Reduction of personnel in exposed areas, safety devices and early steps towards robots in mining

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INTRODUCTION

In underground mining the harsh environment and the possible dangers from rock fall or bursts always leave a certain residue risk to personnel on site. Therefore there is an ongoing trend towards full mechanisation and then automation of the mining process.
But some tasks are difficult to automate and the need for maintenance of the equipment underground still needs some personnel in potential exposed areas.
Today we see early research and development in robots, which are expected to replace the human workforce in underground mining within 30 years.

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The global population is growing and the need of raw materials follows that trend. On September 25th 2015, countries at United Nations adopted a set of goals to end poverty, protect the planet, and **ensure prosperity for all** as part of a new sustainable development agenda. (Haas et al 2016)

Figure 1: Sustainable Development Goals of the United Nations with those encircled which needs more raw materials (United Nations/MUL)

The need for raw materials moves underground mining deeper and deeper and with this operation gets more challenging.

Montanuniversitaet Leoben Chair of mining is addressing in its research also two major topics for deep mining operation:

- Rock mechanics for deep mining

- Development of automation and robotics for mining.

This research work is done in international partnership with universities, research enterprises, authorities and industry both mining operation and suppliers.

The first topic “Rock mechanics for deep mining” is not only important for humans underground – also automated machinery and future robots needs stable roof condition to operate.
Underground mining operations going deeper encounter globally more problems with seismic events, rock bursts causes fatalities and great damage to infrastructure.
To address the rock engineering challenges Montanuniversitaet Leoben has initiated the European Institute of Technology (EIT) RawMaterials education program „Safe Deep Mining“ with a consortium of universities and industry stakeholders.
The stress environment in deep mines does not favour the highly productive caving systems of stoping. The value of energy-based design concepts for very deep mines exploiting tabular mineral deposits is part oft the research. Despite the considerable progress that has been made in the science of rock mechanics since the 1950s, progress in applying this knowledge to solve rock pressure problems in deep mines has been rather slow. The tools are available. What is needed is the development of robust design criteria for mine infrastructure, excavations and support systems for dynamic and changing stress environments. The second critical issue is the lack of highly qualified rock engineering personnel on the mines. This has been recognized by the European mining industry through supporting a continued education programme in rock engineering for deep mines. (Wagner 2019)
Also associated research into better understanding of mining action and rock reaction and the related seismic events has been initiated.

The topic “development of automation and robotics in mining” is a second research focus at Montanuniversitaet Leoben. This work is done in international cooperation with research and industrial stakeholders.
One example is the concept development “Safer charging of bulk explosives” done as project manager for the Nordic Rock Tech Center (http://www.rocktechcentre.se/)
The project shall for mining companies and suppliers of equipment and explosives

- develop concept(s) for a technical solution **for safer charging**
- in order to **decrease risks and strenuous work for personnel at the face** of a drift.

Removing the operator from the face in this project was defined as moving him into a safe location at least 6 (six) meters from the face.
The project team set up a product target specification and then searched for possible solutions and concepts. The selected concept ideas where then detailed and a 3D-CAD model drafted. This was tested against the product target specification.
The concept using an industrial robot is further developed by an industrial consortium.

With more autonomous equipment moving underground today this “automated areas” are total exclusion zones for mining personnel. Functional Safe proximity detection systems, which monitors persons around dangerous equipment and in No-Go-Zones will be a key for autonomous vehicles and personnel using the same underground space in future. Montanuniversitaet Leoben chairs of mining technology and automation are involved in developing functional safe system concepts.

Robots will play a key role in deep underground mining in the next generation of mining equipment until 2050.
Key tasks for robots in underground mining will be
- Monitoring in dangerous areas
- Exploration
- Scaling of roof and rib
- Construction of roof support
- Search and rescue
- Building infrastructure
- Maintenance work
- Repair work
- Mining in veins

Most mining machines can be remote controlled today, but the need for maintenance and repair make them dependent from personnel on site. But otherwise the big mining machines can be automated and then seen as big robots.
Also in critical mining conditions the flexibility of the human miner is still unsurpassed.
So the most important task for future robots in mining will be building infrastructure and doing maintenance and repair work.
But as the mining industry is limited when it comes to R&D budgets, it is fortunate that other businesses can invest billions of Dollars into robotics.
Global military is developing autonomous robots for their purposes – results so far are impressing and based on these developments of robots for maintenance and dangerous work in underground mining will be possible in the coming years. A look on the homepage of the US company Boston Dynamics (https://www.bostondynamics.com/) , which is under the headline “changing your idea what robots can do” shows the impressing advances mobile robots are undergoing.
The appearance of autonomous moving working robots in mining also will have an impact how we build equipment and operate in future.

