マニピュレータの自己遮蔽を考慮した 軌道上観察ロボットによる視点自動提示

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Automatic Viewpoint Selection by Rail-Mounted Observation Robots Considering Self-Occlusion by Manipulator

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Works inside extreme environments inaccessible to human workers are often carried out in the form of teleoperation. It is then important for operators of robots to have constant grasp on situation inside the initially unknown working environment. To set cameras in such extreme environments, one method proposed is the use of rail-mounted observation robots. To lower the cognitive load on teleoperators, the selection of viewpoint is to be achieved automatically. This research proposes a way of using a single rail-mounted observation robot to automatically provide a viewpoint that is able to react to occlusion. The proposed method is verified in a computer simulation.

Key Words : Teleoperation, Robot vision, Viewpoint selection, Nuclear decommissioning

1. Introduction

In order to reduce the risk of operational errors for teleoperation within extreme environments that are inaccessible to human workers, constant observation of the working environment is considered significantly beneficial. It is shown that providing operators with elevated views around robots can decrease operation difficulty and improve efficiency.

To overcome the difficulty of manipulating equipment inside extreme environments rail-mounted robots are being developed as one solution [(1)]. In order for operators to control their robots in an efficient and error-free fashion, it is necessary to provide proper views.

Several developments have taken place on algorithms to automatically provide optimal viewpoints for teleoperation, either based on task modelling and viewing pattern [(2)] or affordances [(3)]. These studies focus more on occlusions caused by manipulated objects instead of the robot arm itself. Since a blocked view by the robot can lead to the loss of a significant amount of information, operators might need to move viewpoints manually, increasing their cognitive load and harming work efficiency.

The objective of this research is to use rail-mounted observation robots to automatically provide a viewpoint inside an unknown unmanned environment to observe target objects of teleoperation. This viewpoint shall be able to respond to the occurrence of occlusion by robot.

2. Proposed Method

The general workflow of the proposed method consists of two steps, with the first being creating candidate viewpoints along with a mesh model of the environment, and the second being selecting optimal viewpoints from created candidates.

The use of Structure from Motion (SfM) is proposed to create a mesh model of the environment along with camera poses along the rail, illustrated in Fig. 1(a), as viewpoint candidates. The model of a moving robot arm is then integrated to the environment model to create occlusions between camera poses and a selected target object within the environment model.

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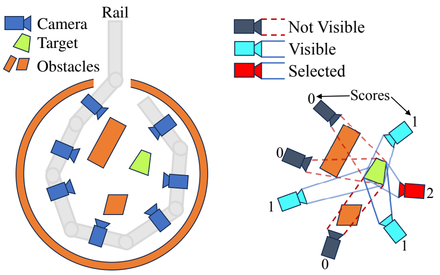

(a) Equipment layout. (b) Viewpoint selection.

Fig. 1 Creation and selection of candidate viewpoints.

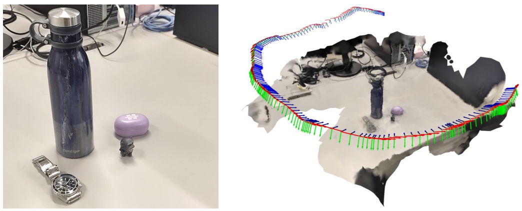
(a) Objects used. (b) Reconstruction result from SfM.

Fig. 2 Recreating environment and camera poses.

Rendering pipeline is then used to look at the size of the target object rendered from each candidate viewpoints. Viewpoints from where the target cannot be seen well in size is eliminated from selection. Remaining candidates are evaluated using a scoring system of how far they are away from their eliminated counterparts. As shown in Fig. 1(b), the candidate viewpoint with the highest score is selected to be the view provided. Along with the moving robot model, elimination and evaluation result also changes correspondingly as occlusion occurs.

3. Simulation

Several objects of various size are used to create an environment for simulation, as shown in Fig. 2(a). The purple ear pod case is assigned to be the target object. A video is then taken using a smartphone camera looking down on the environment and moving in a path resembling one along a rail. The video is sliced into equally spaced frames used for SfM to obtain the environment model along with candidate viewpoints shown in Fig. 2(b).

The model and viewpoint coordinates are then imported into simulation program for rendering pipeline and viewpoint selection. The robot model is added and a green sphere model is put in place to assign the target.

An interactive interface that resembles frames shown in Fig. 3 is then used where the robot arm is controlled by keyboard. With a small time step, the viewpoint selection algorithm is executed repeatedly and selection results are marked out by color of candidate viewpoints.

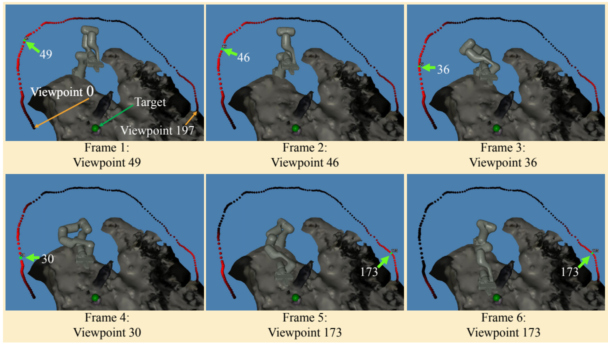

Fig. 3 Frames of robot arm extending and selected viewpoint (light green) changing along.

Real-time change in selection result is observed where the presented viewpoint moves to avoid occlusion by the robot arm, indicating that if a rail-mounted observation robot is to be used, it would move along with the robot arm to keep a good visual on the target object.

4. Conclusion and Future Works

This research demonstrated the feasibility of using a single rail-mounted camera robot to reconstruct an unknown working environment and find a suitable viewpoint while avoiding occlusion with the working robot. With this method, teleoperators can have a view on the target object at all times, even when moving working robots might block the view.

Moving forward, this research plans to consider more factors to further improve the viewpoint selection algorithm.

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