Reliable Human Control in Self-Driving Truck Systems

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Much attention is being paid to the development of self-driving cars and trucks. However, "self-driving" now usually means a high degree of autonomy with human backup. This backup can take the form of either a co-located human assistant or a controller located at a distance, possibly at a central control or distribution terminal. Figure 1 provides a simple illustration of such a system that consist of controllers, interfacing hardware and software, and self-driving trucks. In some cases the usage scenario involves the controller getting the vehicle to a certain location, such as a highway entrance, at which point supervised autonomy takes over. Higginbotham[1] provides a brief but informative description of current concepts and developments. Higginbotham envisions that the remote human controllers will take control of the vehicle when the complexity of the situation exceeds the capabilities of the vehicle programming to deal with it. Tests in Sweden suggest that a human must take control roughly 10% of the time.

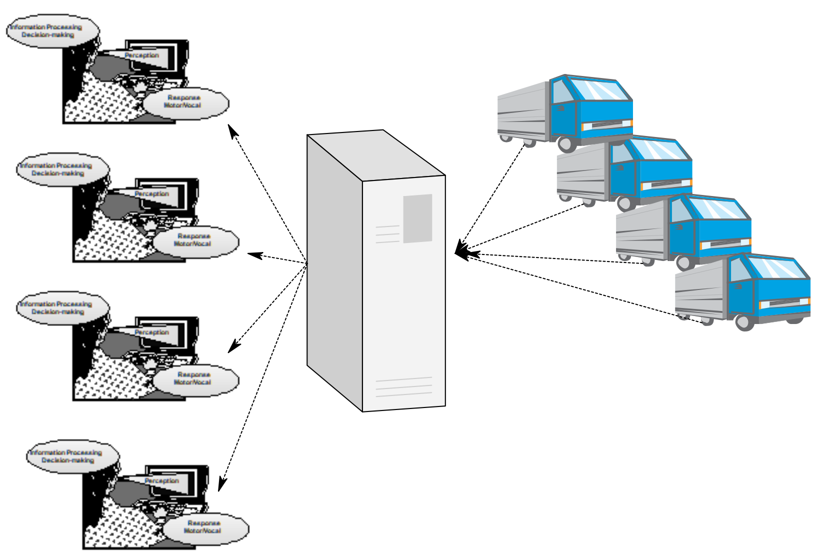

Figure1. Conceptual Self-Driving Truck System

One of the major issues confronting designers of such a self-driving truck system with a central control facility is the design and staffing of the facility. As shown in Figure 1, the function of a controller would be monitoring the performance of one or more trucks and reacting to those situations that might require controller intervention. Figure 2 illustrates what might be the typical information flow.

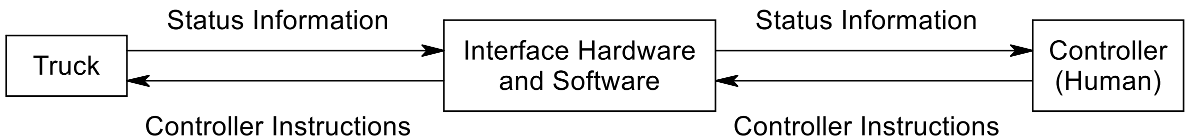

Figure 2. Typical Information Flow in A Self-Driving Truck System

At this point, attention focuses on the controller and what information he or she receives and what he or she does with it. Of course, for the system to be successful, it must be reliable. Design for reliability then becomes an important facet of the design operation.

For reliability engineers, the cognitive model is the most convenient model to use for evaluating the reliability of the human. Figure 3 shows the cognitive model extended to include environmental factors.

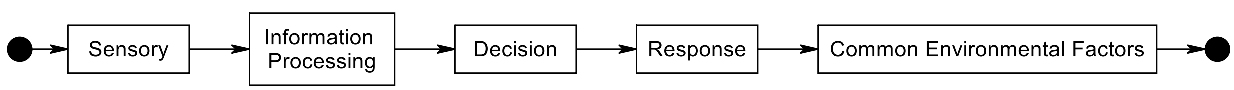

Figure 3. The Extended Cognitive Human Model

This form of the cognitive model is convenient because it is intuitive, generic data can be found for it, and it "plugs" nicely into reliability block diagrams. It allows the designer to address presenting a controller or team of controllers with the mental load associated with the inputs from one or more trucks.

It is worthwhile to explain the above cognitive model in a little detail. As one might expect, each block has underlying structure. For example, the sensory block has underlying sensory modes: visual, auditory, tactile, and even olfactory. For purposes of this paper, the visual and auditory modes are the most useful. Each sensory mode has its own underlying factors. For example the factors affecting the visual mode are brightness, visual angle, and contrast. Factors affecting the auditory mode depend on whether the signal is verbal or non-verbal, both of which have their own sets of factors. Information processing and decision have mental load and skill factors.

