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APPLICATION OF ROBOTICS IN MINING- A REVIEW

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Abstract: The deterioration of mining conditions, the rising cost of labor, the limited potential of both humans and traditional mining machines and the lack of skilled workers are some of the reasons to consider robots in mining. Mining is the practice of extracting resources for utilitarian purposes. The new and developed machines used in mining must operate in harsh, dynamic and uncertain environmental conditions. Robotics technology have recently taken on an international favor and become a significant topic in engineering research. Robotics has a great potential for assisting in the complex task of extracting and processing minerals from the ground. Application of robotics in mining are broad and used in operations such as robotic mapping, surveying, excavation, transportation… This paper will provide an overview of the rapidly evolving fields of mining robotics. The development of new theories and techniques and the potential of both these fields in mine design and planning are examined. And there are many reasons to advance the discipline of mining robotics which include the improvement of productivity, safety and lower cost, this paper also discusses about labor problems and environmental sustainability in mining robotics.

Index Terms **- Deterioration, utilitarian purposes, robotic mapping, environmental sustainability.**

I. INTRODUCTION

Mining always remains hard and hazardous work and the scope for the application of automation is very high. Mining re-quires the handling of enormous quantities of material in a cost-effective and safe manner. Increasing operational costs, the need for greater productivity and improved health and safety outcomes are powerful drivers for robotics. Major suppliers of mining equipment for both under-ground and surface mining operations now offer robotic driving, dumping, and other materials handling functionalities. The demand for computer simulations of robots has increased as robotics has progressed and their utilization has expanded., which can be used for a variety of purposes, including the design of new robots, task planning for current robots, performance evaluation, and cycle time estimation. Robotic technology offers significant potential to improve the plight of the rescue workers by reducing exposures to hazardous conditions. A robotic vehicle can explore the mine and provide valuable information to the teams to assist in planning and implementing search and rescue operations. Industrial robots have been made a significant contribution toward automating the manufacturing processes. The efficient use of robots shows productivity increase, production cost reduction, and product quality improvement. Mining is a dynamic process that must deal with the uncertainties of "outdoor" environments, and is usually conducted in as a series of interacting unit operations (e.g., drilling, blasting, loading, hauling, processing). The harsh, extensive, and unstructured environments found in mining often preclude the application of existing techniques from other industries (e.g., from manufacturing robotics). In the mining, miners have reported difficulties finding the skilled labor needed to support their operations. The newest generation of workers is technologically astute, but holds a different attitude towards physical labor than previous generations. Robotization may be what is needed to entice this new generation into mining. Modern mining firms and equipment suppliers are required to be environmentally and socially responsible. The alleviation of emissions (e.g., through the coordination and optimization of fleets) or reduction in power consumption by reduced operating demands (e.g., ventilation support) might be realized by way of real time monitoring and automation of equipment.

