Chapter 11 – SWE-1: TASK SWITCHING FOR MULTI-UGV CONTROL

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11.1 DATES

1 – 30 November 2006.

11.2 LOCATION

FOI, Linköping, Sweden.

11.3 SCENARIO/TASKS

The operator's task was to navigate one, two, or three partly autonomous UGVs to pre-designated inspection points in a simulated urban environment. The UGVs were mainly manually controlled and had only a limited autonomous function in that they could maintain the current heading and velocity while unattended to by the operator. Figure 11-1 shows an example of the operator's control station where the position of the UGVs and the shape and colour coded inspection points are indicated on the map in the upper right corner. The colour coded 3D-objects representing the inspection points were shown when within view of the UGV's camera. The task was to navigate each UGV to the inspection point with the corresponding colour. A new inspection point was shown when the UGV reached the indicated inspection point. The operators alternated control sequentially between the UGVs to manually change the heading and velocity and engage the autonomous function to maintain the last control action while the operator attended to the other UGVs. Performance was measured by the number of inspection points that were reached within a 10-minute period.

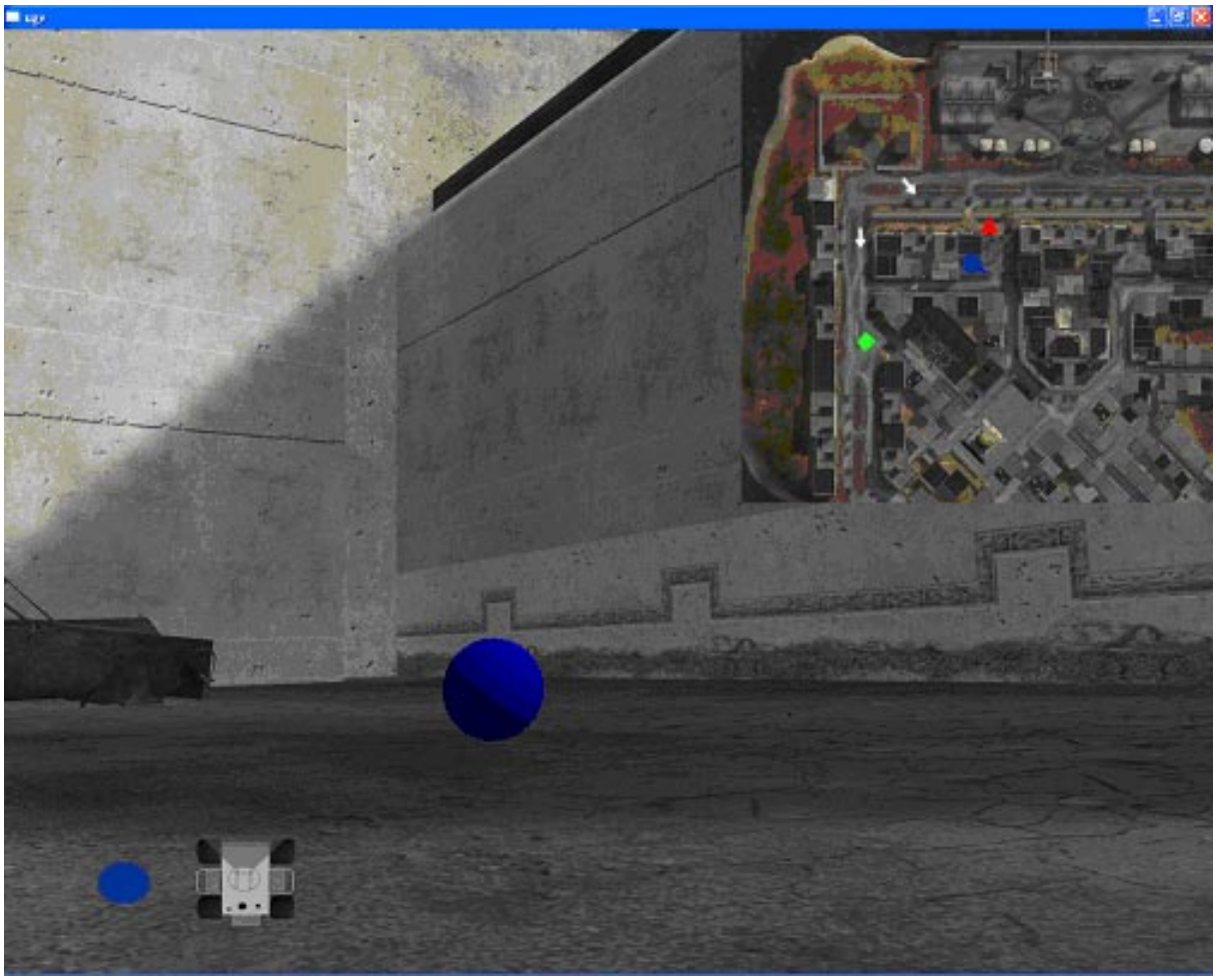

Figure 11-1: Example of the Operator's Control Station. The task was to navigate the blue UGV to the blue inspection point, the red UGV to red inspection point, and the green UGV to the green inspection as indicated on the map in the upper right corner.