Factors that affect a response depend on whether the nature of the response involves speech or some manual activity. Environmental factors can include time-on-station, temperature and humidity, atmospheric pressure and oxygen, and vibration. In an office-type controller station, only a few of these may be significant. There are reliability models for each of the blocks in Figure 3. However, those models are not discussed in this paper for reasons of brevity but can be found in the text and appendix to LaSala.[2]

The reader should note that it is desirable to minimize the number of controllers to get a cost benefit from eliminating truck drivers. To illustrate how complex the situation could get, consider that a single truck could send N status elements back to a controller. Were the controller assigned M trucks to monitor, then he or she would be presented with N x M status elements to process with each status element having an "OK" or remedial action response. Higginbotham notes that some companies want to arrive at a truck-to-controller ratio of 10:1.

Some information that a controller might want to know about each truck could be location, speed, estimated time of arrival, onboard fuel, and engine temperature – indeed much of the information that an individual car driver monitors when he or she drives the car. Adding situational awareness and traffic controls would greatly complicate matters. One could in effect present a controller with the equivalent of an auto instrument cluster, view screens, and a GPS navigator for each truck.   Figures 4 and 5 provide illustrative examples pf control panel configurations.

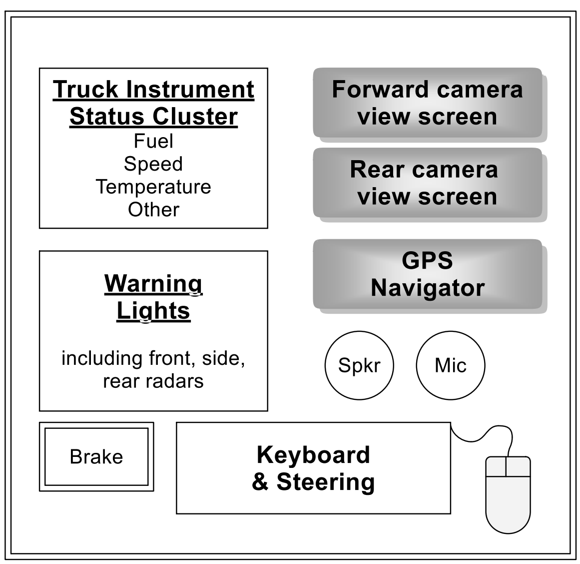

Figure 4. Possible Single Truck Control Panel

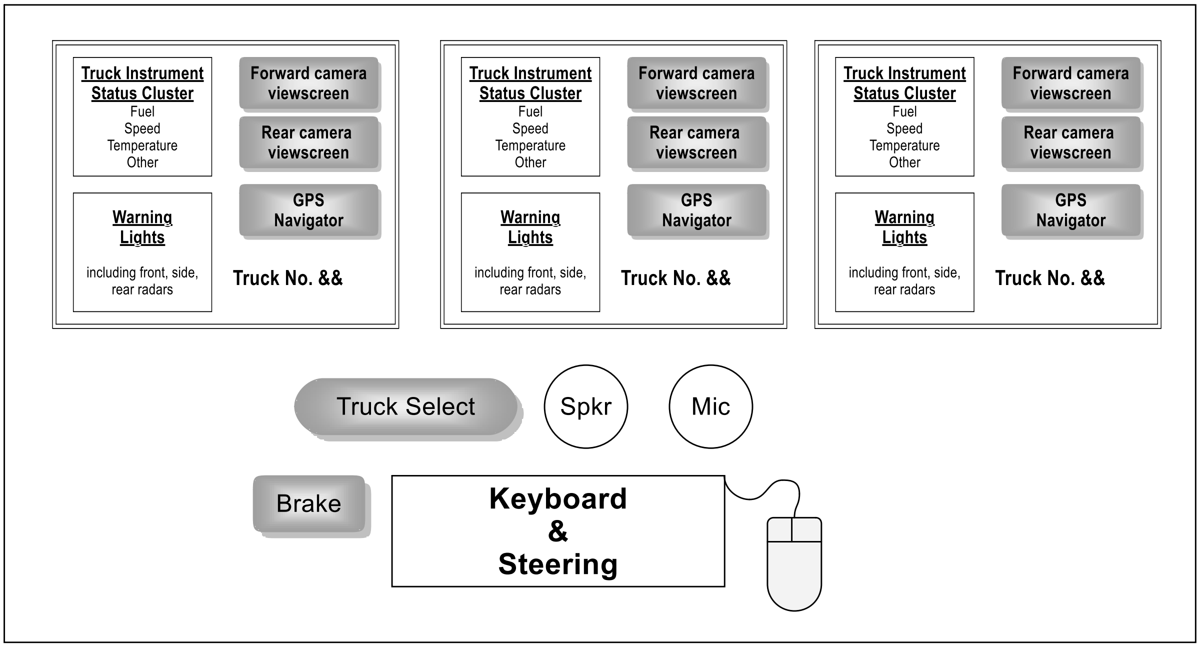

Figure 5. Possible Multi-Truck Control Panel

In designing the truck control panels, one could take advantage of much of the human factors work that had been done already in configuring the truck instrument panel. Note that Figure 5, a three-truck control panel, illustrates how complex the sensory input situation could get. Imagine a ten-truck panel. Also note that the panels require 100% monitoring of all the controlled, active trucks, a practical requirement. Having an active truck that is not being monitored real-time invites hazardous situations.