Montanuniversitaet Leoben is partner in the European Horizon 2020 Research Project ROBOMINERS, with special focus on the possible excavation concepts. (Sifferlinger, Hartlieb, Moser 2017)
The project started in June 2019 and will last for four years.
ROBOMINERS will develop a bio-inspired, modular and reconfigurable robot-miner for small and difficult to access deposits. The aim is to create a prototype robot that is capable of mining underground, underwater or above water, and can be delivered in modules to the deposit via a large diameter borehole. In the envisioned ROBOMINERS technology line, mining will take place underground, underwater in a flooded environment. A large diameter borehole is drilled from the surface to the mineral deposit. A modular mining machine is delivered in modules via the borehole. Powered by a water hydraulic drivetrain and artificial muscles, the robot will have high power density and environmentally safe operation. Situational awareness and sensing is provided by novel body sensors, including artificial whiskers that will merge data in realtime with production sensors, optimising the rate of production and selection between different production methods. The produced high-grade mineral slurry is pumped to the surface, where it will be processed. The waste slurry could then be returned to the mine where it will backfill mined-out areas. ROBOMINERS will deliver proof of concept (Technology readiness level TRL-4) of the feasibility of this technology line that can enable the EU have access to mineral raw materials from otherwise inaccessible or uneconomic domestic sources. This proof of concept will be delivered in the format of a new amphibious robot miner prototype that will be designed and constructed as a result of merging technologies from advanced robotics, mechatronics and mining engineering. Laboratory experiments will confirm the miner’s key functions, such as modularity, configurability, selective mining ability and resilience under a range of operating scenarios. The prototype miner will then be used to study and advance future research challenges concerning scalability, swarming behaviour and operation in harsh environments.
It must be pointed out that while from a “mining industry” viewpoint in 2019 the ROBOMINERS prototype with a planned mass of about 1 to 1.5 tons can be considered a very small machine, from a robotic point of view this is considered to be very large. (Figure 2)
So such small robots can only produce small amounts of excavated material – but the focus is on technology development of the needed skills for robots operating underground.

And it is in most cases more challenging to develop small machinery and sensoric solutions then upscaling them to big size.