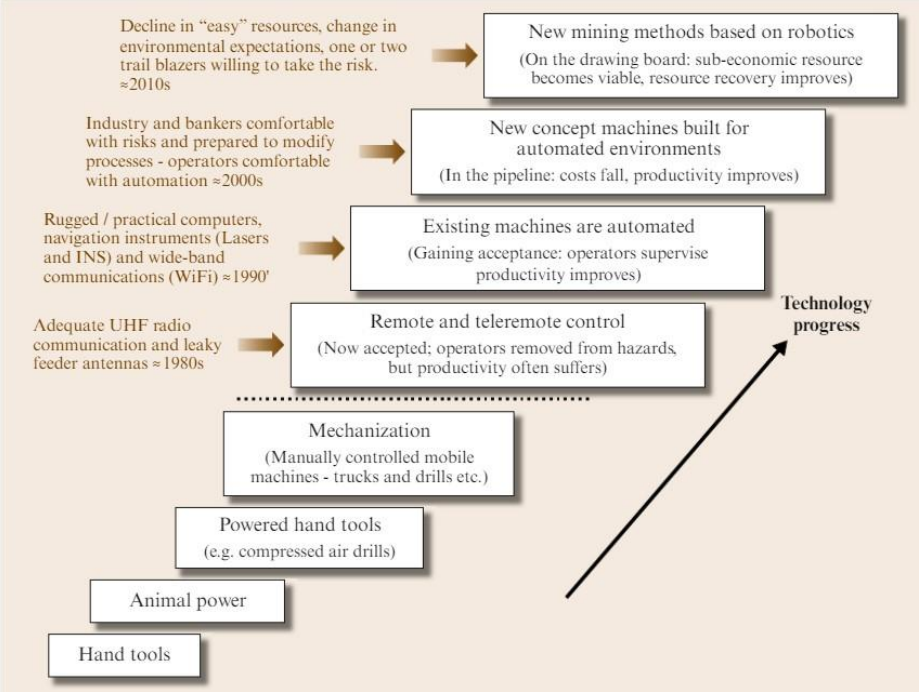

Fig.1: Evolution of mining ***(Corke, P., et al 2008)***

2. OBJECTIVE

The main objective of this present work is to understand the advantages and disadvantages of application of robotics in mining.

3. METHODOLOGY

This report contains research on the topic of robotics in mining evaluation. Data was gathered from a variety of books and websites as part of the research. We can see the usefulness of robotics in mining by accumulating this data. The research is mostly focused on how robotics can assist the mining industry. Many books and periodicals have been used in the research. We deduced from the information gathered that
The various methods used for the completion of this project are:

- In this report research will be done about the topic, evaluation of robotics in mining.
- Data will be collected from several books, website and journals.
- Research will be done on surface and underground robotics system.
- Study will be done about how robotics will help in rescue and recovery operations.
- Data will be collected on efficiency of productivity by using robotics.
- Research will be done on how robotics in mining affecting the labor.
- According to these collected data, only report is made.
- We have taken this project to how the importance of robotics in mining and how it will affect the mining future

4. LITERATURE REVIEW

Vasily V Sinoviev et. al (2016): This paper reports the approach to effectiveness evaluation of robotics technology in mining which encloses the identification of both the technologies best prepared for the robotic automation in terms of their complexity and sources of the effectiveness of robotic technology via computer model simulations.

WP Rogers (2019): In the opinion of these authors, technology alone can never give an organization an edge over competitors or provide an industry step change. However, history has shown that technology applied with correct logistics and strategy makes a significant difference. Never has the minerals industry faced such daunting challenges and been in such need of a step change.

D Paredes (2021): Although mining is a capital-intensive industry, its contribution to employment creation is generally praised as a leading local benefit to justify new or expanding extraction projects. However, labor substitution from automation and robotics is increasing in a wide range of modern mining processes. Such labor replacement is likely to intensify in the coming years due to advances and cost reductions in technology.

5. ROBOTICS IN MINING

5.1. SURFACE MINING

Surface mining is always a high-tonnage activity with enormous mobile equipment, as well as challenges like difficult surroundings (e.g., dust, fog, and extreme weather), as well as remote locations and a stringent cost-cutting requirement.

Need for robotic system in open pit mining:

Because the opencast mining sector uses a greater number of high-capacity earthmoving machines and manpower, robotic technologies were employed to maintain quality and enhance manufacturing capacity. It's also used to automate machinery and boost productivity. Different types of robotics used in surface mining are:

5.1.1. AUTOMATED HAULAGE

Haulage is the process of transferring materials from one site to another. Surface mining applies haul trucks to transport material from the blasting/excavation site to the point of processing or stacking. Mobile robotics that operates in a demanding, dynamic environment are included in autonomous haul trucks. As a result, they'll need to put systems in place to deal with issues like sensing and perception, situational awareness, location, and control.

Fig. 5.1: Autonomous haul truck.

5.1.2 ROBOTIC DIGGING

Mass excavation is one of the most crucial components of mining. Because it is extremely sensitive to economies of scale and needs a large capital investment, it became a target application for robotic technology in the mid-to-late 1990s. Surface mining device consists hydraulic excavator, hydraulic shovel, and electric rope shovels. Robotic digging study includes a device called system design.

5.1.3 FLEET MANAGEMENT

Fleet management solutions are typically deployed to an office environment and allow operators to quickly survey large amounts of mine data so that appropriate actions can be taken in real-time on the mine-site. Computerized fleet management must integrate and evolve with the deployment of robotic mining machines.

Fleet management is a catch-all term that may define a number of different technologies used in mining. Commonly though, fleet management is divided into three main tasks.

