A study of the teleautonomy approach to the door opening task of a mobile robot for accident response at operating nuclear power plants

Dongjun Hyun [a*], Hocheol Shin [a]
[a] *Korea Atomic Energy Research Institute,*
989-111 Daedeok-daero, Yuseong-gu, Daejeon, Republic of Korea, 305-353
[*] *Corresponding author: dongjunn@kaeri.re.kr*

1. Introduction

In the event of an accident at an operating nuclear power plant, robots are increasingly being deployed to perform tasks that are too dangerous for humans. One crucial task for these robots is opening doors to enter the building or navigate inside the facility. To accomplish this, a teleautonomy technique has been developed that uses pre-planned robot motion and three-dimensional point cloud matching to efficiently open doors.

This technique allows the robot to pre-plan its motion based on the known environment, including the location of the door handle, and match the three-dimensional point cloud data in real-time to determine the precise location and orientation of the handle. The robot then executes its pre-planned motion to efficiently turn the handle and open the door.

The development of this teleautonomy technique represents a significant advancement in the ability of robots to perform complex tasks in hazardous environments such as nuclear power plants. This paper will explore the development of this technique and its effectiveness in performing door-opening tasks in nuclear power plants, as well as its potential applications in other industries.

2. Methods and Results

This section describes the technique of creating a kinematic chain that connects the coordinate system of the motion planner with the coordinate system of the 3D scanner and the coordinate system of the robot, and the technique of applying the pre-planned motion to the actual door opening task through 3D point cloud matching.

2.1 Building a testbed

The testbed was built on a table to validate the kinematic chain, which is the key to the door opening task, from the 3D scanner to the end-effector, as shown in Fig. 1. For most position-based robotic tasks, guiding the end-effector to the correct location is key, and in this study, a 3D scanner guides the end-effector. Therefore, a testbed was built on a table to efficiently validate the kinematic chain from the 3D scanner to the end effector.

2.2 Creation of kinematic chain

Kinematic chains are created within the Motion Planner platform because they will implement pre-planned robot motions. In this study, the motion planner platform is a CAD system and the created kinematic chain must synchronize the motion within the CAD system with the motion of the physical system.

The kinematic chain is composed of three transformation matrices, which are a transformation matrix that matches the 3D scanner's coordinate system to the CAD coordinate system, a pose transformation matrix of the robot base in the CAD coordinate system, and a transformation matrix that matches the robot's joint values through the robot's kinematics to the pose of the end effector.

The transformation matrix **T**scn2cad to match the 3D scanner's coordinate system to the CAD coordinate

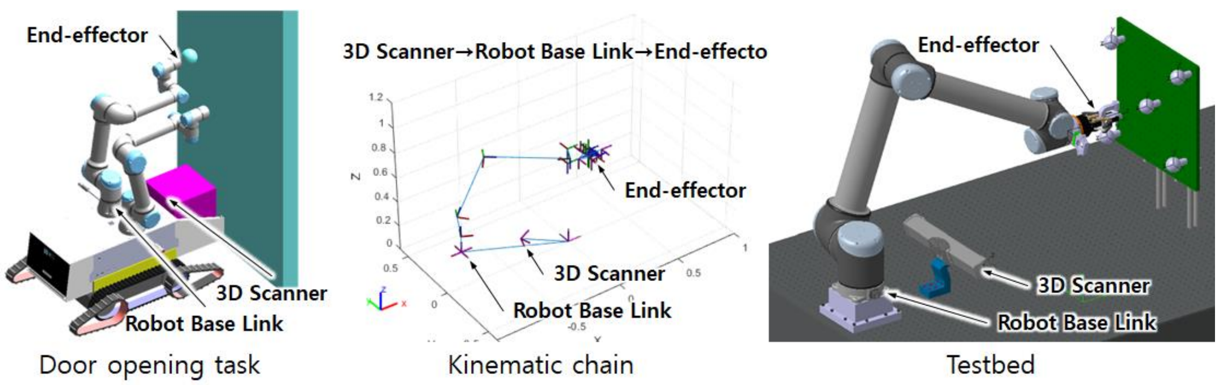

Fig. 1. Building testbed for kinematic chain of door opening task

system is found using a method for registration of 3D shapes [1, 2]. The pose transformation matrix **T**rob2cad of the robot base in the CAD coordinate system is found using a motion tracking system. The transformation matrix **T**rob2eef to match the robot's joint values to the pose of the end effector is found using a kinematic parameter calibration method and an error compensation method [3~5]

2.3 Door opening task

In this paper, we report on the successful execution of a door opening task by transforming robot motion generated by a motion planning system to a target position calibrated by a 3D scanner. The motion planning system uses pre-defined motion sequences to guide the robot to the door handle, and the 3D scanner accurately locates the handle to determine the target position for the robot's gripper. (See Fig. 2 and 3)

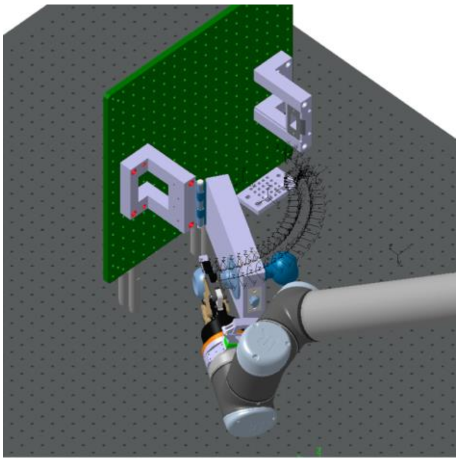

Fig. 2. Generation of door-opening motion.

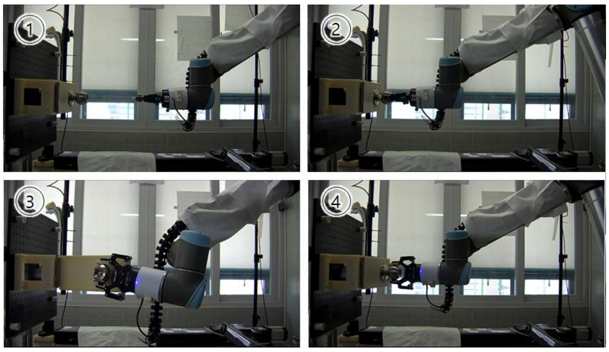

Fig. 3. Experiment of door-opening task.

3. Conclusions

In conclusion, we have successfully developed and experimentally validated a teleautonomy technique for performing a mobile robot's door opening task in an accident at an operating nuclear power plant. This technique combines pre-planned robot motion with three-dimensional point cloud matching to efficiently and accurately identify and turn door handles.

The experimental results have demonstrated that this technique is effective in opening doors in complex environments with varying lighting conditions and occlusions. Furthermore, the use of teleautonomy allows for remote operation and monitoring, reducing the exposure of workers to radiation and other hazards.

The successful development of this technique has significant implications for the safety and efficiency of operations in hazardous environments such as nuclear power plants. Future work will focus on further refinement of the technique, including the integration of additional sensors and the optimization of motion planning algorithms. Overall, this research represents an important step towards improving the capabilities of robots in responding to nuclear accidents and other high-stress situations.

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