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A Simulator for the Operation and Maintenance of the PRIDE Facility

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1. Introduction

This study introduces a remote simulator to verify and validate an operability and maintenanceability of a remote manipulator in a pyroprocess facility at a design stage. To evaluate an operability and maintenanceability of the devices, it needs various modules. This article describes a system architecture which illustrates an interface between its modules. In nuclear industry, an advanced modeling and simulation technology which can simulate various phenomena by using a digital mockup has been increased. Even several research and development[1, 2]in order to improve the efficiency of a remote operation in the ACPF digital mock-up were carried out, these research results have a lot of limitations in order to apply it to real world. Especially simulations that depend on 3D graphics are limited to the analysis of an accessibility and operability of a manipulator. To solve these limitations, this article proposes a scheme to enable an operator to improve a remote manipulation by using a haptic device which is a force feed-back device.

2. Methods and Results

2.1 System Architecture

A remote simulator composed of a number of modules such as a module for modeling a 3D virtual environment, a module for analyzing maintenance tasks based on human-manipulator interaction interface, and a module for visualizing a analyzed results. Figure 1 illustrates the system architecture for a remote simulator.

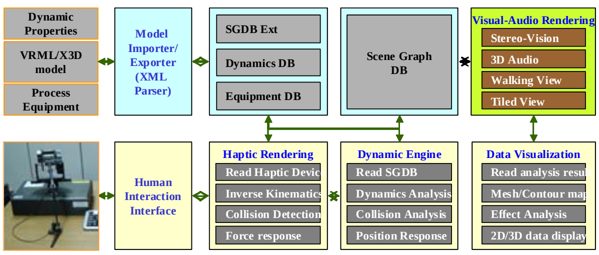

Fig. 1. Schematic diagram of a remote simulator

The system begins with loading VRML files which were constructed by 3D CAD tools such as ENVISION, SOLIDWORKS, and 3DS MAX. In the haptic interface, we used a PHANToM premium 1.5A for an input with 6-DOF and an output with 3-DOF made by Sensable Ltd, and we used Open Haptics with software.

2.2 Haptic device and Graphic rendering

The reason we selected the haptic device was that a simulation that depends on 3D graphics has a limitation when analyzing various situations of a remote manipulation. Especially a maintenance work that deals with nuclear materials remotely requires a high manipulator skill of a human operator. Figure 2 illustrates the relationship between a haptic rendering and a graphic rendering in order to analyze the remote accessibility and operability in the digital mock-up facility.

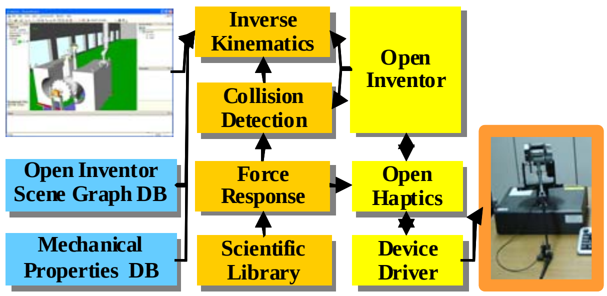

Fig. 2. Configuration of a haptic device rendering and a graphic rendering

2.3 Analysis of the forward and inverse kinematic of the MSM

To check on the interference between the MSM and the devices in the virtual space, we should know the 6-DOF movement of a gripper functions. To acknowledge the 6-DOF, we have to calculate the angle of the joints with the input for the position and orientation of the MSM in a Cartesian space. Table 1 shows the parameters along with the inverse kinematic chain developed by Denavit-Hartenburg. In the force feed-back input device, it is difficult to map it with a one-to-one ratio because of a difference between the manipulator and the kinematics. In this case it is necessary to calculate the forward kinematics for the end-effector position, orientation, and to calculate the inverse kinematics for a joint angle. The end-effector position and orientation using the transformation matrix of each joint can be represented by a 4x4 transformation matrix. The coordinates describe the end-effector position and orientation using position coordinates and the relative-axis(Euler angles) is defined from the transformation matrix as follows:

Table 1. Denavit-Hartenburg parameters for the MSM

	θ	d	a	α
1	θ_1+90	537.5	0	90
2	θ_2+90	0	32.5	-90
3	0	956.6+d_3	0	0
4	θ_4	73.6	43.8	90
5	θ_5	0	0	-90
6	θ_6	208.22	0	0

$$X = [xyz\phi\theta\psi]^T \qquad (1)$$

If a coordinate system of each joint is defined as $q = [q_1 q_2 q_3 q_4 q_5 q_6]^T$ which is the current robot configuration, then we obtain Eq. (2) from Eq. (1).

$$X = F(q) \qquad (2)$$

This equation is a forward kinematics one, which means a transformation from a joint space to homogenous coordinates. For a linearization, if we assume an infinitesimal displacement from Eq.(1), then we can obtain it as follows;

$$\delta X = J(q)\delta q \qquad (3)$$

where $J(q)$ is the Jacobian matrix. In the case of a 6-DOF manipulator, joint motions. we can calculate the infinitesimal displacement of a joint as follows:

$$\delta q = J(q)^+ \delta X \qquad (4)$$

where $J(q)^+$ is the pseudo-inverse of the Jacobian matrix, δq is an 6-dimensional vector of the cartesian components of the end-effector with reference to the base coordinates, and δX is a vector of a joint.

2.4 Case Study

To verify if a collision detection could be achieved for a collision with other objects, preliminary experiment about an interface between a human operator and the haptic device was carried out. For experiment, a Vol-Oxidizer, which can convert UO_2 pellets to U_3O_8 powder through the process of a decladding and vol-oxidation of rodcuts, was chosen. Figure 3 depicts the lever of the Vol-Oxidizer. The result shows that the collision detection and force response algorithm were appropriated as we felt the force feedback whenever the MSM collided with other objects(Figure 4).

3. Conclusions

Based on the system architecture, a remote simulator to build a digital mock-up at the design stage and to analyze its remote accessibility and operability at the maintenance stage was implemented.

A preliminary experiment in order to elucidate an interface between a human operator and a haptic device was completed successfully.

The results show that a collision detection could be detected well during a collision with other objects and the force feedback response could also be felt from the force feedback whenever bumping against other objects.

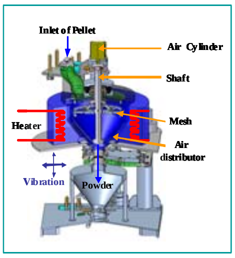

Fig. 3. Components of Vol-Oxidizer and a lever near the Inlet of Pellet

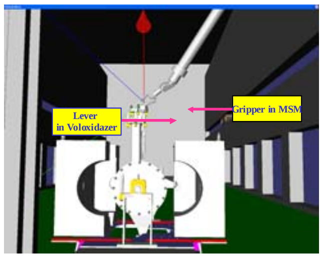

Fig. 4. Scene of MSM access a lever and grip it.

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[2] Tai-Gil Song, et al., "Development of the Interface Module for an Effective Application of a Digital Mock-up", Pro. of theICAS 2005, KINTEX, Gyeonggi-Do, KOREA, June 2-5, 2005.