1. Position (and perhaps materials) monitoring
2. Production monitoring
3. Equipment task assignment

5.1.4 ROBOTIC DOZING

In most surface mines, dozers are utilized. The job of operating a dozer under dynamic settings, with risks that might change and be subtle and difficult to detect, adds to the complexity of the duties that personnel perform on these machines. Many of these jobs need operators with extensive ground-engaging tool control and machine positioning experience. Dozer operators are also exposed to a number of risk factors, including whole-body vibrations, difficult posture requirements, noise, and shift work, all of which can contribute to health concerns. While machine guidance systems are increasingly commonplace, they still need the presence of an operator in the cab and are known to have issues due to their reliance on GNSS- based localization.

Fig. 5.2: Robotic dozing

5.2 ROBOTICS IN UNDER GROUND MINING

Deep mining environment which seems to be particularly hazardous and generally unpleasant operator safety and fatigue cost of labor and the ubiquitous load-haul-dump cycle all motivate autonomous and semi-autonomous and teleoperation-based solutions for underground machines and processes.

Need for robotics in underground mining

The use of robotics in underground mines is extremely important for safety reasons. The usefulness of automation in underground mining is demonstrated in the following example.

- Mine navigation or charting underground the usage of robotics is being considered.
- Estimation of the location
- Automation of machinery
- Concentrate solely on one topic.

Fig. 5.3: Machinery helping miner in underground

5.2.1 TELEROBOTIC OPERATIONS

Remote control in mining typically involves the collection of a machine from a range where the operator has a direct line-of-sight view of the machine. Remote control is often used exclusively for excavation (or mucking), not for loader drive (or tramming). When loaders must access subterranean draw sites where there is a risk of collapsing earth, remote control devices are commonly employed. It stands to reason that by remotely running equipment or partially autonomously operating equipment, for example, employee exposure to potentially hazardous situations may be significantly minimized.

5.2.2 ROBOTIC LOADING

Despite a significant amount of research work in the field of robotic excavation, no autonomous or semi-autonomous excavation system has yet to be widely developed or adopted in the mining sector. Although this section concentrates on loading from the standpoint of subterranean mining, robotic loading may also be used in open pit mining. Because of the dynamic and unexpected nature of bucket-rock interactions, robotic excavation is particularly difficult.

The robotic loading problem can be split into two fundamental tasks;

1. Dig planning
2. Dig execution and control

Dig planning constitutes the problem of deciding where and what to dig, possibly considering the geometry of the rock pile, the distribution of particles, and the physical characteristics of the loader and bucket. Dig control refers to algorithms for modifying plans based on the nature of the media encountered, so as to efficiently fill the loader's bucket. This task of the problem is particularly challenging in fragmented rock.

5.2.3 UNDERGROUND MAPPING, SURVEYING, AND POSITIONING

In a number of sectors, including mining, mapping, surveying, and real-time equipment placement are all vital services. In the 1980s, the introduction of the satellite-based global positioning system (GPS) in surface mining led to significant changes in daily operations, with new applications developed even more recently. Surface mining, for example, has used precise site surveys, information systems, and robotic equipment based on GNSS to increase safety, productivity, and cost-effective maintenance operations. Underground mining, on the other hand, has progressed more slowly because to the lack of a comparable placement method.

5.3 EFFECTS OF ROBOTICS IN PRODUCTIVITY

Significant organizational improvements are obtained when digital technology is coupled with management and mindset adjustments. For example, advanced analytics and sensors are lowering cost of maintenance and downtime while improving productivity and chemical recovery. Robotics and semi-autonomous equipment are replacing humans in mines, reducing demand and hazard. According to miners in Western Australia, autonomous hauling technology has improved output by 20%.

Fig. 5.4: Statistics of mining productivity
(Nathan Flesher., et al 2018)

Underground mining has always been difficult to coordinate since it is hard to know where people and assets are or how far they have advanced. It's becoming more realistic to combine off-the-shelf technologies with in-house solutions to create a system that improves transparency, safety, performance monitoring, and overall equipment efficacy. Mine supervisors, for example, might

build subterranean networks using Wi-Fi or 5G wireless technology to communicate with work crews in real time. When combined with the other two primary engines of technology-enabled transformation, one single invention can have far-reaching implications.

