Exploring the Human Factors Challenges of Automated Mining Equipment

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Abstract
Over the past few years there has been an upsurge of interest in automated mining equipment, ranging from in-vehicle assistance systems (such as collision detection) through to visions of a fully automated and ‘people-less’ mine of the future. This project is aimed at understanding how new technologies can be developed in ways that take into account the human factors issues related to remote controlled/ automated mining equipment. In particular, this ongoing research is analysing the skills and cognitive capabilities that will be required to operate or maintain remote controlled equipment, where the focus is upon developing optimal interface designs to address performance gaps, rather than purely relying on operator training. Initially, the work includes conducting literature reviews, compiling an “active” database of existing and emerging technologies, and interviewing technology developers, regulators, managers and end-users. The interviews are ongoing at the time of writing and are still to be completed and fully analysed. Tentative analysis of the results of this work show several themes emerging. The work to date will be presented in the poster.

Keywords:
Minerals Industry, Automation, Equipment, Skills, Mining

1. Introduction

1.1 The increasing use of automation
Similar to other domains, the minerals industry is being slowly transformed by the increasing use of automation technologies. Automation is broadly defined as the intelligent management of a system using appropriate technology so that its operation can occur without human involvement (Minerals Industry Skills Centre, 2010). Currently, most automation effort is concentrated on providing semi autonomous operation or assistance technologies, such as, collision avoidance systems for mobile mining equipment (Cunningham, 2010). Major equipment manufacturers are already trialling technologies that stop their equipment self-colliding, and truck manufacturers are experimenting with driver assist technologies to better position trucks for loading. Blast- hole drill manufacturers are developing automated blast-hole drills, while other suppliers are working to provide technologies that improve situational awareness in the mine environment (Dyson, 2010).

As technology advances, there will most likely be an increasing focus on automation at the mine site level and already, at their “Mine of the Future” in the Pilbara region of Western Australia, Rio Tinto operates a fleet of autonomous haul-trucks, blast holes drills, and driverless trains to transport ore 300km from mine to port facilities (Cribb, 2009). BHP
Billiton have a similar program for large scale automation at the Olympic Dam site in South Australia. As the reliability of autonomic equipment is enhanced, there will be a gradual shift of focus to automation of unit operations as highlighted by the RioTinto mining operation where mine control is gradually being transferred to an operating centre 1300km away in Perth. The integration of multiple pieces of equipment will lead to fully autonomous operation cycles, such as, dig/blast, load, haul, dump and ore process.

Both manufacturers and mining companies are looking towards autonomous mining equipment and automated mine sites, however, the problem remains of how to make all the pieces of equipment and software fit together or work with each other. Of course, this issue of integration is not a unique problem to mining, other domains, such as, aviation, medicine, road transport or defence have similar issues (Sheridan, 2002). Smaller mines may not have the need to have all of their operations automated, creating further issues with interaction between manned and unmanned equipment at the same mine site and the need to ensure manned vehicles do not get in the way of un-manned vehicles.

Autonomous or remote teleoperation systems will form part of the most important and transformational technology in the future of mining on a world wide scale. In the past 15 years, Australia has come to lead the work in autonomous mining applications (Minerals Industry Skills Centre, 2010). The biggest of these applications are in safety and improved productivity, improved utilization of resources, labour and equipment, infrastructure maintenance and disaster management. Mining already has autonomous material movement vehicles, trucks and loaders, smart drills for both production and material characterization, and precise movement and positioning of equipment. The emerging trend in autonomous or teleremote equipment will encompass the whole mining process from ore body delineation, rock breaking and mineral excavation through to stockpiling, delivery and loading in a safe, incident free and on-time manner.

1.2 The need for Human Factors input
Whilst large scale and rapid uptake of automation has often been pursued, the human factors and skilling of staff to support this automation has not progressed at the same pace as the technology. New operational or maintainance skills are required to support these technologies. An automation skills shortage where insufficient workers with the required technical knowledge, skills and abilities to support current and future workforce requirements is foreseen as a significant obstacle to the uptake of automation technologies (Minerals Industry Skills Centre, 2010).

The workers most affected by automation uptake are those working in some of the harshest and most remote areas of Australia and, for some, this is the reason they are attracted to the mining industry. The workforce is highly mobile and many workers regularly leave and re-enter the industry. For some, it is their individual personality traits that attract them to the industry in the first place, with the industry often attracting strong personalities with an attitude of “getting on with the job” and an enjoyment of working in a remote environment (Minerals Industry Skills Centre, 2010). For the mining industry to adopt automation implementation human factors challenges must be explored and understood and strategies that include a change management framework put in place to address the impact automation will have on improved safety, working conditions and up-skilling opportunities of the workforce.
In summary, the increase in automation or teleremote operation in the mining industry and elsewhere and the human factors issues that are likely to result unless a user-centred approach is adopted are the main drivers for this research. These issues will be explored here by means of stakeholder interviews, concerning available and emerging technologies and their visions for the mine of the future, establishing what technology is currently available (or near-market), undertaking literature reviews of the impacts of automation (especially looking at lessons learnt from other domains) and then analysing these collected data to help form a roadmap of future human factors challenges in this area.

