An Investigation of Situational Awareness in Real World Control of Robotic Assets with Communication Latency

Jason Luck, Patricia McDermott, & Laurel Allender

Unmanned vehicles (UVs) are already being used in a variety of applications, including the military battlefield. The applications will only increase as robotic technology, such as autonomy, continues to advance. As the technology advances, the number of applications will increase, as will the demands on the associated network. Limited bandwidth, extended transmission ranges, and high network traffic can all result in communication latency. A previous publication summarized the effects on operator performance from two experiments investigating the effects of communication latency when controlling a robot (Luck, 2006). This paper will detail the effects on operator Situational Awareness (SA) from the same two experiments.

The experimental task was a simulated MOUT reconnaissance in which participants drove an UV through four courses. Participants were given a map depicting the route and the location of reconnaissance "spins". At three pre-determined points the participants were instructed to stop, the map was hidden, and participants attempted to mark the UV's location and to retrace the route of the UV as accurately as possible, including deviations from the intended route. Participants also provided subjective ratings of SA after each mission and filled out a subjective questionnaire at the conclusion of the experiment.

One current thrust in robotics aims to increase the Level Of Automation (LOA) of robots. The rationale is that, reducing the amount of control required of the operator will extend the utility of the robot and simultaneously reduce operator workload. The results from this study indicate that increasing the LOA will also decrease the impact of latency duration on operator SA. The number of stoppages to gain SA and the number of SA marking errors (i.e., incorrectly marking the UV location, rooms entered, and location of driving errors) were all significantly lower under the higher compared to the lower LOAs tested.

The duration of latency also impacted operator SA. No significant effects on the ability to guide the robot along the proper route were found. However, significantly more marking errors were made with short delays than long delays. This counter-intuitive result most likely indicates that the higher level of concentration required with longer delays aids operators in maintaining SA.

Communication latency can also arise in different forms. Latency duration may be constant, as with hardware or path induced delays (ex: satellite-based communication), or may fluctuate due to varying traffic or routing conditions (ex: typical internet based communication). Significant effects on control performance were found for varying latency (Luck, 2006), however very few effects are seen for SA. While subjective ratings indicate more time was spent on maintaining SA under variable latency, there was only one measured effect on SA: Participants made more incorrect markings of drive error locations in variable latency. Accordingly varying latency has little effect on overall operator SA, but may require more effort and have a negative effect on an operators ability to remember small events while en route to a known goal.

Latency conditions may also differ between commands sent from the user to the robot (U2R) and feedback sent from the robot to the user (R2U). Perceived difficulty in maintaining SA was much larger when feedback was delayed then when control signals were delayed. Participants also made more navigation mistakes in the R2U condition, however no differences in marking mistakes were found.

Before making decisions about both the use and design of UV interfaces and systems, it is important to understand the impact of all of these factors on an operator's ability to maintain awareness of the situation.

Luck, J.P., McDermott, P.L., Allender, L., and Russell, D.C. "An Investigation of Real World Control of Robotic Assets under Communication Latency". *Proceedings 2006 Human Robot Interaction Conference* (Salt Lake City, UT).