5.4 ROBOTICS HELPING IN MINE SAFETY

In recent years, technological advancements have substantially decreased mining safety concerns. Robotic carts outfitted with lasers and detectors can perform subterranean movement, mapping, and item detection. Other robots use gyroscope navigation systems and gyros, as well as sensors, to provide precise location estimates. Materials and gases can be identified by other robotic detecting systems. These hazardous operations are not only automated, but downtime due to shift changes is also eliminated. Safety must be a top priority in every healthy workplace. Mines, in particular, are hazardous environments that provide a greater risk of large-scale environmental damage and human mortality than many other workplaces, making mine safety a continuous concern. As mines increase in size and depth, and mining companies build larger operations with more personnel, safety has become a new issue. This problem was solved by developing specialized processes and technologies aimed specifically at providing notice and protection to miners. This robot's primary function is to detect potentially hazardous gases.

For Example,

- Load-haul-dump trucks that can negotiate tunnels on their own and clear barriers by centimeters.
- The world's largest robot is a 3500 tons coal dragline with automated loading and unloading.
- A robot for securing mine roofs after blasting by drilling and fastening them.
- A pilot-less burrowing machine for mining underground in flooded gravels and sands where humans can't go.
- A robotic drilling and blasting instrument capable of producing controlled caving.

Fig. 5.5: Mine rescue robots ***(Jingchao Zhao., et al 2017)***

5.5 EFFECTS OF ROBOTICS IN LABOUR

Robots improved productivity while lowering labor expenses. Much has been written on the emergence of robots and the economic consequences of automation. However, most research is prospective in nature, and predictions of future employment implications vary significantly, with some studies projecting that as many as half of all workers might lose their jobs due to automation. Even less is known about how robots will affect employment, salaries, and employees in the future. Intensity of robot growth Day by day, the amount has risen. The graph depicts the rise of robots throughout time. We can see how the robot has a significant impact on today's world.

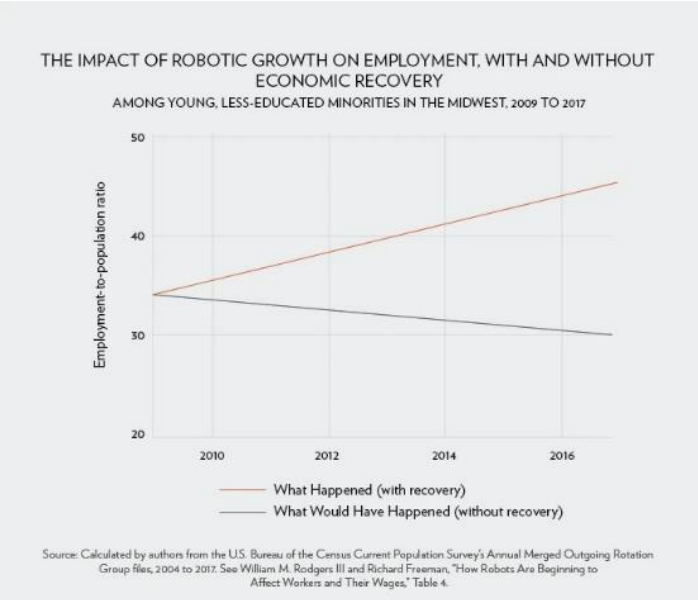

Fig. 5.6: Robotics on economy ***(R. Freeman., et al 2019)***

6. CONCLUSIONS

Today, mining remains hard and hazardous work with a wide scope for the application of robotics. The main drivers are the need for greater productivity, improved health and safety for mining personnel. With some advantages, it also has some disadvantages like employment shortage and many environmental problems. Traditional manufacturing robots are not the same as mining robots. The mining environment is evolving, in the sense that the goal of mining is changing, and the equipment are becoming more hydraulically operated and diesel driven. These challenges have meant that robotics has not been rapidly adopted by the mining industry to date, but it is clear that the mining industry will have to adopt more automation, and with robotics. Further significantly improve productivity and safety as traditional methods such as staff training, improved work practices, and larger and improved machine design are providing diminishing returns. The desire to improve productivity, safety, and lower the costs of mining are key motivators for the use of robotics in the mining industry. Every robotic system is updating day by day as new technology arrives.

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