Context-Aware Safety Information Display for Nuclear Field Workers

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ABSTRACT:

The overall goal of this project is to test the hypothesis that Augmented Reality (AR) glasses that adopt advanced computer vision and model-based safety compliance checking methods will significantly increase the personnel safety and reduce operating costs by displaying safe maintenance processes to nuclear power plant (NPP) field workers. The current practice of operation, outage, and online monitoring of NPPs require workers to switch between digital models, data, and physical workspaces for identifying relevant but potentially occluded objects and assessing the risks of maintenance processes. For example, a field worker has to compare his/her observations in a given scene with the available drawings and maintenance guidelines to determine which valves are the ones that would reduce the water level in the cooling tower. When multiple valves are next to each other but have different control functions, incorrect valve identification can pose risks of accidents or incidents. On the other hand, field conditions can change rapidly, requiring field workers to report field conditions to supervisors in order to get real-time guidance to ensure that changing conditions will not invalidate or endanger the work order. Besides, incorrect recognition of equipment objects (e.g., switches of motor control systems) could result in communication errors and safety problems. During fieldwork, AR techniques could assist engineers in viewing the physical workspaces with objects labeled by the maintenance process information and safety reminders.

Related to the overall goal, the specific objectives are: 1) Navigating field workers through safe and radiologically conscious routes and assisting them in locating the maintenance site; 2) Automatically highlighting the correct processes of operating NPP equipment in the real-time video views of AR glasses; 3) Highlighting minimum task-related objects and environmental and facility conditions (e.g., water level, temperatures of objects) in the real-time AR video views for guiding safe field operations; 4) Developing methods that can predict the likely conditions of typical flow loops (e.g., water levels) when network service for real-time data transmission for the AR device is disrupted; 5) Reducing the computational resource needs of the computer vision and intelligent maintenance process visualization algorithms so that AR glasses with limited computing power can execute these algorithms.

The project team plans to develop an "Intelligent Context-Aware Safety Information Display" (ICAD) for field workers. The developed ICAD should achieve integration of the real-time overlay of physical workspaces with maintenance process and safety information visually through AR glasses to assist and guide field workers in assessing workspace risks, locating task-relevant objects, and carrying out the tasks in the correct order. Three correlated tasks will collectively overcome the challenges mentioned above through a comprehensive consideration of the relationship among these challenges and field needs. Task 1 is "Automatic Matching of Work Order and AR Video Capture," which focuses on developing spatiotemporal pattern matching and computer vision methods for checking whether a worker is at the correct maintenance site and recognizing the task-related objects in the real-time video views of the AR device. Given the capability of locating workers and task-relevant objects, Task 2, "Intelligent Process Visualization," focuses on reasoning algorithms that automatically identify task-related field objects and safety-related field data, so that the AR device will be able to highlight critical objects, task-related field conditions, and the process of operating objects without showing irrelevant information. Task 3, "Real-time Execution of Algorithms on AR Glasses," examines novel algorithm designs that enable real-time execution of the computer vision and visualization algorithms on AR devices having stringent memory and computing power constraints. Deliverables of the research include: 1) visual pattern matching algorithms that enable worker navigation and field object recognition for supporting maintenance task executions; 2) intelligent maintenance process visualization and data filtering algorithms that overlay minimum texts and highlights in the views of AR glasses for guiding the task execution without information overloading; 3) real-time implementation of visual pattern matching and intelligent process visualization algorithms on AR devices with limited computing power and memories.

The proposed project will integrate project team members' expertise in computer vision, safety, spatial analysis, process automation, human factor analysis, and control systems of nuclear power plants to address the data challenges in NPP operations. The project team is composed of a data scientist for construction safety, a computer vision scientist, a human factors scientist, and an industry expert who is examining the use of VR-AR in training nuclear workers and have access to a flow loop simulator for the proposed research.