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RESEARCH RESULTS

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AN AUTOMATION AWARENESS ASSISTANT FOR AUTOMATED TRAIN OPERATIONS

SUMMARY

From August 8, 2022, to January 31, 2024, the Federal Railroad Administration (FRA) sponsored Monterey Technologies, Inc. to design and develop an improved interface between human operators and advanced automation in rail systems. Applying user-centered design (UCD) methodology, the team prototyped and demonstrated a locomotive cab user-interface (UI) concept called the Automation Awareness Assistant (A3). A3 is designed to improve human operator situational awareness of automated rail functionality and provide decision support if a possible automation failure is detected.

A3 supports the human operator cognitive monitoring requirements to maintain awareness of train automation, enabling recognition of anomalies in both system performance and operational situation. A3 supports achieving and maintaining automation awareness, in turn supporting the broad capabilities required to meet railroad enterprise safety and performance goals. A3 is designed for locomotive cabs, but the A3 user interface concept can be applied and extended to other rail, transportation, and defense systems with human-automation interaction.

The Association of American Railroads' Automated Train Operations (ATO) Technical Advisory Group (TAG) is developing an "automated rail taxonomy," including a concept of operations (ConOps) for interoperable aspects of ATO systems for freight rail operations (Hunter & Bryant, 2023). To ensure rail systems safety, this guidance asserts that train automation requires the locomotive crew to cross monitor interactions among automation systems and subsystems. The A3 human machine interface (HMI) concept and UI prototype form an interoperability solution with assured human control. This solution can generate automation and UI requirements to support the ATO TAG ConOps for adding automated functionality into existing and future rail systems. The A3 concept can be scaled to achieve assured human control for all automated functions in any vehicle.

BACKGROUND

A3 seeks to reduce human error related to rail systems design, thereby reducing the likelihood of accidents. Human error causes accidents in all transportation modes. While automation is often intended to reduce the likelihood and limit the consequences of human error, inappropriate integration of automation into human job tasks can have the opposite effect. Accidents and incidents in transportation often arise because of human operator confusion about precisely what complex automated systems are doing.

Compressed cycle times increase automation uncertainty and risk by introducing higher human workloads into the rail operational environment. A major goal of the A3 technical solution is to mitigate risks associated with human-on-the-loop (HOTL) rail system control, for which machine errors and brittle automation could lead to cascading failures. HOTL here refers to management of the automation to drive a train. As rail system automation advances, human interaction requirements should be specified, defining assured human control authority: how the human operator will reassert control and retain decision-making while minimizing critical function activation delays. For HOTL rail systems, developing a locomotive cab display to optimize human-machine function allocation could help assure human control. This would provide sufficient insight into and human control of the system to be able to intervene if the automation malfunctions.

UCD, a human task-centered approach, organizes system information and controls in a human activity-centric manner such that normal workflows are efficient and task products can be easily created. Information is “brought to the task” instead of requiring the end user to collect, gather, and synthesize information from separate sources. Using UCD to display information and assure human control of automated rail systems will involve the trade-off of function allocations between human and systems for completing task steps and accomplishing goals. UCD methodology includes UI constructs that support function allocation decisions to deliver capability as safety cycle time approaches zero. This can include shared system-user task states and awareness of past, current, and planned tasks.

OBJECTIVES

The objective of this project was to apply UCD to develop a locomotive engineer HMI that displays correct and timely information and functionality to manage, adapt to, or override potentially unsafe automated rail equipment behaviors. The HMI design solution will provide necessary situational awareness of rail systems’ states, processes, and operational environment so the locomotive human crew can adapt to unexpected situations. The HMI concept will support the monitoring and control of current-generation and future automated locomotive and rail infrastructure capabilities, features, and functions.

METHODS

UCD is an agile, human task-centered process, conducted as an iterative design-test spiral, using interim results to devise incremental, measurable improvements in both hardware and software. The goal is to identify and address user needs that are not well-supported in the system, leading to a more intuitive UI. As each design cycle increases the prototype fidelity, usability analysis provides design feedback for inclusion in the next product evolution. UCD involves iterative drill-down into job task and sub-task details until the project team determines that sufficient detail is gathered to enable software development. This approach follows a task-centered design technique in which emerging visualizations of rail systems are presented and evaluated at each design step, to be discussed by end-users and designers. This provides a team approach to the visualization of HMI concepts, as opposed to traditional design processes with textual descriptions of requirements. UCD focuses on achieving enterprise capabilities through continuous discovery and the flexibility to experiment with creative ideas that may lead to insight and innovation. As part of the design cycle, these ideas are molded to fit developer resources and software architecture, configuring the ideas into realistic prototypes.

