ROBOMINERS

Resilient Bio-inspired Modular Robotic Miners

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The Centre for Automation and Robotics

Staff: 140 (approx)
- 30 permanent researchers
- ≈ 90 researchers: PhD candidates, PostDocs and Visitants
- 10 technical assistants and 10 admin assistants
Project’s quick facts

- **Call Topic:** SC5-09-2018-2019 “New solutions for sustainable production of raw materials” (RIA)
- **Project duration:** 48 months
- Project total cost/ EU contribution : 7,4 M€
- Coordinating entity: Universidad Politécnica de Madrid
- Country: Spain
- Project web site: [www.robominers.eu](http://www.robominers.eu)
- 14 partners, 11 European countries
  - Geo-scientific SMEs (LPRC, GEOM, KUTEC, RCI)
  - Academics covering both mining (UNIM, MUL) and robotics (UPM, TALL, TUT)
  - Non-governmental (ASSIM, EFG)
  - Governmental (GeoZS, RBINS, IGSMIE)
Objective

To develop a **bio-inspired, modular and reconfigurable** robot-miner

For **small** and **difficult to access** deposits

Equipped with **selective mining** perception and mining tools

That can be **delivered in modules** to the deposit via a large diameter borehole

Mining underground, underwater in a flooded environment.
1. Robot parts (modules) are sent underground via a borehole
2. They self-assemble to form a fully functional robot
3. Using specialised sensing devices, they detect ore
4. They produce slurry that is pumped out
5. They can re-configure on-the-fly
**Targeted mines**

- **Abandoned mines.** ROBOMINERS presents a solution for reopening many of Europe’s abandoned underground mines, **without the need for a full recommissioning and in particular without the need for dewatering the mine.**

  **Left:** Metals mined from the Cornwall mineralised belt. **Right:** Ruins of the abandoned Botallack Mine in Cornwall. Operating from the 1500s to 1895, Botallack was once one of the greatest copper and tin mines in England.
Targeted mines

- **Ultra depth.** Under this application scenario a large diameter borehole will be drilled from the surface to the deep-seated deposit.

Extension of the Kupferschiefer Formation
• **Small but high grade mineral deposits.** *The proposed technology does not require the development of any mine infrastructure and even very small deposits can be mined.*
Specific objectives

🛠 Construct a fully functional modular robot miner prototype capable of performing selective mining

✅ Validate all key functions of the robot-miner to a level of TRL-4.

💻 Design a mining ecosystem of expected future upstream/downstream raw materials processes via simulations, modelling and virtual prototyping

🛠 Use the prototypes to study and advance future research challenges on
   • scalability, resilience, re-configurability, self-repair, collective behavior, operation in harsh environments,
   • selective mining,
   • production methods, as well as for the
   • necessary converging technologies on an overall mining ecosystem level.
• **Bio-inspired, modular and reconfigurable**

*Inspired on insects and burrowing animals*  
*2D and 3D feeding patterns as shown by trace fossils.*
- Bio-inspired, modular and reconfigurable
• **Bio-inspired, modular and reconfigurable**

**Tech specs:**
- 0.5-1 ton
- 20-30 kW
- Hydraulic
- Tethered

COTS artificial muscles
• **Bio-inspired, modular and reconfigurable**

Modular robotic platform.

Each leg is a completely autonomous robot, equipped with CPU, batteries and comms.

The end-effector is changeable.

Used to validate the concepts that are being discussed in Robominers.

*(Source: M. Hernando, UPM)*
The miner

• Big robot, small mining machine

- Robominers (0.5-5 T)
- Industrial robots
- Autonomous driving cars/machines, singular designs
- Conventional drilling machines
- Tunnel boring machines, draglines, large trucks
- Bio-inspired robots
- Mobile robots
- Toy robots
- Micro-nano robots
Selective mining/1: sensing

Instrumentation strategies for **in-stream** elemental analysis:
• high sensitivity solid state XRF spectrometer / LIBS spectrometer and Gamma-Ray spectrometer.

Instrumentation strategies for **in-stream** molecular analysis:
• Optical UV-VIR-NIR techniques, including Resonance UV Raman spectroscopy, time resolved VIS Raman spectroscopy, NIR absorption spectroscopy and LINF spectroscopy.
Selective mining/1: sensing

• “Digestive” mineralogy
Selective mining/1: sensing

• “Digestive” mineralogy
Selective mining/1: sensing

• “Digestive” mineralogy
Selective mining/2: production

Production tools

• Tricone drill bit
• Hydrodemolition
• Cavitation
• Micro-blasting?
• Need of a **new approach to mining strategy and mine design**

• Studying and simulating the various systems components in future mining scenarios

• Creating a **simulated environment for the entire mining operation**, considering
  • drilling methods
  • mineral exploration
  • minerals processing and transport options
  • power supply scenarios
  • mine design and mine geometry

• Micro and macroeconomics studies
**Vision**

**Robotics**
- **Robominers**: Demonstrator for modularity, self-assembly, perception and navigation, resilience in extreme underground environments.
- **2030 Vision**: First industrial pilot, tethered, semi-autonomous operation.
- **2050 Vision**: Full autonomy, self-reconfigurability, self-awareness collective robotics.

**Selective Mining**
- **Robominers**: New mineral perception, detection and classification, as well as new production tools, demonstrated to TRL 4/5.
- **2030 Vision**: First industrial pilot application.
- **2050 Vision**: Autonomous mining.

**Mining Ecosystem**
- **Robominers**: Study of a mining ecosystem of downstream and upstream processes, identify research challenges for logistics, environment, mineral processing, borehole drilling technology, dredging & pumping.
- **2030 Vision**: First industrial application in a “small deposit scenario” or “abandoned mine scenario” with on-site minerals processing and paste refilling.
- **2050 Vision**: Industrial applications in “ultra-depth” scenarios. Small mines deliver a considerable share of the EU’s critical minerals production.

**Sustainability Assessment**
- **Robominers**: Financial viability assessment, sustainability, environmental and ethical considerations.
- **2030 Vision**: Research roadmap for development of supporting technologies.
- **2050 Vision**: Simplified permitting procedures for small-scale mining, supporting policy and legal framework for small-scale mining.
- **2050 Vision**: New innovation ecosystem: SMEs and entrepreneurs are working towards further miniaturisation and versatility.
Thank you!