Why robotics in mining?

Henryk Karaś, Sherpa Group in EIP on RM, KGHM Polska Miedź; Provisional coordinator „Robotics in Mining” SPARC Topic Group

“Pushing boundaries beyond - Circular by 2020?”
International Conference on New Technologies and Policies for Mining and Mining Products; Dublin; 9th March 2015
Content of presentation.

1. Automation in mining – EU and other initiatives.
2. Mining in SPARC program.
The main problems to overcome in deep underground mining operations (below 1 200 m) are:

- Significant increase of rock pressure, which has influence on rock stability, occurrence of seismic events and rock bursts;
- Rising temperature of rock (between 50-55 °C at KGHM copper orebody) which requires much better ventilation, air conditioning, lower gas emission and better dust control;
- Mining operators are entitled to ensure healthy and safe working conditions;
Challenges for future metal mining operations.

**BASIC PRE-CONDITIONS FOR AUTOMATION**
- Rock Mass Characterisation
- Predictive Maintenance
- Condition Monitoring of ZEPA vehicle

**BASIC TECHNOLOGIES FOR AUTOMATION**
- Communication
- Localisation systems
- Road and Traffic Management

**REPLACING HUMANS IN ZERO ENTRY PRODUCTION AREAS**
- Human in Automated systems
- Augmented Reality
- Automated Inspection and Image Analysis
- Autonomous Patrolling Robots

**APPLICATIONS**
- Continuous mining
- Automated drilling
- Automation of Loading and Transportation
- Automation of Charging
- Automation of scaling and reinforcement
- Automation of Media Installation

After Prof. Håkan Schunnesson; Division of Mining and Geotechnical Engineering, LTU, Sweden
1. The machines that mine and move the ore will be increasingly controlled remotely and more automatically, with instrumentation on the machine helping define the value of the ore being removed.

2. That operation will continue to move personnel away from the working face, with integrated sensors warning in advance of the need for maintenance, to ensure that technicians no longer have to carry that out in the mining area.

3. Distributed sensors, and real-time mine models will operate to increasingly monitor mining operations, to reduce personnel and to increase levels of safety from a wide range of hazards, ranging from roof falls, to emissions and ignitions of gas and the start of fires underground.

David A. Summers, Curators’ Professor of Mining Engineering Missouri University of Science and Technology

Source: VENTYX, ABB; December 8, 2011 Predictions for the Future Research ©2011
„Intelligent Mine” implementation in Europe.

Helsinki University of Technology, Finland

source: Prof. Pekka Särkkä, HUT, Finland
Outline of the RWTH Aachen initiative (2008)
Intelligent Deep Mine project in FP7.

"The Intelligent Deep Mine"

- Mine-wide Information Network
- Remote controlled and Autonomous Equipment
- New Sensor Technologies
- Intelligent Mass Flow Management
- Mining Methods
- Ore, Industrial Minerals, Coal
- Critical Raw Materials
- Green Mining
- Lean Mining
- Transport and Logistics
- Working Environment
- Ground Control / Rock Mechanics
- Near to face Processing

ETP SMR Meeting, Aachen, 2009.12.16
Nordic Rock Tech Centre AB (RTC) established a consortium for the conceptual study “Smart Mine of the Future” (SMIFU) to develop a common vision for future deep mining (2009-2012).

1. Taking the advantages of advance in automation and robotics based on IT and ES technologies, the deep mining will require the wide use of remote monitoring and controlling of all underground operations.

2. The future mine will need remote controlled production for unmanned processes, mine-wide information network for all autonomous machines. This is the vision for the “Smart Mine of the Future” which encompasses:

- removing people from hazardous environments;
- can give Europe the technological leadership in resource-efficient production of raw materials
- design Next Generation machines to operate remotely and autonomously;
- introduce integrated and intelligent monitoring and control systems;
- create future perspectives for extractive industry with newly manufacturing technologies.

Göran Bäckblom, LKAB, project leader-the VINNOVA „Mine of Future” project, Sweden (2009-2010)
KGHM - Boliden- LKAB; future vision as an inspiration for new solutions in future technological operations in mining (2010).

- One control room;
- Zero entry mine;
- Mine – attractive and safe place to work;
- Continuous mining;
- Pre-concentration;
- **On line monitoring** of mining and mineral processing operations.

source: Report „Setting the Scene: „ Smart Mine of the Future” (SMIFU) – stage I, .
I2Mine – FP7 UE funded project:


1. I²Mine project will develop some innovative projects to execute the vision of Intelligent Mine.

2. EU expects innovative methods, technologies and machines enabling efficient and safe extraction of minerals from deep laying deposits.

I²Mine is the biggest EU RTD project in extractive sector funded by FP7 grant.
Looking for international cooperation between EIP on RM and world RTD centers in automation and robotics in mining.

source: Prof. Håkan Schunnesson, LTU, Sweden, Mine Automation Key Research and Development Partners: Universities, Research Institutes and Companies
The “Robolution” in mining – Canadian example. The first phase has been accomplished, the others have lagged.
Examples of commercially available systems for LHD automation.