At least some of this complexity could be dealt with by using the sensory part of the cognitive model to design the inputs to the controller so that they have characteristics that allow the controller to perform the monitoring function in a reliable manner. However, even with good sensory input design, the designer is faced with confronting the controller with a number of inputs which he or she must evaluate and make an “OK” or remedial action decision. When examining the information processing and decision parts of the cognitive model, one develops some serious concern about going to the 10:1 truck-to-controller ratio described above.

An “OK” decision probably would result in no action on the part of the controller. However, if a remedial action is required, then the response part of the cognitive model comes into action. A tool that assists greatly in the design of remedial actions, should they be needed, is the Operational Sequence Diagram. In simple terms, the Operational Sequence Diagram is a flow diagram that identifies actions to be performed and who or what performs them. For more information on this tool, see https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4503264. This article focuses on military applications of the tool, but the tool can be used in almost any system or process application or where humans and machines interact. To illustrate how complicated the situation can get, see Figure 6.

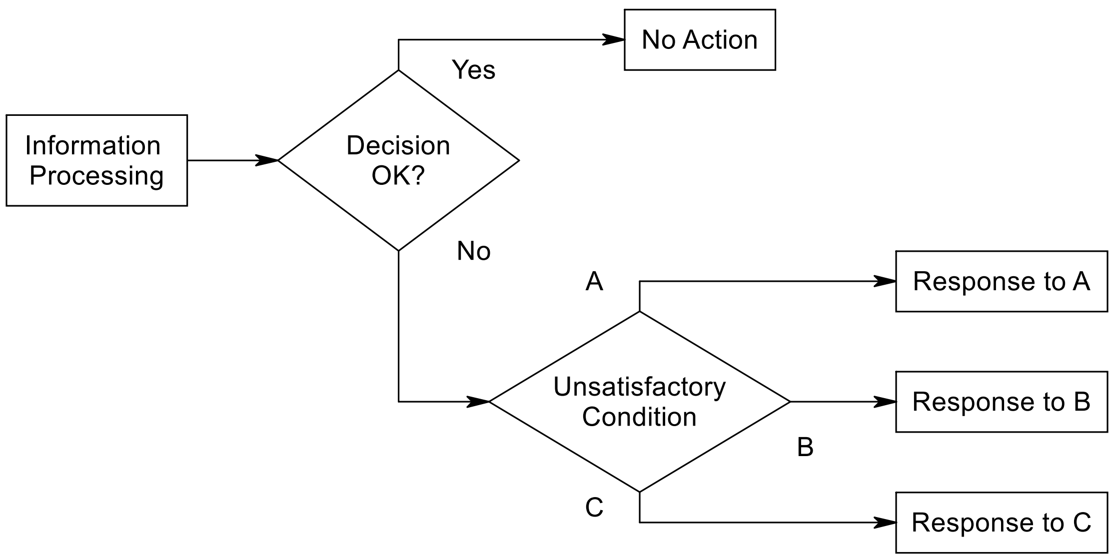

Figure 6. Response Potential Complexity

Multiply Figure 6 several times when several trucks are being monitored by a single controller and see how quickly a controller can get overwhelmed. Incidentally, Figure 6 is a very simple operational sequence diagram in a horizontal format. For reliable controller performance, each response in Figure 6 should be designed according to the vocal or manual response models within the cognitive model.

Deploying system of self-driving trucks and controllers might seem economically desirable. However, the receipt of the economic benefit is highly dependent on the reliability of both the trucks and the controllers. As discussed above, the extended cognitive model provides a means for designing and analyzing the reliability of the controllers in the system. Even this basic discussion shows how rapidly complexity could appear and hamper reliable controller performance. Inclusion of controllers provides a means for offsetting self-driving truck reliability shortcomings but only if sufficient attention is given to allowing the controllers to perform reliably.

References;

1. Higgibotham, S.; “Self-Driving Trucks Will Always Need People;” IEEE Spectrum, March 2019.

2. LaSala, K.P., **A Practical Guide to Developing Reliable Human-Machine Systems 2nd Edition**, April 8, 2016, Quanterion Solutions Inc., Utica , NY, qinfo@quanterion.com

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