論文の内容の要旨

Study on Gesture based Human-Robot Interface with Multimodal Cognitive Perception for Remote Collaboration

（遠隔協働をめざした，多様認知知覚を有するジェスチャーに基づくヒューマンロボットインタフェースに関する研究）

宋　泳恩

This study proposes an intuitive teleoperation scheme by using human gesture in conjunction with multimodal human-robot interface. Recently, the teleoperation systems carry out a decisive role where the environments are dangerous, unstructured and under-recognized; such as bomb disposal, rescue or space exploration with the abilities of robot that are precise, and mechanically strong. However, conventionally, researchers have used joystick like control sticks or keypads. But, with such method, the more the task is getting complicated, the more workload is increasing in geometric progression, and also the operators have to be trained enough prior to the session. To solve these problems, the gesture capture is applied as a input system to control robots by moving simultaneously with operator's own motions. The early studies captured only the hands of operators to control the end-effectors of the robots by using marker based optical systems or exoskeleton motion capture devices. However these kinds of systems often disturb the natural movements of operators and also had to be installed beforehand. It brings to a conclusion to stress the importance of having portable device which can capture the whole body gesture to sustain the natural movement of the operator. It also means more natural and intuitive teleoperation system for the remote collaboration task

is possible with such device. To support better perception of remote environments, this study apply the multimodal human-robot interface which consists of immersive 3D visual feedback and vibrotactile feedback. In the case of the immersive 3D visual feedback, operators are surrounded with 3D virtual reality (VR), which makes it seems as if they are inside of a different place. Therefore, It is possible for the operators to feel the remote places as close to the real world when they interact with objects or other people in a certain virtual world through their own avatars, and that allows complicated collaboration tasks between them possible. But there is a crucial factor of the immersive 3D VR. In order to reflect the operator in the virtual world as the avatar, continuous capturing of the operator's pose is necessary. For such activity, application of ¥emph{the intelligent space (iSpace)} concept would be ideal. iSpace concept had been proposed by Hashimoto laboratory at the University of Tokyo since 1996. The iSpace makes surrounding space to have intelligence by using ¥emph{distributed intelligent network device (DIND)}, and the DIND observes all events including human movements in the space. However the conventional iSpace necessitate operators to not deviate from the sensor range, since DINDs are fixed in specific places it makes nearly impossible to transfer the device around. To overcome these space restraints and to make iSpace system more flexible, a new type of DIND is required. As a solution, this paper newly presents the mobile iSpace, a personal portable device which is also able to provide the multimodal feedback. Further, in order to deal with the complication of dynamic daily environment, the haptic point cloud rendering and the virtual collaboration are applied to the mobile iSpace. Therefore, firstly, a surrounding environment of a teleoperated robot is captured and reconstructed as the 3D point cloud using a depth camera. Virtual world is then generated from the 3D point cloud, which a virtual teleoperated robot model is placed in. Operators use their own whole-body gesture to teleoperate the humanoid robot. The Gesture is captured in real time using the depth camera that was placed on operator side. The operator receives both the visual and the vibrotactile feedback at the same time by using a head mounted display and a vibrotactile glove. To enhance the perception of remote environments, the sound-based vibrotactile feedback rendering scheme is newly presented to make operators are able to recognize the textures naturally. The system renders the vibrotactile feedback based on the sound which is generated from the actual touch between the human hand and certain objects. Then the vibrotactile feedback is rendered based on the human gesture movements, e.g. direction or velocity of hand, to make a possible to present the cognitive haptic illusion to the operator. Moreover, the rendered multimodal feedback parameters are evaluated and used to figure out the human stimulus model via the psychophysical study, and the feedback parameters are regenerated based on the human stimulus model. With the cognitive haptic illusion and psychophysical study, this system is able to overcome the lack of reality of the portable device. All these system components, the human operator, the teleoperated robot and the feedback devices, are connected with the Internet-based virtual collaboration system for a flexible accessibility. This study showcases the effectiveness of the proposed scheme with experiments that were done to show how the operators can access the remotely placed robot in anytime and place.