A tipically, remotedly steered LHD vehicle is equipped in 150 sensors.

source: Prof. Håkan Schunnesson, LTU, Sweden, Mine Automation Key Research & Development Partners: Universities, Research Institutes and Companies
Main Target – increased efficiency.

Mining activities during 24 hours

- It is not unusual that the face utilization in underground mines is typical 25%. This usually due to reasons such as:
  - Blast ventilation, machine breakdowns, shift changes, lunch breaks and travel time within mine reduce face utilization
  - The complex sequencing of mine operation combined with a variable environment challenges optimization of production
- Mine Automation makes it possible to run a underground mine 24/7 and enhance the face utilization. Open pit mines and underground can optimize machine utilization
- Autonomous Machines enables huge improvements but requires huge investments and takes time to implement
- **A Mining Operational Centre** enables improvements both in short and long term
  - Easy and fast to implement
  - Requires an existing datacom infrastructure

Hans Wahlquist; Director Business Development | Mobilaris AB; Sweden
New knowledge and mobilization of existing competence should contribute to:

- Safer mines through remote control and automation
  - No Human Exposure to Production Faces (Short term goal)
  - No Humans in the Mine (Long term goal)
  - No Accidents

- Maximize the production efficiency in existing and new processes; (example of Swedish underground mines).

- Optimize the complete production chain from mine to mill to customer through integrated process control systems.
Real and sustainable productivity improvements may require significant adjustments including changes to mine plans, reassessment of mining methods, changes to equipment fleet and configuration, and increasing automation.
euRobotics was founded on 17 Sep 2012 by 35 organisations. By May 2014, euRobotics represents 182 companies, universities and research institutions, ranging from traditional industrial robotics manufacturers to producers of agricultural machinery and innovative hospitals.

With €700M in funding from the EC for 2014 – 2020, and triple that amount from European industry (€2100M) SPARC is the largest civilian-funded robotics innovation programme in the world.
The Public Private Partnership in SPARC program.

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SPARC - Operating Environment.

There are six primary operating environments for robots in SPARC;

- on the ground, *(incl. mining)*
- in the air,
- underground *(incl. mining)*
- underwater *(seabed mining)*,
- in space *(incl. mining)*
- inside the human body.

1. Robotics technology has the potential to impact on a number of social challenges both directly and indirectly.

2. It is also recognised that robotic mining may be the only way of extracting the significant mineral resources that lie deep in the earth and under the oceans.

Why Robotics is important to Mining?

Robots will transform almost every industry and service sector. Examples for extractive sector area.

1. Robots have the potential to provide cost effective services in environmental monitoring.

2. Their ability to map and monitor large spaces (underground, under water, and from the air) will provide a new and cost effective means to gather valuable information important for mining and smelting operations (monitoring of environmental pollution).

3. Robots provide the means to work in hazardous environments improving safety for emergency service workers, in mining and mineral extraction and in mine closure/decommissioning.

Seabed mining – an example of solution.

High technology, high quality products, less waste, low pollution of environment.

Production support vessel

Seafloor production machine.

Ore transport on the surface

source: New Frontiers - Ocean Minerals Exploration and Development; Jonathan Lowe V.P. Strategic Development and Exploration; Brussels; 14 June, 2014
It is highly likely that improved equipment and better mining techniques will enable extraction of minerals at greater depth and under the sea.”

Commercial Domain - Mining and Minerals.

1. There is a long standing use of robots and remote guided vehicles in the oil and gas sectors and more recently in mining.

2. Many of the Mining and Mineral industries operate within hazardous environments and the extraction of earth resources is often limited by the level of risk associated with human working conditions.

3. There is a significant opportunity to utilise robots for extraction in order to reach more inaccessible mineral resources. In particular there are considerable mineral resources on the deep ocean bed where robots could provide the solution to long term and viable extraction.

An example of robot primary functions to carry out some mining operations.

**Surface Process:** The function of applying a process to a flat surface or the surface of an object. *This could be spraying, scraping, drilling holes.*

**Interaction:** The function of interacting with either a human or another machine or robot.

**Exploration:** The function of exploring an unknown or partially known space with the goal of mapping that space or the specific goal of, for example, *finding a person, resource or location.*

**Transporting:** Transporting involves orienting and moving objects or people between known *start and end locations, movements* may be over short or long distances.

**Inspection:** Mapping and scanning the space to monitor specific parameters or mapping for specific purposes, *for example monitoring pollution.*

**Grasping:** The function of holding and orienting an object, tool or person. Includes *firstly identifying and then working out how to hold the object.*

**Manipulation:** The function of utilising the characteristics of a grasped object to achieve a task. For example: *charging explosives in drilled holes.*
KGHM is going to develop mining activity program both in Poland and world-wide.

- **Canada, Ontario**
  - Victoria (Cu, Ni, Pt, Pd, Au)
  - Sudbury region exploration

- **Canada, B.C.**
  - Ajax (Cu, Au)

- **USA, Nevada**
  - Robinson (Cu, Au, Mo)

- **Chile**
  - Franke-Pelusa (Cu)
  - Sierra Gorda (Cu, Mo, Au)
  - Atacama region exploration

- **Greenland**
  - Malmbjerg (Mo)

Source: KGHM
KGHM operates on the one of the biggest resources of copper ore in the world.

