Simultaneous Tele-visualization of Robot and Surrounding Environment Using Body-mounted Fisheye Cameras

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This paper proposes a high quality tele-visualization system for showing both the robot and the surrounding environment from an arbitrary viewpoint by using body-mounted fisheye cameras. A new calibration method which estimates the accurate positional relation between the robot and the body-mounted fisheye cameras is proposed in this paper. The new calibration method can reduce the calibration error. In addition, the visibility of the robot is tested, which can reduce the mis-presentations of the visualization. In the proposed method, the actual scene images captured by the body-mounted fisheye cameras are projected onto the screen which is composed by the robot CAD model and the surrounding environment CAD model. The robot and surrounding environment are able to be visualized simultaneously during the experiment. In this way the high quality tele-visualization system is able to be confirmed.

Key Words : visualization, robot, body-mounted camera, teleoperation

1. Introduction

Teleoperation of robots are widely used in construction and disaster sites in order to keep the operators' safety [(1)]. During the robots' teleoperation, visualization of the robot body is also highly needed. For example, in the operation of a bulldozer robot, the operator needs to adjust the load of the blade by grasping the shoe slip information of the crawler parts, in order to improve work efficiency. Also, to make the manipulation of the robot easier, visualization of the teleoperation should be correct and easy-to-understand. In (2)–(4), the surrounding environment was well presented in a bird's-eye view, however the robot body itself was shown as an image which was taken in advance. This is because the arrangement of the cameras was designed to only capture the surrounding environment. In(5), both the robot body and the surrounding environment were able to be visualized simultaneously. The result was able to be visualized in real-time. Even though, when the method mentioned in (5) was used in a real construction site, the deviations and the mis-presentations of the tele-visualization became more obvious. Thus, it is necessary to build a high quality real-time simultaneously tele-visualization system.

2. Proposed method

In order to simultaneously visualize both the robot and the surrounding environment in real-time, a method that consists of five steps are proposed. The overview of the proposed method is shown as Figure 1. Firstly, three-dimensional mesh models of the robot and the surrounding environment are built. Secondly, positions and orientations of the cameras are defined, in order to obtain images of the actual scenes of the robot and the surrounding environment simultaneously. Thirdly, the correspondence between the actual scenes images and the three-dimensional robot mesh model is estimated. Fourthly, the visibility test of the robot and the environment is executed as the depth test. Finally, images of the actual scenes are mapped to the visible regions of the three-dimensional models. This step is executed in real-time. In this manner, the high quality real-time simultaneously tele-visualization can be achieved.

3. Tele-visualization experiment

Experiment was performed with a construction robot shown as Figure 2. Four fisheye cameras were

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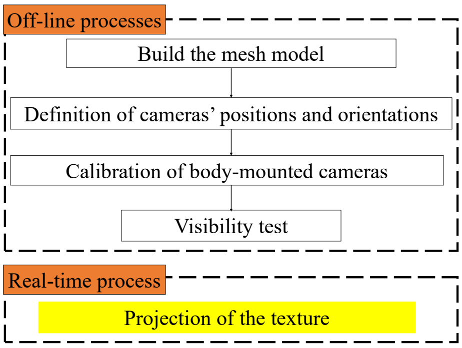

Fig. 1: Step flow

mounted on the front, left, right and back sides of the robot, in order to observe the 360° angle of the view. The surrounding environment of experiment was approximated as a semi-sphere mesh model with 15 m radius. The mesh model of the construction robot was built by CAD software from previously known CAD data. Fish-eye cameras were set to capture the images of the actual scenes at 20 fps. Meanwhile, the images were mapped to the mesh models. The result of the texture mapping was presented on a monitor of a computer at 20 fps in the same time.

4. Result

Experiment result is shown in Figure 3. The result can be confirmed as a 20 fps real-time video as well. The invisible parts of the construction robot are in black.

5. Conclusion

The adequacy of the system was confirmed by simultaneous tele-visualization experiments. The result of the experiment showed the change of the surrounding environment during the operation of the construction robot clearly. In addition, the construction robot was presented with less deviations and mis-presentations.

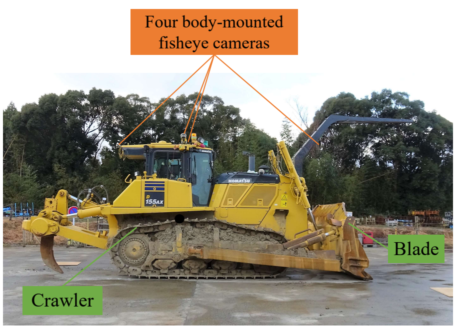

Fig. 2: Construction robot with four body-mounted fisheye cameras

Fig. 3: The tele-visualization experiment result. The invisible parts of the construction robot are in black.

For future work, optimal positions and orientations of the mounted fish-eye cameras will be considered. In addition, because the movements of the operation parts are in great ranges during the manipulation, it is necessary to change the mesh model accordingly.

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