11.4 TECHNOLOGIES EXPLORED

Only a limited autonomous function was used that enabled the UGVs to maintain the current heading and velocity.

11.5 HUMAN FACTORS ISSUES EXPLORED

One reason why it is so difficult to improve the operator to vehicle ratio and enable one or a few operators to control several robots is that the attentional requirements are so high for controlling even one robot that any additional robots overload the operator or operators and hampers the performance. The purpose of the study was to investigate these attentional requirements for a typical ground robot when performing a basic navigation task in a military setting, and to what extent a limited autonomous function was useful in facilitating control of several robots.

An exploratory performance measure called Instantaneous Performance was also used to measure performance continuously during a trial rather than only at the end of a trial by the number of inspection points that were reached [2]. The Instantaneous Performance is computed by normalizing the UGVs' current velocity and heading relative the shortest path towards the next inspection point and the maximum velocity. This results in measure where 1 means that the UGV is moving along the shortest path towards the inspection point at maximum velocity and -1 that the UGV moving in the opposite direction at maximum velocity. The benefit of Instantaneous Performance is that is allows an assessment of operators' control strategies. Please see Lif et al. [1] for more information about the study.

11.6 UNMANNED SYSTEMS USED

One, two, or three simulated UGVs.

11.7 SUMMARY OF ANY NATO COMMUNICATIONS/COLLABORATIONS/ INTERACTIONS

The results of the study have been presented at Task Group meetings, as well as at a conference session arranged by a Task Group member [1]. The following table summarizes the extent of the NATO collaboration.

	Planning/Design	***Execution***	***Analysis***
Communication			*X*
Coordination			
Collaboration			

11.8 SUMMARY OF TD RESULTS

The results show that the operators reach 30% more inspection points when using two UGVs compared to when only using one UGV. Adding a third UGV did not provide any additional improvement in performance, however. Due to mental overload when using more than one UGV, the UGVs stand still 30% of the time when using two UGVs and 50% of the time when using three UGVs. Furthermore, the duration of the stand stills last between 5 seconds and 1 minute, which is undesirable in a potentially hostile environment. The mental overload was also evident in the operators' control strategies where some operators aimed the UGVs towards walls to know where to find the UGV when they regained control, or even completely abandoning UGVs. Overall, the operators control the UGVs manually 90% of the time although they use the autonomous function more when controlling more UGVs. The correlation between Instantaneous Performance and the number of reached inspection points was .95, which shows that it is valid performance measure. The operators' control strategies were not explored further, however.

11.9 LESSONS LEARNED

Typical issues in control of multi-robot systems can be investigated in a laboratory environment without experienced operators.

11.10 STUDY CONSTRAINTS/LIMITATIONS

The operators did not have any previous experience in controlling UGVs and were thus rather naïve. The lack of experience was evident in that some subjects had difficulty operating the UGVs in a safe way, particularly when controlling more than one UGV.

11.11 CONCLUSIONS

The results show that the limited autonomous function was insufficient to significantly improve the operator to vehicle ratio. The operators are saturated even when only controlling two UGVs in a basic navigation task. More advanced partly autonomous functions or control station interfaces that reduce the attentional requirements are therefore necessary to improve the operator to vehicle ratio.

11.12 FUTURE RESEARCH NEEDS AND PLANS IN THIS AREA

Although research programs, such as the DARPA Grand Challenge, show that ground robots can navigate autonomously in an uncertain environment, such technologies are typically not available for UGVs that are used for tactical reconnaissance. An alternative approach is therefore to develop better interfaces that reduce the attentional requirements and improve the operators' strategies for sequentially alternating the control between robots. One approach to develop such interfaces is to derive a prioritization order for relevant goal attainment states from either simulated or empirical data [3]. This prioritization order can then be used to indicate which UGV that is in most need of service. There are currently no plans for future research, however.

11.13 ACKNOWLEDGEMENTS

The study was performed by Patrik Lif and Johan Hedström.

11.14 REFERENCES

[1] Lif, P., Hedström. J. and Svenmarck, P. (2007). Operating Multiple Semi-Autonomous UGVs: Navigation, Strategies, and Instantaneous Performance. In *Proceedings of the 7th International Conference on Engineering Psychology and Cognitive Ergonomics*, Beijing, 2007, 22-27 July, CD-Rom.

[2] Crandall, J.W., Goodrich, M.A., Olsen, D.R. and Nielsen, C.W. (2007). Validating Human-Robot Interaction Schemes in Multi-Tasking Environments. *IEEE Transactions on Systems Man, and Cybernetics*, Part A, 4, 438-445.

[3] Crandall, J.W. and Cummings, W.L. (2008). *A Predictive Model for Human-Unmanned Vehicle Systems*. Report No. HAL2008-5. MIT, Cambridge, MA.