Source: KGHM
When going down to the level 1500 m in mining operations new solution in underground operations became more challenging at KGHM.

- Minimising ore dilution and copper ore losses in low seam copper ore deposits;

- Eliminate human exposure in deep underground conditions (hot rock temperature, humidity, gas and diesel fuel emissions, dust, noise, rock burst hazards);

- When going deeper most of of underground mining operations should be run from remote places.

- Implementing automated communication and data transfer systems in mining operations.
KGHM participates in numerous R&D projects focused on innovative technologies in mining.

- Innovative systems to access and explore deposits – automated technologies, biometallurgy and hydrometallurgy (BioMore) that will allow previously unmined deposits to be reached.
- Minimizing human presence in hazardous areas (I2Mine)
- Automation of production processes. Usage of artificial intelligence and Big Data (Robotics in Mining)
- Online mineralogical and chemical analysis in production processes

Roadheader MH 620 (SANDVIK) in Lubin Mine and Polkowice-Sieroszowice mine at KGHM

Testing the longwall complex (ACT Caterpillar, USA) with continuous mining at a copper ore mine, KGHM; 2014

Source: KGHM
SPARC topics groups which could be important for developing autonomous mining operations.

<table>
<thead>
<tr>
<th>Total number of SPARC Topic Group (33)</th>
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<tbody>
<tr>
<td>Autonomous Navigation</td>
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<tr>
<td>Benchmarking and Competitions</td>
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<tr>
<td>Artificial Intelligence and Cognition in Robotics</td>
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<tr>
<td>Industrial Robotics</td>
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<tr>
<td>Maintenance and Inspection</td>
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<tr>
<td><strong>Marine Robotics</strong></td>
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<td>Mechatronics</td>
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<td>Miniaturised Robots</td>
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<tr>
<td>Perception</td>
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<tr>
<td>Physical Human Robot Interaction</td>
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<tr>
<td>Software &amp; Systems Engineering, System Integr.,</td>
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<tr>
<td>Telerobotics and Teleoperation</td>
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<td>(...)</td>
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<tr>
<td><strong>Robotics in Mining ?</strong></td>
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Overview of calls in H2020/ICT-24 Robotics in 2015

<table>
<thead>
<tr>
<th>Roadmap-based R&amp;I in Robotics</th>
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<tbody>
<tr>
<td>Deadline: 14 April 2015</td>
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<tr>
<td></td>
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<tr>
<td>• ACTION TYPE</td>
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<tr>
<td>• Funding %</td>
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<td>• Size</td>
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<td>€83m</td>
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<tr>
<th>ICT24.a – Research &amp; Innovation Actions</th>
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<tr>
<td>Priority market domains: healthcare, consumer, transport</td>
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<tr>
<td>Advance key technologies for priority domains</td>
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<tr>
<td>RIA 100% Small/Large</td>
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<td>€50m</td>
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<th>ICT24.b - Technology transfer</th>
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<tr>
<td>Industry-academia cross-fertilisation</td>
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<tr>
<td>IA 70% Large</td>
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<td>€12m</td>
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<tr>
<th>ICT24.c - Technology transfer</th>
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<tr>
<td>Robotics use cases</td>
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<tr>
<td>IA 70% Small/Large</td>
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<td>€12m</td>
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<th>ICT24.d - Pre-commercial procurement in robotics: especially healthcare</th>
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<tr>
<td>Pcp 70% Large</td>
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<td>€5m</td>
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<th>ICT24.e - Community building and robotics competitions</th>
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<tr>
<td>CSA</td>
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<td>€4m</td>
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The first step to establish topic group (TG) - Robotics in Mining in EU SPARC program is setting up international consortium to apply for EU-funding in H2020/ICT 24e Coordination and Support Action (CSA) - Community building and Robotic competitions.

Source: Conference Robotics Horizon 2020 ICT Call 2 – Brussels, 9 December 2014
ICT 24.e Coordination and Support Action (CSA). Topics in Community building and Robotic competitions.

- Supporting the European robotics community;

- Networking, education, outreach, public awareness, technology watch, standardisation, and industry-academia collaboration, links to national programmes and initiatives.

- Ethical, legal, societal and economical aspects

- International cooperation (intra or extra-EU) impact to be demonstrated, matching resources expected

- Coordinating work on the next generation of cognitive systems and robotics.

Source: Juha Heikkilä, PhD; Head of Unit Robotics DG for Communication Networks, Content and Technology Second Horizon 2020 Call Robotics – ICT24
Conclusions.

1. One of the biggest challenges the mining industry faces today is the ability to manage the complete the entire value chain as one operation.

2. Ensuring worker safety in deep underground mining operations is another challenge going forward. As an industry, we’re trying to remove people from dangerous situations by leveraging greater mechanization and automation.

3. Solving the problems of deep underground metal mining can give Europe technological leadership in the resource-efficient production of raw materials.
Thank you.

http://www.sparc-robotics.net/about/

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