論 文 の 内 容 の 要 旨

論文題目　Study on Application Systems using Smart Glasses Aimed at Field Service Assistance
（フィールドサービス支援を目指したスマートグラス応用システムに関する研究）

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Augmented reality (AR) has been a promising tool in engineering fields. AR systems can show digital contents to the worker's view of a real scene and give understandable information and instructions. Thus, it is a promising way for field service applications such as assembling, maintenance, and construction and for training novice workers. Especially, smart glasses are a key device for such AR applications and usually have embedded sensors such as a RGB camera and depth camera to collect environmental data to provide various functionality. With such sensors and functionality, one of the prospects of smart glasses technology is to let the worker carry and use only smart glasses for such field service applications and training. Moreover, to further improve user experience in AR, researchers have proposed that integrating eye tracking sensors into AR glasses can enable display enhancements for better overlay accuracy, hands-free interactions with virtual objects, and sharing gaze for remote assistance and analytical studies. Although the development of such AR glasses with eye tracking is still in its infancy, we can establish related systems in advance by using existing smart glasses. Aiming at using such AR glasses with eye tracking to support field service applications and training more efficiently and effectively, in this research, we studies two types of smart glasses to develop two prototype systems: (1) eye tracking glasses for user's cognitive research and analyses and (2) AR glasses for assembly assistance.

For eye tracking glasses, which record the user's gaze fixation in a scene video, most related applications are in 2D space, and there should be more applications in 3D space to give more understandable gaze analysis results. In this study, we propose a method to demonstrate user's gaze in 3D space using only a pair of eye tracking glasses. After a user performs an eye tracking recording in a certain environment, we generate a 3D mesh model of the scene from the frame images in the scene video by applying the image registration method. The intersection of a triangle in the model and user's line of sight, which is determined by linking the camera center of the frame image and the recorded gaze point, is the target 3D gaze fixation. Moreover, based on this methodology, we propose another method to compare multiple users' 3D gaze visualization more efficiently and effectively. Similarly, by applying the image registration method, we register the frame images of all the users' recording into the same 3D model generated from one of the users' recording, that is, reconstructing only one model of the scene to visualize all users' 3D gaze. In our experiment for three users observing the same scene, the processing time decreases by 50%. In addition, an eye tracking recording in a room-scale environment is conducted to demonstrate the advantages of 3D gaze visualization in complex and large-scale environments, which can be hardly demonstrated well by typical 2D visualization methods. With the developed methods, we can use only eye tracking glasses to generate user's 3D gaze visualization and compare users' gaze difference to train novice workers more efficiently and effectively.

For AR glasses, the development of AR technology has enhanced the experience of assembly operations by showing virtual parts of assembly at installation locations to a worker. Good assembly instructions can improve the effectiveness of assembling operations and training; meanwhile, it is important to detect whether misassembling occurs during such operations. In the study of AR glasses, we construct an AR assembly assistance system using only a head-mounted display of Microsoft HoloLens. Because the HoloLens is originally designed for room-scale applications, we use point clouds generated by a depth camera in the HoloLens and propose two methods to apply the HoloLens to desktop applications. One method is coordinate calibration to display virtual objects at installation locations by aligning reference virtual object, which is at the origin of the virtual world, to the associated reference real object's position. The other evaluates in real time whether misassembling has occurred by evaluating misalignment between real and virtual objects. For efficiency, we compare the depth images of the real and virtual objects instead of the calculation in 3D space. With the preliminary tests, the position error can be within ±1 cm and misalignment evaluation can be performed at 30 fps. Thus, with the presented methods, a standalone AR assembly assistance system can be realized to support assembling operations and training.

In summary, with the usage of existing sensors and functionality provided by smart glasses, we demonstrate that it is possible to further expand their capabilities. In the future, as the mature development of AR glasses with eye tracking, we can apply the proposed systems into such smart glasses and construct a standalone system. The system will be able to assist the worker in assembling operations through AR. Meanwhile, the worker's visual attention can be recorded during the operations, and then visualized in 3D space. The 3D gaze visualization is further used to assess the worker's skill and to compare between experienced and novice workers for training and analytic studies. This will construct a more complete system for field service assistance.