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RESEARCH RESULTS

FRA OFFICE OF RAILROAD POLICY & DEVELOPMENT

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A Preliminary Design for a Heads-Up Display for Rail Operations

SUMMARY

This research project designed a locomotive Heads-Up Display (HUD), a secondary display that helps the operator locate possible hazards in the surrounding environment while maintaining an awareness of the vehicle's current state. HUDs are widely used in both military and commercial aviation and they are gradually being adopted in general aviation, but much less common in automobiles. A study that examined the usefulness of HUDs for locomotives concluded that they could help engineers avoid accidents and improve their performance.

The prototype HUD design is based on a set of information requirements created by Voelbel [2] for an in-cab situation awareness display that is used in passenger rail operations. These requirements use a hybrid Cognitive Task Analysis of en route operations as a basis for step-by-step descriptions of an engineer's critical tasks and decision processes. Finally, the requirements traced the design of the individual display elements back to each task.

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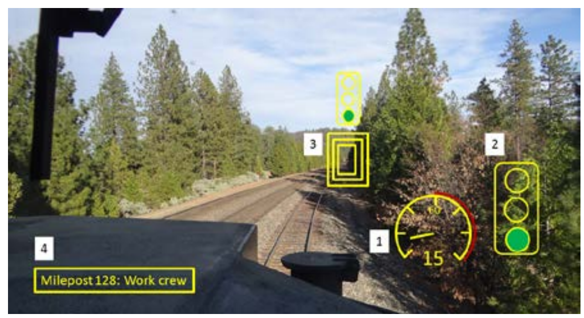

Figure 1 –The prototype HUD design. The symbology includes (1) a speed display, (2) in-cab signals, (3) a moving dynamic element highlighting external objects of interest, and (4) a message box for upcoming events.

The resulting design displays information about the train's state and external information objects (such as signals) on a wide-field display transmitted on the locomotive's front windshield. A head tracking system allows for proper registration.

The proposed interface (Figure 1) has four primary elements. The speedometer (#1) has digital and simulated analog indicators that indicate upcoming speed restrictions. There is an in-cab signal display (#2), an element (#3) which locates upcoming signals, and a message box (#4) for relevant information to the engineer.

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For this project, the team assembled and tested a prototype HUD system, which included a simple train simulator, a half-silvered mirror, a small projector, and a Microsoft Kinect tracking system. The laboratory test showed that the Kinect could be used as a tracking device in the limited volume of a locomotive cab.

In a future study, FRA should test a higher fidelity prototype in a realistic locomotive cab simulator with experiments that include participants. If that prototype improves situation awareness and task performance, further field testing may be warranted.

BACKGROUND

In transportation, the Heads-Up Display (HUD) is used to improve operator situation awareness while he or she operates the vehicle. HUD overlays convey critical operating information for controlling a vehicle (e.g., speed, location, vehicle state, etc.) in the external environment, assuming that the operator can also pay attention to the environment ahead.

HUDs are widely used in military and commercial aviation, and they are gradually being adopted in general aviation. Though HUDs are optional for many cars, they are much less common in automobiles, and display less information than HUDs from other modes of transportation.

In a user study of prototype locomotive HUDs by Davies et al. [1], non-engineer subjects thought that HUDs reduced their workload compared with traditional head-down displays, although their performance in a simplistic speed maintenance task was no different. The study also analyzed 200 representative accidents and it concluded that 44% of these accidents would have derived some benefit from an operational HUD.

OBJECTIVES

The project's goal was to design a locomotive HUD that would supplement the cab's primary driving display by providing additional situational awareness during en route operations. It should use the wide field-of-view available with the front windscreen and accommodate the range of head motion that is expected during operations. Finally, the HUD should not distract the engineer while he or she is controlling the locomotive.

METHODS

The project made two design assumptions:

- A full color display with a wide field of view would be available commercially. Two current technologies are possible: (1) a scanned laser projection-based HUD that could be installed on the ceiling or control stand or (2) a transparent organic LED panel mounted on the forward windshield.
- A head or body tracking system is available. The Microsoft Kinect is an example of a low-cost commercial system that could be integrated into a locomotive cab to track the engineer's head or body motions in real-time. A tracking system would need to be placed in the cab where occlusions of the engineer's head or body would be minimized.