2. Method

Initially, an “active” database has been developed of all current/near market automation, in particular, for mobile equipment. Stakeholder interviews have commenced with the aim of interviewing approximately 25 participants representative of developers, regulators, and mining company end users.

2.1 Database
A database has been developed as a “technology watch” of current and likely future human-related automation technologies that could impact on the resources sector. The database includes fully automated and semi-automated technologies that are likely to have an impact on production, employment and workforce up-skilling. The scope of the database is limited to technologies involved in underground and open cut hard rock operations and the initial focus is on mobile plant equipment, although the completed database may also contain automated technologies applied to processing through to transport operations.

The database remains “active” and will continue to be populated. In order to accurately populate the database with current and emerging technologies, in-depth literature reviews, consultation with mine site personnel and site visits have been necessary. The headings representing the relevant data to be collected and stored are: Name, Function, Automation Level, Description, Status, Technology, and Contact. A screenshot of the database is shown in the Results Section (Section 3). In a sense, such databases are never “final”, but they do help reveal the current state of play regarding mining automation.

2.2 Questionnaire and Interview
The second component of the research involves interviewing stakeholders to obtain an understanding of what automation technology is already out in the market, what the developing trends are, what products they have been exposed to currently and previously, and their perceptions of limitations and drivers of the uptake of that technology. A questionnaire has been developed that focuses in particular on the human factors issues surrounding automated mining equipment. As this work is part of a larger project, the questionnaire also includes questions aimed at understanding the social implications of mine equipment automation.

2.2.1 Interview procedure
Relevant approval was sought and received from the University of Queensland Ethics Committee in accordance with the National Health and Medical Research Council’s guidelines. Participation in the study is voluntary and interviewees are free to withdraw at any time without penalty from either their employer or the researchers. Interview information will be treated as confidential to the researchers of the study and all data
collected stored in a de-identified format for analysis. Interviewees will not be personally identified in subsequent reports or publications with their written approval. Many interviews will be taped with two researchers in attendance and, it is anticipated, these interviews may be up to an hour long. Researchers realize that industry based interviewees may not be in a position to provide this much time and provision has been made for briefer semi-structured (non-recorded) interviews, as deemed appropriate, for the successful collection of the required information. Some interviews will be conducted by phone and some questionnaires will be completed by email.

2.2.2 The participants
Interviewees will be selected from a broad stakeholder base in an attempt to gain as wide an understanding of automation technology as possible. The study aims to interview approximately 25 stakeholders ranging from technologists and developers through to regulators and mine personnel of varying levels of seniority and including technology end users. To date regulatory representatives, automation engineers, software engineers and developers have been interviewed. The interviews are ongoing at the time of writing and are still to be completed and fully analysed. Tentative analysis of the results of this work show several themes emerging.

3. Results

3.1 Interview Results
It should be noted that these themes are consistent with the more specific human factors problems and challenges associated with collision detection/proximity warning systems described by Horberry, Burgess-Limerick and Steiner (2010). The themes emerging here are:

3.1.1 Operator and Maintainer Deskilling
Deskilling of the labour force was perceived by the interviewees to be a real problem. This was thought to be of particular importance when dealing with new/unexpected conditions and the operator need to use knowledge-based behaviour to decide on a course of action.

3.1.2 Over-reliance on the Technology by Operators
Technologies were being used in ways not thought of by the developer. Also, there was an unexpected reliance on technology; often for tasks where automation was not intended by the developer to be used. In one example, operators often used the ‘cartoon’ display, rather than the real one as it provided additional task-based information (such as optical flow).

3.1.3 Importance of User Trials
Due to the above-mentioned problems with over-reliance, the importance of user trials to test the behavioural effects of technologies on actual operators was emphasized by the interviewees. It was noted that these should be iterative, such that the findings from the user-trials could be used to modify the technologies.

3.1.4 Change Management Processes for Introducing Mining Automation
The process of managing how new, automated technologies is introduced into mines is of key importance (especially for human element considerations). For example, mixing manually controlled and automated vehicles on the same mine roadways is currently not acceptable. Existing mines might need to rely more on assistive technology (such as collision detection systems), whereas new mines could potentially operate with only automated vehicles.
3.1.5. Levels of Automation
The interviewees recognized that there were different human factors challenges for different levels of automation. One important concept emerging was the notion of sliding autonomy. The level of automation depends on the task from full automation to full manual control. Of course, there are lots of Human factors issues in the changeover between levels (e.g. human out of the control loop, situation awareness limitations).

3.1.6. Poor Operator Acceptance of New Technologies/Automation after they are introduced
Interviewees recognized a skilled and informed workforce is needed to work with the new technologies automation or teleremote equipment will bring. Concerns were raised about acceptance of these technologies including appropriate maintenance, turning off of alarms, and malfunctioning equipment, even destroying/mistreating the equipment. Some interviewees discussed the need to gain user acceptance of the equipment and a system where the operators’ decision making powers and responsibilities were recognized /used rather than seeing the technology as removing operator control. The need for positive and supportive management involvement was also highlighted.