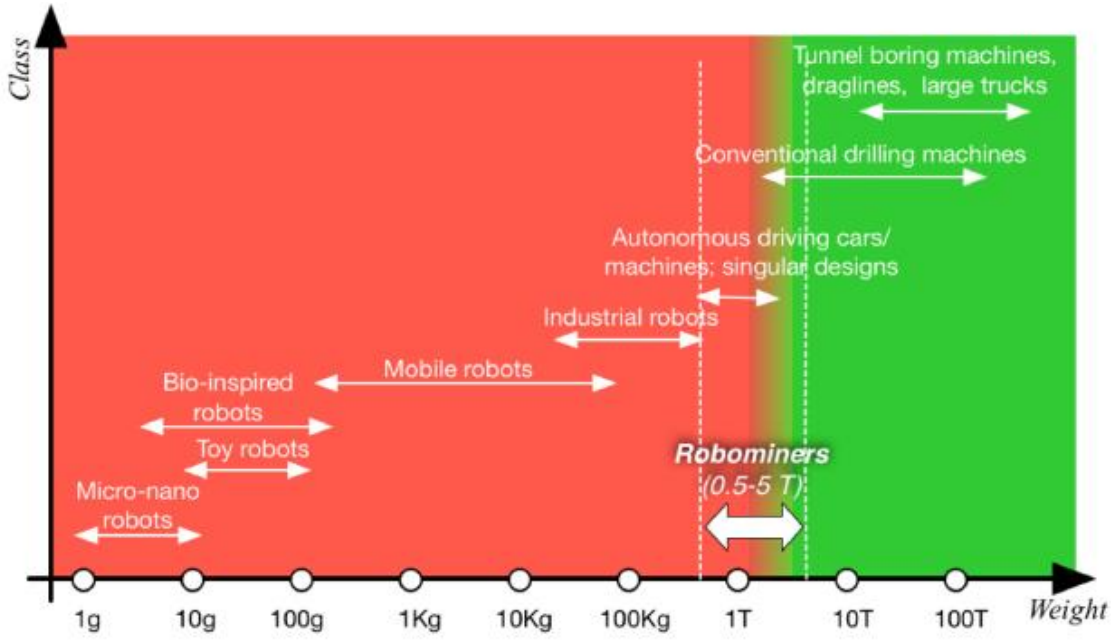

Figure 2: Range of robots and mining equipment (ROBOMINERS Consortium 2019)

From the time perspective the ROBOMINERS Project Consortium sees in the next decade robot prototypes used as a technology demonstrator, from 2030 the first industrial pilot robots in underground mining and by 2050 fully autonomous operating robots. (Figure 3)

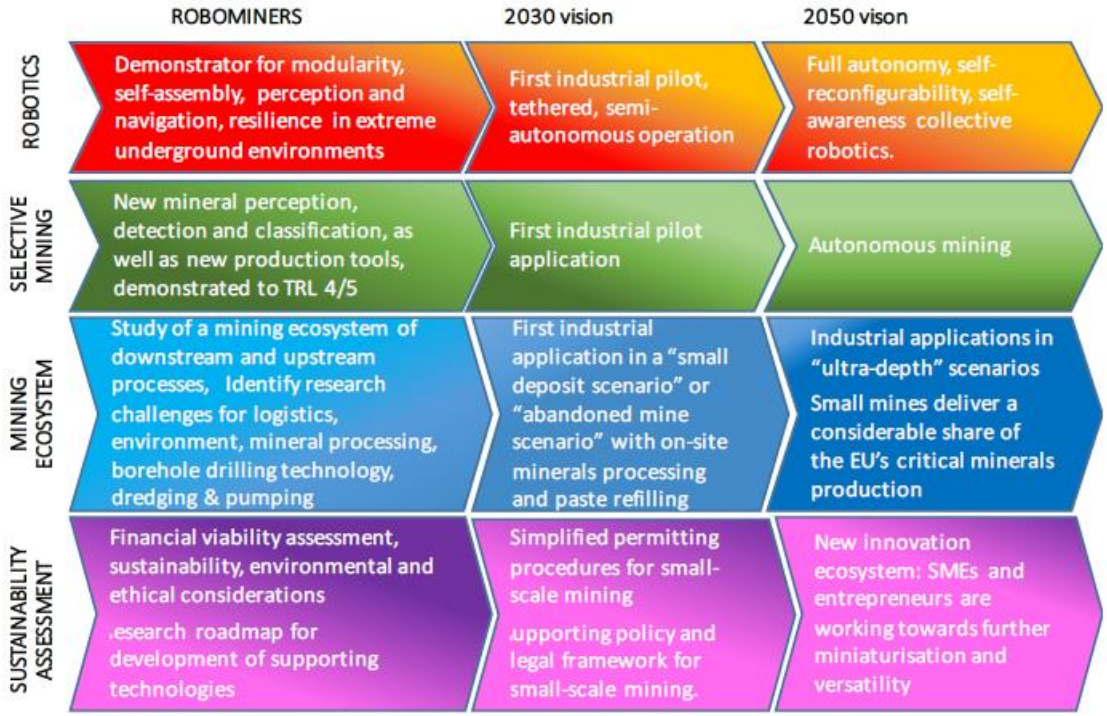

Figure 3: Anticipated evolution of the ROBOMINERS technology to 2030 and 2050 (ROBOMINERS Consortium 2019)

Robotic solutions are entering underground mines today for research purposes, but will be able to remove humans out of dangerous and unhealthy environment in the coming three decades. And do their work – but a lot of research and development work is ahead to achieve this.

ACKNOWLEDGEMENTS

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