RESULTS

A3 UI constructs were derived from an analysis of locomotive systems, job tasks, and workflows and assembled into a notional UI wireframe (Figure 1) and an initial mockup. Employing UCD methods, the mockup was simplified to a low-fidelity prototype, then to a high-fidelity prototype (Figure 2). The team developed preliminary software to realize the UI prototype in the locomotive cab and successfully tested it at FRA’s Cab Technology Integration Laboratory (CTIL) located at the U.S. Department of Transportation, Volpe National Transportation Systems Center, Cambridge, MA.

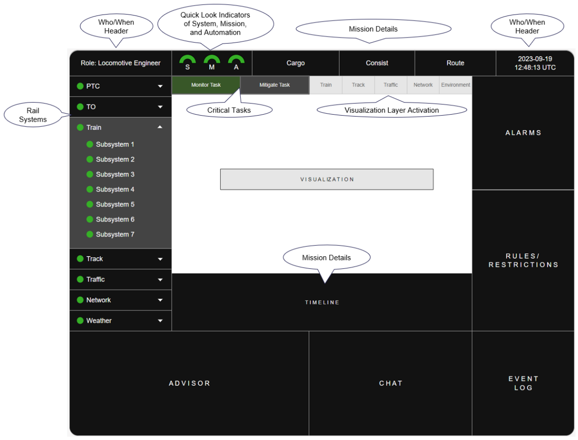

Figure 1. Notional wireframe of A3 UI constructs

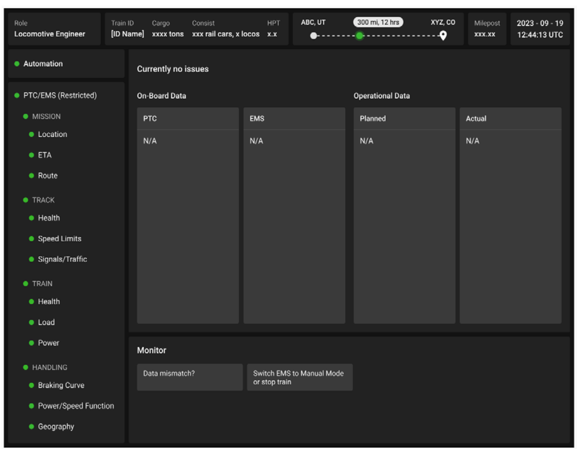

Figure 2. A3 UI high-fidelity prototype

CONCLUSIONS

To make sense of large amounts of rail systems data, the locomotive crew needs HMI assistance to manage surges in workload from unexpected automation behaviors. The A3 decision support application will provide the locomotive engineer with the necessary awareness of the operational environment and rail systems' status to override or adapt train automation in unexpected situations. To improve situational awareness and operations safety, the team built and evaluated an A3 UI prototype, containing UI constructs for critical information and functions to manage train automation. A3 will support gathering information or affordance to progress in detecting and classifying faults occurring under automated control. A3 is a total systems HMI solution: a cab console display that will provide the awareness necessary for the human operator to override or adapt to rail systems in unexpected situations.

FUTURE ACTION

Railroads are accelerating investment in automation technology, telematics, artificial intelligence, and other advanced capabilities for real-time and near real-time operations. An automation awareness application was prototyped and demonstrated for integrating these emerging technologies into railroad operations and infrastructure. The prototype is available for evaluation and further refinement with reasonable expectation that it will measurably improve railroad bottom line performance and achievement of safety goals. This demonstration was in the context of a freight locomotive cab to help visualize and evaluate the A3 prototype, but its architecture and demonstrated principles apply at all levels of railroad infrastructure.

REFERENCES

Hunter, D. C., & Bryant, Q. (2023). Automated Train Operation Interface Requirements Specification Development Summary Report (DOT/FRA/ORD-23/31). Washington DC: Federal Railroad Administration.

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