Interaction with Autonomous Off-Highway Vehicles

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ABSTRACT

Vehicles of all kinds are becoming increasingly autonomous. This paper looks to expand the discussion to not only the automotive vehicle domain but also to a vehicle category that may require a richer interaction than transportation vehicles, off-highway vehicles. A few cases and scenarios will be presented to examine the transition of increasingly more autonomous vehicles and the future challenges it might hold for interaction design.

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KEYWORDS

Autonomous; off-highway; vehicles; situation awareness

Figure 1 Picture from a simulation where transparent symbols are used to make the operator more aware of the surroundings using transparent symbols.

INTRODUCTION

Vehicles that are used for working tasks, often refered to as off-highway vehicles, have become increasingly autonomous as incremental advancements have been integrated, albeit perhaps more silently than automobiles. It began with the mechanisation of human labour and has since grown into more automated processes. Today's more advanced vehicles can almost be seen as mobile factories. A few examples of this transition into higher autonomy include:

- Self-driving tractors – Tractors and combine harvesters working on fields can already move autonomously on the field and maintain their speed and course. Giving the operator more time to focus on the production process [9].
- Autonomous hauling – Autonomous dump trucks are operating in mining environments to transport material from the mine ores to the processing plant, without any operator onboard. The operators are only controlling the vehicles when needed, using remote control [6].
- Autonomous workflow supported by autonomous vehicles – Recently a research project together with Volvo and Skanska, ran a field test with electrified and autonomous work processes for material haulage [14]. One interesting aspect of this test is the use of many smaller vehicles instead of a few large vehicles. Another interesting aspect reported is the decrease of CO_2 emissions by 98% and the reduction of operator costs by 40% [3].

OPERATPORS' SITUATIONAL AWARENESS WHILE BEING OCCUPIED BY OTHER ACTIVITIES

One scenario, related to interaction in vehicles that are increasingly autonomous, is in the extension of the current working practice. The human might for the foreseeable future still travel with the vehicle, but unlike today, the human has moved from being the one that drives the vehicle into a role of monitoring its progress and only controlling specific tasks. The rest of the time the operator is performing parallel tasks, such as controlling other machines, doing work reporting, calling, or performing other office related work. It can also be that the operator is sitting at a remote location, monitoring and controlling a fleet of machines. A challenge here, as for road vehicles, is to maintain situation awareness, a balanced workload, and trust in the system [7]. Endsley, categorizes situation awareness into three categories, 1) perception of the elements in the environment, 2) comprehension of the current situation, and 3) projection of the future situation [2]. From our field observations we see that operators are mainly focused on their current tasks of action when doing specific work, thus, there is a constant risk of them losing awareness on what is happening around the machine [12].

As the operator becomes more occupied with tasks unrelated to the active control of the vehicle, there is also an increased risk of loosing awareness on the vehicle's surroundings, due to the operator's divided focus.

One of many opportunities to create an interaction that supports operators' situation awareness, including assisting them to monitor the vehicle's surrounding, is the use of augmented reality. Evaluations that we have made in simulated environments show that transparent interaction techniques, where information is shown in the line of sight (as seen in figure 1) has a potential for increased operators' performance and is preferred by the users [12]. It would be of interest to further explore these opportunities for information exchange, to help the user to be more aware of how the machine interprets its surroundings, to quickly gain an understanding of the activities that the machine is currently performing, and to stay up to date on what the machine has in its work plan. This can, for example, be a visualization of the vehicles understanding of the world and its planned actions or to share information from other vehicles or information sources. Two sketches of such visualization can be seen in Figure 2, where the upper image show coming actions for a vehicle using a movie script metaphor and the lower image show an augmented view for a crane on a construction site.

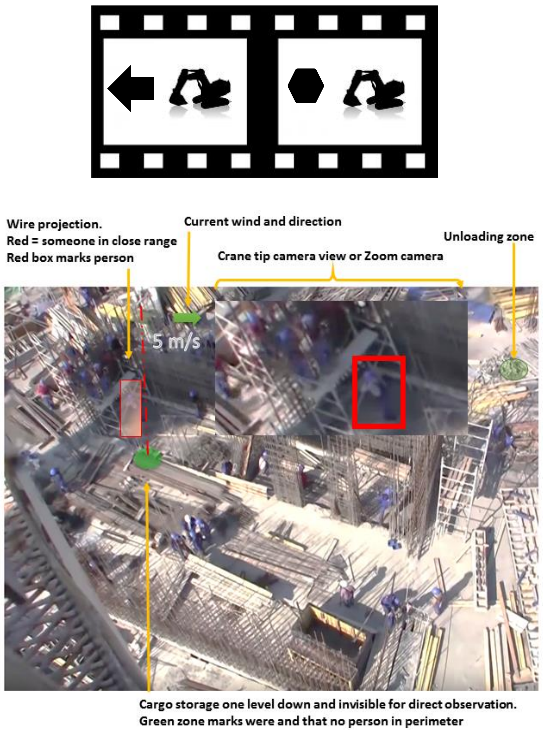

Figure 2 Sketches on different levels of information to inform users about vehicle intentions, to present warnings, or to present more complex work-site information.