3.1.7. Human Factors in Maintenance
The main Human Factors in maintenance issues with automation were thought to be both the high level, diagnosis issues (where no operator is present to be able to explain the problems to the maintenance staff) and lower level sorting out/interfacing with somebody controlling remotely. Maybe the lack of skill issue is for both operators and maintenance workers on sites; experts could be elsewhere to do higher level cognitive/fault finding when things are wrong.

3.1.8. Poor Human Factors Design of Equipment Interfaces
Pleasingly, it was generally recognised that human machine interfaces for mining automation should be developed according to best practice user-centred design methods and findings. This was seen as being of particular importance when operators may be potentially controlling multiple vehicles rather than one. This situation presents unique Human Factors challenges in which the role of the operator changes from being the active controller to being a passive observer much of the time and only being an active controller at key points (eg during dumping for haul trucks). The main driver responsible for this was the mining companies. Routine parts would be automated (e.g. during haul- where the operator only maintained supervisory control) but the loading was more demanding/interesting which needed to be manually controlled.

3.1.9. Problems with Integration of Multiple Warnings/Alarms
Interviewees commented that visual information is the most dominant form of feedback in the mining sector followed by sound; often situations arose where both modalities were essential. Operator mental overload or distraction with the introduction for multiple warnings and alarms was also a concern raised by interviewees.

3.1.10. Lack of Equipment Standardization
Interviewees commented that it would be difficult to standardize equipment across mine sites and companies, but inconsistencies would arise if displays were not consistent across different pieces of equipment; errors were more likely to occur. Comment was made regarding design and iterative testing with the relevant operator/maintainer population.

3.1.11. A New Device being Essentially Irrelevant to the Task
Interviewees expressed concern that devices would be developed that were not required, and essentially provided no assistance to the task operator. It was considered that additional
unnecessary devices may be developed by technologies, and bring unexpected problems and safety issues into play.

3.1.12. Inadequate Operator and Maintainer Training and Support

The main issue emerging was the need to ensure ease of operation and maintenance of equipment, and that risks associated with interacting with the equipment were designed out as far as possible. Interviewees indicated that with new automated equipment; the associated technologies would require different operator skills and different ways of working compared to current and past practices. Training for new equipment would be challenging in that there was uncertainty around the type of equipment that would be used and, therefore, uncertainty around the knowledge and cognitive skills that would be required to undertake problem solving, such as, fault diagnosis or the correct response in an emergency situation. Interviewees expressed concern regarding the level of basic and additional skilled operators and, in particular, maintainers required when considering the uncertainty of the type of equipment of the future automated/teleremote mine. An area of particular concern was the method of delivery of training (“on the job” or virtual reality simulation) and the ongoing maintenance of training levels.

3.1.13. Organisational Issues

As is often found for automation in many domains, introducing new technology often changes the nature of the tasks to be performed. Thus, a careful analysis of the new tasks is a vital early step in ensuring that organizational issues are addressed. This was recognised by the interviewees and issues, such as fatigue, shift work, autonomous work teams and supervision were mentioned.

3.2 Database Results

The intention of this activity was to develop a ‘technology watch’ database (Table 1) of current and likely future human-related automation technologies that could impact on the resources sector. Although, in one sense, such databases are never ‘final’ they do help reveal the current state of play regarding mining automation.

Table 1: Automation Database Snapshot
4. Discussion

The research remains work in progress and future work includes an in depth analysis of all the data collected. It is also planned to create a road map vision of the human factors issues involved in “the mine of the future” with respect to currently used, known current technologies that are not currently used, and future emerging technologies. This roadmap will include both human factor implications and social implications of the implementation of autonomous technologies, and will include a series of scenarios, such as, a haul truck breakdown.

Some field trials are planned for 2011. It is anticipated that a limited amount of field work will be undertaken at an Australian mine site that is introducing or has recently introduced new automated technology. Suitable sites are being investigated by the research team to select the most appropriate site to study the human factors and social impacts arising from newly automated technology. It is anticipated that this site will be used for the fieldwork to be undertaken in early 2011.

It is envisaged the field work will involve operators/maintainers at a mine site where automation has been implemented and work will be directed to examine training, skills, interface design and communication gaps identified with respect to human factor issues and social implications from a stakeholder perspective. The technologies developed are likely to have significant social, safety and economic implications for the workforce of several of Australia’s major mining regions. While automation and, specifically, remote tele-operation, has the potential to lead to cost savings and production efficiencies as well as better delivered health and safety outcomes, a likely direct impact will be on the composition of the workforce located in these communities, both in operators’ roles, such as, truck and train driving, and in support roles. The loss of traditional mining roles will be partly replaced by new positions, such as, console operators and technicians and it is likely that many of these new roles will be located in operation centres remote from the mine itself.

Overall, where possible, this work will take an operator centred perspective whereby the remote controlled equipment interfaces would be recommended to be matched to the abilities of operators, rather than trying to fit operators to previously designed equipment by means of training and selection.

References