods based on the reaction force [3, 4], in order to allow the operator to experience a reasonable sense of grasping objects.

5. Visual Presentation Method

Conventional teleoperation systems depend solely on color video images captured by a normal camera on the robot. Our presentation method is based on computer graphics (CG) images from a stereo vision system on the robot [5], and it provides real-time range images of the remote field. A task object is recognized from the images, and its 3D geometry is reconstructed. The object and the robot are presented by 3D-CG to the operator. Images can be seen from the desired position and direction in the virtual space of the remote field. Recently, we developed a presentation method based on augmented reality (AR) [6] (**Fig. 3**). In its implemented system, a 3D-CG image that augments the recognition precision of real objects is created by processing a normal video image. The image overlaps the video image in real time, helping the operator to perform operations accurately.

6. Conclusion

In this report, we introduce a part of our study on the development of a teleoperation system for a construction robot. In future research, we will attempt to augment the realistic presence of its operation by processing the data provided by a sensor such as a range scanner.

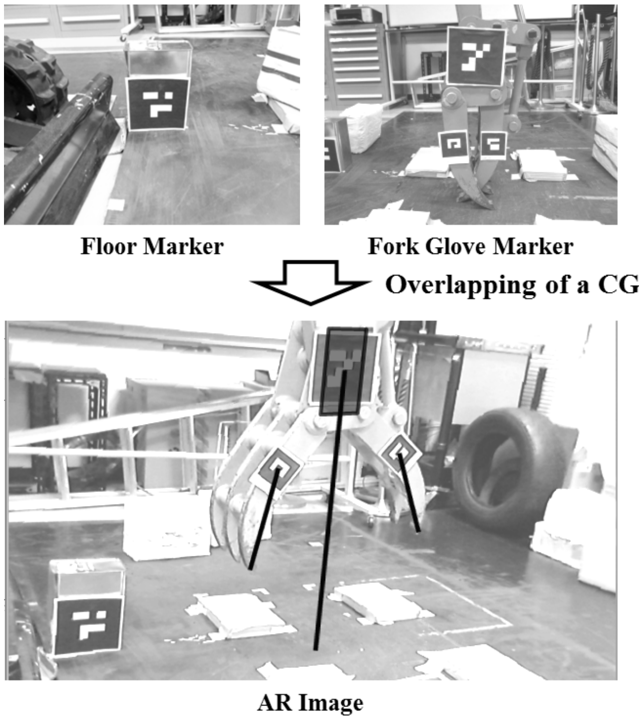

Fig. 3. AR presentation for a operational support.

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