Implementation of a Digital Mock-up for Remote Hot cell Operations

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1. Introduction

A remote manipulation environment that a human operator has to observe is the inner side of a hotcell through a lead grass window which has many obstacles due to many existing 'blind-spots' where are several cameras installed. The lack of visual information when operating in a cluttered environment makes manoeuvering a manipulator very difficult and when this situation is exacerbated by strict time limits for a task completion, then a manipulator and environmental collisions and resultant damage can occur. To cope with these problems, there has been efforts to develop a virtual simulator to validate control programs visually[1] and to establish maintainability-engineering tools that automate generation assembly/disassembly procedures by using Computer Aided Design(CAD) visualization systems with human figure models to virtual reality systems where engineers can interact with the system using virtual input devices[2]. This article introduces a system that can simulate a deployment analysis on a digital mock-up effectively and proposes a scheme to enable an operator to improve a remote manipulation by using a haptic device.

2. Methods and Results

2.1 Functional Architecture

The system consists of an input module, a simulation module, and an external input module. Fig. 1 shows a schematic diagram for the remote simulator. The input module imports a 3D CAD data to the simulator. To simulate the related remote manipulator by using an OpenInventor, the 3D CAD data has to be converted to a VRML format. VRML geometry models are used to setup the virtual environment. These complex geometry files hold the information of the shape and characteristics of the model designed.

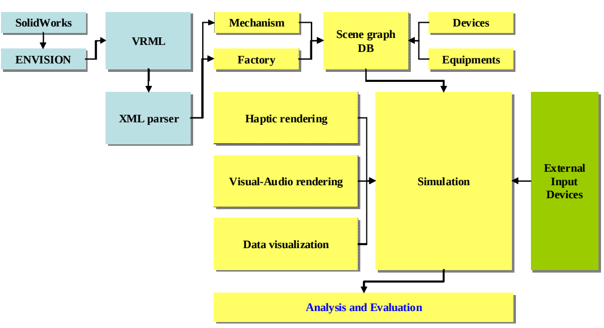

Fig. 1. Schematic diagram of the remote simulator

2.2 Haptic Rendering and Kinematic Analysis

Haptic rendering seeks to provide the human operator with the appropriate force feedback to feel the geometry, surface and material property of an object. To check on the interference between the manipulator and the pyroprocessing devices in the virtual space, the 6-DOF movement of a gripper functions should be defined. 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:

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

A forward kinematics equation and the Jacobian matrix and the pseudo-inverse of the jacobian matrix are as follows;

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

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

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

2.3 Scenarios for prototyping

In July, 2006, the remote technology Lab. had evaluated remote operability and maintainability on the major devices composed of ACPF during ACP campaign. For conducting virtual prototyping, maintenance task of the separation of a heater module of Vol-Oxidizer was chosen. Fig. 2 depicts a rendered view of the Vol-Oxidizer.

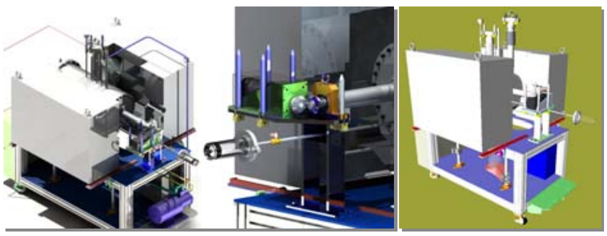

Fig. 2. Rendering view of the Vol-Oxidizer

Series of scenario which was used in virtual prototyping are as follows;

- in order to analysis deployment of devices by using the analysis result of the workspace area, it is assumed that position of powder mixing in air-cell being located in a place far more than original coordination

- a human operator must replace a motor of Vol-Oxidizer in order to maintain by using haptic device
- there are no obstacles in space from lead grass window to Vol-Oxidizer
- a human operator presses down on a lever which is surrounded by a motor of Vol-Oxidizer with 30 degree
- a human operator feels force feedback when a virtual manipulator collide other objects

2.4 Results and Discussion

The left picture of Fig. 3 shows that an initial design value of Powder Mixing describes x=4.1, y=0.0, z=-2.55 and the device was left from the workspace of the remote manipulator.
In order to find out how devices leave from the workspace area of the remote manipulator, a distance of two positions that was left must be measured by clicking with mouse between an edge of the workspace of the remote manipulator and an edge of the device which was excluded from the workspace(two points colored with black on the Fig. 3). A leaved distance between two points was ascertained by 0.75m.
Using this value and an initial design value, we obtained a value that needs to be redesign.
The right picture of Fig. 3 shows that the device was deployed normally after reassigning of the device's position.

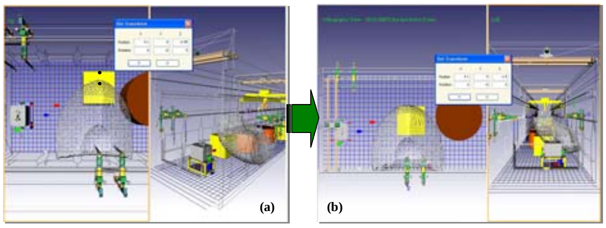

Fig. 3. Deployment analysis of devices using a virtual manipulator

3. Conclusions

A virtual prototyping was carried out in order to ensure all the requirements that need to develop the system and whether a workspace evaluation for the deployment analysis can operate normally and if an interaction between a human operator and a haptic device can be effective as an appointed scenario.

An interaction research about the interface between a human operator and the haptic device was successfully completed. A collision detection was detected well during a collision with other objects and the force feedback response was also felt from the force feedback whenever bumping against other objects. From a remote accessibility experiment using a haptic device, this device will be an alternative tool for analysis of remote accessibility in the maintenance task. But there is still lack of issues that reflect the real manipulator's kinematic conditions on account of several differences between an assumed experiment condition and a real experiment condition that was operated in hotcell.

This technology will be a useful tool to analysis deployment of the devices which treats radioactive materials in the course of designing a nuclear fuel cycle facility.

Acknowledgement

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