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Zeshan Hyder
Missouri University of Science and Technology, zhfy6@mst.edu

Keng Siau
Missouri University of Science and Technology, siauk@mst.edu

Fiona Fui-Hoon Nah
Missouri University of Science and Technology, nahf@mst.edu

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Fiona Fui-Hoon Nah
Missouri University of Science and Technology
nahf@mst.edu

ABSTRACT

Mining is an important industrial and economic sector that plays a major role in the economic development of a country and provides many employment opportunities. Implementation of Artificial Intelligence (AI), machine learning, and autonomous technologies in the mining industry started about a decade ago with the first application to autonomous trucks. The autonomous technologies provide many economic benefits to the mining industry through cost reduction, productivity improvement, reduction in exposure of workers to hazardous conditions, continuous production, and improved safety. However, implementation of these technologies has faced economic, financial, technological, workforce, and social challenges. This paper discusses the current status of AI, machine learning, and autonomous technologies implementation in the mining industry, challenges resulting from these technologies, strategies to overcome these challenges, and questions for future research.

Keywords

Artificial intelligence, autonomous technology, machine learning, mining industry, autonomous trucks.

INTRODUCTION

Mining plays an important role in the world economy. In 2016, revenue from the world's leading mining companies was US$496 billion (Statista, 2018). The mining and extractions industry employed around 756,000 people in the US in 2016 (DOE, 2017). After being on the decline for the last few years, mining industry is growing again and investment in the mining sector is increasing (Deloitte, 2017). One factor that can boost the growth of mining sector and make it more lucrative to investors is the application of AI, machine learning, and automation to improve the technological, economic, and environmental outlook of the industry.

AI and machine learning are two technologies that have the potential to change the technological framework of the future and both are based on big data manipulation and analytics (Marr, 2016). In this paper, we have discussed the use of AI, machine learning, and autonomous technologies to the mining industry and how it can help in a new mining revolution.

LITERATURE REVIEW ON CURRENT APPLICATIONS OF AI AND AUTONOMOUS TECHNOLOGIES IN MINING INDUSTRY

The following are the sectors of mining industry in general and mining operations in particular that are experiencing increased application of AI and autonomous technologies.

Prospecting and Exploration

Prospecting is the first stage of looking for an economic mineral deposit and evaluating this deposit in terms of current economic and market conditions to ascertain if further investment is viable for the given prospect or not. Exploration involves sampling, laboratory work, borehole logging, and further investigation of prospect (Böhmer and Kucera, 2013). Both these stages involve extensive collection and use of data, and with the use of traditional methods involving human labor, site visits of remote areas, manual sampling and assaying, and primitive techniques can last a period of two to twenty years before the actual worth of the deposit is established (Böhmer and Kucera, 2013). AI systems and data analysis software can be fed with geological,

topographical, mineralogical, and mapping data and can be used to pinpoint the anomalies and variances in the data and to locate areas of potential interests.

Exploratory and Production Drilling

AI and machine learning can be applied to develop autonomous drills that can locate the potential sites identified in the prospecting stage and perform drilling activities and can feed the drill log data to the system. This technology can also be implemented during production drilling. Typically, a drill cycle includes moving the drill to the desired location, setting up the drill at that location, leveling up and start drilling, applying adequate load or energy to drill as per requirements of the rock and strata, cleaning the drill and hole, removing the drill after completing the hole to a predetermined depth, and moving the drill to the next location. Currently, these processes are done manually but it can be automated and AI can control the processes.

Mining Operations

AI can greatly improve the productivity and efficiency of mining operations. Mining by its very nature is a dangerous and hazardous operation (Paithankar, 2011). Limited working space, poor lighting, accumulation of hazardous waste and poisonous gases, dust particles from metals, nonmetals and toxic substances, radioactive materials, poor air supply, use of explosives, unstable roofs are among the factors that make mining operations dangerous. However with the help of AI, machine learning and autonomous technologies, the exposure of workers to dangerous underground and surface operations can be minimized. Machines can autonomously monitor the atmosphere, send signals and warnings, locate problematic areas, and work continuously even in dangerous situations. Hence, implementation of AI, machine learning, and autonomous technologies is increasing in mining operations (Vella, 2017).