INTERACTING AND BUILDING TRUST WITH INCREASINGLY AUTONOMOUS VEHICLES

The future holds even higher level of automation, where vehicles will not only move autonomously but also handle whole tasks by themselves. For example, a tractor can load material on a truck by driving to a pile, picking up the material, and then driving to the truck and unloading [5]. Another example researched is autonomous systems that operate on farms to distribute fertilizer and pesticides based on analysis of the needs of each individual plant [10].

However, despite the huge benefits of using automated machinery, Pedersen et al. conclude that complex tasks are nearly impossible to automate due to the required accuracy in specifying the given task [8]. The human is still more versatile and can adapt to changing conditions, while machines must still be programmed specifically for each task [4]. Thus, it is of interest to investigate the interplay between a human and vehicle systems and how they can fulfill tasks in collaboration by utilizing each other's strengths.

The future ground worker might work together with autonomous vehicles, that transport material, dig, lift, harvest, demolish, etc. working in unison with the human labor in the same way as current machine operators do today, they form a "team play" between human and machine [1]. The vehicle must then also be able to understand a dynamic working process and be able to interpret the situation and adapt to perform the correct action at the correct time. This interaction could benefit from a richer duplex interaction between the vehicle and the ground worker [13]. For example, using gestures to signal movement, distances, etc. This is an area that is currently mostly underused [11].


Figure 3 Picture from the cabin of the excavator, showing the ground worker instructing where to pour gravel and how much.

A human worker can, for example, tell an operator to approach via gestures (see figure 3 of an example how a worker interacts with an excavator operator to adjust the level of gravel poured from the bucket), and the operator can confirm by subtle body language, such as nodding, accelerating the engine, etc. A worker and an operator of a mobile crane can, for example, communicate trust in awareness by showing eye contact. The worker needs to receive similar information when interacting with an autonomous vehicle, to build trust between the ground personnel and the autonomous vehicle. Both trust that the machine has understood the task to perform and trust in that the machine is aware of the worker and will not cause any harm.

SUMMARY

Like automobiles, off-highway vehicles are also turning increasingly autonomous, both in terms of the navigation and the production process. This might change the role of the operator in the vehicle, to become a supervisor of the production process, or to monitor and control a fleet of machines. It might mean that the operator is no longer needed in the vehicle, the vehicle will instead operate autonomously and interact with the worker on the ground or at a remote location. Regardless, this future will need new interaction designs, both in terms of presenting the vehicle status and intention to the user, as well as new ways of interacting with the vehicle, to give it instructions on what to do in a given situation.

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REFERENCES

1. Sidney W. A. Dekker and David D. Woods. 2002. MABA-MABA or Abracadabra? Progress on Human–Automation Co-ordination. *Cognition, Technology & Work* 4: 240–244.
2. Mica R. Endsley. 1995. Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 37, 1: 32–64.
3. Dan Gilkes. 2018. https://www.sae.org/news/2018/11/volvo-skanska-concept-electric-site. *SAE*. Retrieved January 18, 2019 from https://www.sae.org/news/2018/11/volvo-skanska-concept-electric-site.
4. David Greenfield. 2015. Inside the Human-Robot Collaboration Trend. Retrieved August 8, 2018 from https://www.automationworld.com/inside-human-robot-collaboration-trend.
5. Blom Jonatan. 2013. Autonomous Hauler Loading. .
6. Joshua A. Marshall, Adrian Bonchis, Eduardo Nebot, and Steven Scheding. 2016. Robotics in Mining. *Springer Handbook of Robotics*: 1549–1576.

7. Raja Parasuraman, Thomas B. Sheridan, and Christopher D. Wickens. 2008. Situation Awareness, Mental Workload, and Trust in Automation: Viable, Empirically Supported Cognitive Engineering Constructs. *Journal of Cognitive Engineering and Decision Making* 2, 2: 140–160.

8. S. M. Pedersen, S. Fountas, H. Have, and B. S. Blackmore. 2006. Agricultural robots - System analysis and economic feasibility. *Precision Agriculture* 7, 4: 295–308.

9. Julian Sanchez and Jerry R. Duncan. 2009. Operator-Automation Interaction in Agricultural Vehicles. *Ergonomics in Design: The Quarterly of Human Factors Applications* 17, 1: 14–19.

10. D. C. Slaughter, D. K. Giles, and D. Downey. 2008. Autonomous robotic weed control systems: A review. *Computers and Electronics in Agriculture* 61, 1: 63–78.

11. Valeria Villani, Fabio Pini, Francesco Leali, and Cristian Secchi. 2018. Survey on human-robot collaboration in industrial settings: Safety, intuitive interfaces and applications. *Mechatronics* June 2017: 1–19.

12. Markus Wallmyr. 2017. Seeing through the eyes of off-highway vehicle operators. *(accepted at) The 16th IFIP TC.13 International Conference on Human-Computer Interaction, INTERACT '17*, Springer LNCS Series, 21.

13. Markus Wallmyr. 2017. Reflections on augmented reality for Heavy machinery- practical usage and challenges. *ARV 2017: Workshop on Augmented Reality for Intelligent Vehicles, Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications Adjunct*, ACM.

14. 2017. Volvo CE unveils the next generation of its electric load carrier concept. Retrieved August 7, 2018 from https://www.volvoce.com/united-states/en-us/about-us/news/2017/volvo-ce-unveils-the-next-generation-of-its-electric-load-carrier-concept/.