RESULTS

The proposed HUD (Figure 1) is a secondary display that would support engineers as they maintain or change speeds as civil speed limits, track warrants or weather conditions dictate:

The HUD replicates the basic design of the in-cab speedometer with its own digital and simulated analog speed displays. The red arc surrounding the analog display indicates the current speed limit. This allows the engineer to determine if their speed is within appropriate limits. Davies et al. [1] also found that most engineers had a slight preference for the analog speed dial. The large signal symbol on the bottom right represents the signal aspect for the current track segment and it provides an external cue to memory.

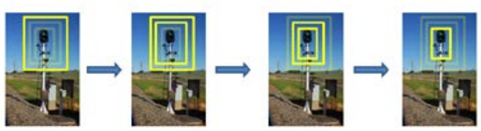

Figure 2 – A dynamic graphical overlay uses implied motion of the surrounding box to direct attention to the target in the center.

A dynamic graphical overlay (Figure 2) will display the locations of important items such as an upcoming signal or the location of a work crew. If the indicated item is a signal, then its aspect could also be displayed on the screen, as shown in Figure 1. The overlay will have to change in size as the item looms closer and the engineer's head position would be tracked to maintain the correct registration. The overlay also uses implied visual object motion of the yellow squares surrounding the signal (Figure 2) to capture and direct the attention to the central target.

Finally, a message box appears in the lower visual field of the HUD that displays information such as upcoming track warrants, reminders of other operational conditions, or even messages directly from the dispatcher.

A simple prototype HUD and a Kinect tracker were tested in a simple lab environment (Figure 3). A simplified train simulator automatically drove the "train" while HUD symbology was projected onto a half-silvered mirror in front of the computer display. The lab test showed that the Kinect was capable of tracking the operator's head in real-time and in a cubic volume similar to that of a typical locomotive cab.

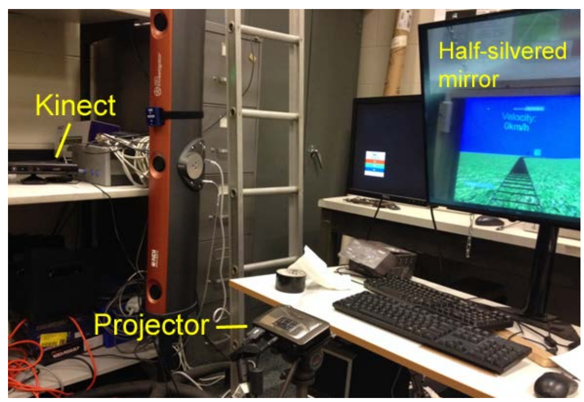

Figure 3 – The laboratory HUD prototype. The Kinect tracks the head position from the side while the HUD symbology is projected onto the half-silvered mirror in front of the computer display.

CONCLUSIONS

The research project has created a prototype design for a locomotive HUD that provides information supporting the en route operations of the locomotive engineer. The design evolved from a Hierarchical Cognitive Task Analysis (hCTA) and a principled analysis of task information requirements. The results of a laboratory test with a simplified prototype suggest that the Kinect tracker could work in the locomotive cab.

FUTURE ACTION

The prototype HUD should be tested in a high fidelity locomotive simulator such as the FRA's Cab Technology Integration Laboratory, where the components can be installed in a realistic manner and the efficacy of the system can be tested with human-in-the-loop tests. Tests should be conducted to determine if the display contributes positively to engineer situation awareness, workload, and driving performance under a variety of operating conditions. If efficacy can be demonstrated in a controlled setting, then field testing would be the next recommended step.

REFERENCES

1. Davies, K. et al. (2007) *Feasibility of Head-Up Displays in Driving Cabs*, Final report to the Rail Safety & Standards Board, #T513.
2. Voelbel, K. (2014) *A Systems Approach for Developing, Designing, And Transitioning Moving Map Technology In U.S. Rail Applications*, Master's Thesis, Dept. of Aeronautics & Astronautics, Massachusetts Institute of Technology, Cambridge, MA.

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KEYWORDS

Heads-Up Display, situation awareness, engineer, locomotive, hybrid Cognitive Task Analysis, information requirements, head/body tracking