Autonomous Vehicles

Several manufacturers have been working on autonomous mining haulage trucks and Caterpillar operated its first fleet of autonomous trucks in Australia (Caterpillar, 2017). BHP and RioTinto are currently using fleet of autonomous truck and have reported a 15% reduction in operation costs compared to manually operated trucks (Dyson, 2017; Simonite, 2016). These autonomous trucks can operate 24/7 without the need of rest breaks and changes in shift. Although Tesla and Google have been working on a self-driving, they have some setbacks in terms of rules, regulations, and infrastructure requirements (Chopra, 2017). However, mining sites provide an excellent launch pad for autonomous vehicles. The roads are mostly clear of other traffic, can be designated just for these vehicles, and infrastructure within the site is already developed and privately owned and maintained so upgrade and remodeling is easier compared to public roads and infrastructure. That is why in addition to self-driving haulage trucks, autonomous loaders, trains, and excavators are being developed to meet mining industry needs.

POTENTIAL APPLICATIONS OF AI IN MINING INDUSTRY

Gases and Hazard Detection

An important application of AI to mining industry can be detection of hazards especially dangerous gases, toxic dusts, and radiations in the mine. AI systems can be developed to inspect the worksite ahead of workers by using robots, sensors, and by collecting data from preinstalled monitoring stations. These stations can trigger alarms, give warning signals, and block the affected area to decrease further expansion of hazard. When connected to mine fans and ventilation networks through intelligent systems, AI systems can direct the air flow, increase or decrease the air quantity and pressure of mine fans, and start and stop certain fans to automatically direct the hazards out of mine.

Production

Shearers, coal cutters, jumbos, conveyors, cutting heads, and road headers are integral parts of mining production cycle (EIA, 1995). AI and machine learning can be implemented on these machines to direct their operations, automate application of energy at cutter heads to match the rock strength and hardness, monitor gas and methane inrush during operation, continuously monitor roof condition while in operation and disseminate data about working conditions to make informed decision, and take corrective actions well in advance of escalation of problems.

Sampling

Autonomous samplers can sample minerals, atmosphere, gases, dusts, and toxic materials even in areas of high concentration. Continuous monitoring intelligent systems can provide early warnings, suggest preventive measures, and reduce the need of

workers access to hazardous area for sampling. These AI systems can reduce the need to bring samples for laboratory testing by providing images, conducting in situ tests, and communicating results as and when needed.

Autonomous Support Systems

Another area of AI and machine learning implementation is autonomous support systems and several companies are researching to provide the first such autonomous system that will reduce the need of human intervention for this delicate and dangerous mining operation (Van Duin, Meers, Donnelly, and Oxley, 2013). Roof support is one of the most important and most hazardous task of mining operations (Ghasemi et al., 2012; Peng, 2015). Several accidents occur because of roof falls while supporting operation is underway (MSHA, 2017). Weak areas of the roof and strata, water inrush, and release of hazardous gases pose high risks to this work. This dangerous operation can be automated where roof support can be made an integral part of the autonomous cutting machine that shields the areas after cutting and install bolts and temporary support to the worked out exposed strata while moving ahead for further production.

Mineral processing application

AI based systems can be designed to sort useful minerals and gang material from the run of mine production. These systems can use color-sorting, x-ray transmission or near-infrared sensors to remove waste from useful mineral. The application of these systems before grinding and crushing machines can greatly increase the efficiency of the comminution process and reduce energy cost as crushing and grinding are most energy consuming and least energy efficient parts of mineral processing cycle (Jeswiet and Szekeres, 2016).

Accident Analysis

Data analysis and visualization techniques can be used to analyze causes and factors leading to accidents and preventive measures can be designed with more focus on removing the causes of accidents. Intelligent systems designed with a focus on removal of potential hazardous situations, decrease or complete removal of human presence from dangerous and hazardous works such as transporting, loading and blasting explosives, installing roof supports, and removing hazardous gases and dusts can help in reducing accidents and fatalities.

CHALLENGES IN IMPLEMENTING AI IN MINING INDUSTRY

Although the implementation of AI and autonomous technologies in mining started more than a decade ago, the pace of implementation is painfully slow and has faced several hurdles and setbacks. One of the biggest challenges in implementing technology is resistance from workers, supervisors, and even AI researchers who are not sure of the actual impacts of this technology on jobs, economics, social system, working relations, and on the societal makeup (Kappal, 2017; Siau, 2018; Siau and Yang, 2017). The opposition is mostly based on the fear of losing job to technology, unknown behavior of AI and autonomous systems, unequal distribution of wealth and capital, complicated and complex interaction and relationship with technology, and unclear future of technology implementation (Siau, 2017; Siau and Wang, 2018). It is also not clear how individual and group decision making can be supported by technology in AI (Nah et al. 1999; Nah and Benbasat, 2004).

Other factors that are slowing down the implementation of AI and automation are sluggish improvements in intelligent systems, difficulty in obtaining regulatory approvals, huge initial investment and capital requirements, inadequate infrastructure for the implementation of technology, limited availability of skilled personnel, difficulty in obtaining capital funding when the future and benefits of implementing technology are not yet clear, and declining availability of high grade ores and mineral resources impeding large capital investment.

RESEARCH QUESTIONS, METHODOLOGY, AND PROCEDURE

AI and autonomous technology implementation to mining industry are still in their infancy and not much data is available to quantify the impact of this implementation on the industry. Thus, it is appropriate to use qualitative approaches to assess how this implementation is received by different stakeholders in the industry and what their perceptions are about the threats, challenges, benefits, and potential impacts of this implementation. Keeping in view this objective, the following questions are designed to get the relevant data:

1. What are the potential uses of AI and autonomous technologies in mining industry?
2. What are some major impacts of implementing these technologies?
3. What are the main hurdles/challenges in implementing these technologies?

4. How do the implementation of these technologies affect the workforce demographics and worker relations, and availability of jobs?
5. What is the way forward and how to successfully implement autonomous technologies in the mining industry?

As these open ended questions are subjective, they best suit the qualitative method of research design, data collection, and analysis. One-on-one interviews and unstructured surveys will be carried out to gather the perceptions, suggestions, viewpoints, and opinions of the stakeholders. The interview method provides more flexibility in terms of engaging in open and frank discussions, allowing follow-up questions to clarify issues or points of view, and better understanding of an interviewee's position.

Open-ended surveys help in understanding different dimensions of the objects' vision and perceptions about the surveyed questions and help in the qualitative analysis of issues at hand (Jansen, 2010). The interviews and surveys will be conducted according to the accessibility and location of the relevant stakeholders. Potential stakeholders include mine owners, mining executives, mining managers, executives of mining machinery manufacturing companies, mine workers and operators, labor union representatives, investors and financers, AI experts, conventional and autonomous mining equipment manufacturers, government regulators, legislators, health and safety experts, and local community and town representatives where mine is in operation. Preference will be given to face-to-face, recorded audio or video interviews, followed by online interviews via skype and other online communication channels and lastly to surveys through traditional and/or electronic mail. The availability of qualitative data from interviews and quantitative data from surveys enables the triangulation of results.

CONCLUSIONS AND EXPECTED CONTRIBUTIONS

AI, machine learning and autonomous technologies have the potential to bring a new revolution to mining industry by reducing cost, improving productivity and efficiency of operations, and by decreasing environmental footprint of mining through use of intelligent systems. Mining industry is slowly moving towards the implementation of these systems especially in the field of autonomous machines and self-driving vehicles. However, to realize the full potential of these technologies in all operations of mining, more concerted efforts are needed. This research will provide a foundation to gauge the perceptions of various stakeholders about the implementation of these technologies for the policy makers, mining companies, equipment manufacturing firms, regulators and legislators, and labor unions. This research will provide new data to analyze various impacts, to evaluate current issues and future trends, and to provide a basis for better understanding of continued AI implementations.

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