Underwater exploration and mining, the UNEXMIN project

Norbert Zajzon coordinator and the UNEXMIN team

- MIN-GUIDE Policy Laboratory 2: Innovations and supporting policies for minerals exploration and extraction, Leoben, 21-22\textsuperscript{nd} of March 2017

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON H2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO 690008.
KEY FACTS ABOUT THE PROJECT

EU funded H2020 research project (RIA: Research and Innovation Action)

Grant Agreement number: 690008 (H2020-SC5-2015)

13 partners (7 countries)

45 month duration

(1st of February 2016 – 31st of October 2019)

Funding sum: ca. 4.87 million Euro

Deliverables: Three working prototype robots

Spin-off company offering the technology
ABOUT THE PROJECT: CONSORTIUM

- University of Miskolc
- Tampere University of Technology, Department of Mechanical Engineering Systems
- Universidad Politécnica de Madrid, Centre for Robotics and Automation
- Inesc Tec – Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência
- Resources Computing International Ltd
- La Palma Research Centre for Future Studies
- Geological Survey of Slovenia
- Geoplano Consultores Sa
- The European Federation of Geologists
- Geo-montan Kft
- Empresa de Desenvolvimento Mineiro
- Ecton Mine Educational Trust
- Center za Upravljanje z Dediscino Zivega Srebra Idrija

Technology development

Technology exploitation

Key stakeholders
ABOUT THE PROJECT: CONCEPT

- There are of the order of 30,000 closed mine sites in Europe and many of them potentially contain considerable amounts of valuable mineral raw materials.

- The closure of a mine is usually more related to economics and technological challenges than to the actual depletion of mineral resources.

- Often minerals were disregarded during the operational life of the mine (such as fluorite in lead/zinc mines).

- These mines are now flooded and the last piece of information of their status and layout is decades or over a hundred years old.
ABOUT THE PROJECT: CONCEPT

Physical Appearance
• Max operational depth: ~500m
• Shape: spherical
• Size: ~ 0.6 m diameter
• Expected weight: 112 Kg
• Neutral Buoyancy
• Power consumption: 150–300 W
• Max speed: 1–2 Km/h
• Autonomy: up to 5 hours
• Thrusters power: 2–5 Kgf

Propulsion:
• one tail thrusters (2), plus two thrusters for longitudinal (sway) motion (8) Vertical
• movement (heave): based on buoyancy control (3) and vertical thrusters (4)
• Attitude control (pitch and yaw): pendulum-based (displacement of the centre of mass)
ABOUT THE PROJECT: GOALS

- The project will use cutting edge science and technology from deep sea robotics to develop a **fully autonomous robotic surveying** solution for mapping abandoned and flooded deep mines. **Major technical challenges** are related to the harsh environment, mine depth and the need for autonomous navigation and mapping of semi-structured environments, while at system level the **major focus will be on robustness and dependability.**

**Specific goals**

- Design and build a multi-platform robotic Explorer for autonomous 3D mapping of flooded deep mines
- Demonstrate the operation of the prototype at a set of representative pilot sites
- Develop an open-source platform for technology transfer and further development
- Develop a research roadmap in support of further technology development
- Develop commercial services for exploiting the technology
ROBOTIC FUNCTIONS VALIDATION
(LAYOUT AND BLUEPRINTS)

- Technical specifications
  - Maximum operational depth: 500m
  - Shape: Spherical with diameter 0.6m
  - Material: Aluminium Alloy

- Subsystem models
  - Propulsion
  - Ballast
  - Pendulum

- Structural part
  - Middle Pressure hull
  - Two Lateral pressure hulls

- Strength analysis
  - The hull is under 5 MPa pressure
  - Maximum stress inside the manifold
STABILITY TESTS IN POOL

https://youtu.be/P9OalHRc-Fg

Acceleration [m/s²] vs Horizontal Thrusters [ERPM]

Angle [degrees] vs Horizontal Thrusters [ERPM]
SLS – ROTATING LASER AND ILLUMINATION – PROTOTYPE PRESSURE TEST

- Completed first working prototype
- Laser and LEDs in cylinder
- 7 light LED
- 5 UV LED (3W each)
- Trigger control for Laser, lights and UV …

Current prototype resisted 130 bar
(max. limit of the chamber)
SCANNING SONAR TANK TESTS (small iron anchor) AND SIMULATION

- Software driver interface developed (WP3)
- ROS integration (WP3)
- Simulation model developed (Gazebo)
- Preliminary tank tests

Simulation
SLS AND MULTIBEAM COVERAGE SIMULATION

- Sensor simulation in UWSim /ROS
- Coverage analysis (Ecton mine data)
- Cameras, laser stripes and multibeam sonar
Selection of possible (feasible) methods:
  Limitation: physics (environment), prices, time
  Other limitations: size (weight, energy), attitude (non-contact, continuous movement)

Selected devices:
• pH measuring unit
• Magnetic field measuring unit (3 axes flux-gate sensors)
• Natural (integral) gamma ray activity measuring unit
• Electrical conductivity measuring unit
• Water sampler unit
• Multi-spectral unit
• UV fluorescence imaging unit
• Sub-bottom sonar
MAGNETIC FIELD MEASUREMENT (LAB-TESTS)

MCP-9701
Integrated temperature sensor.
(Own development)
WATER SAMPLER AND STORAGE UNIT

- Number of collected samples: 16 pcs
### FLUORESCENT IMAGING
Long UV (and short UV?)

<table>
<thead>
<tr>
<th>Part number</th>
<th>Voltage (V)</th>
<th>Current (mA)</th>
<th>Wave Length (nm)</th>
<th>Output power (mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TY-365nm 10W</td>
<td>12-13V</td>
<td>900-1200</td>
<td>365-370</td>
<td>320-360</td>
</tr>
</tbody>
</table>

- **Visible light**
- **Visible + 365 nm UV, no filter**
- **365 nm UV, no filter**
- **365 nm UV + filter**
The multispectral system has two units:
- lightning module (LED light and control)
- camera module
MULTISPECTRAL CAMERA LIGHTNING – IMAGING – POST-PROCESSING

Post processing:
- Building xyz-point database
- Multiple corrections to create spectra of the points
- Search, evaluation, identification → visualization
Work package 3

Autonomy for mine exploration and mapping

AN AUTONOMOUS UNDERWATER EXPLORER FOR FLOODED MINES

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON H2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO 690008.
3.1 MIDDLEWARE

- Defining basic software architecture (UPM)
- Defining NODES specific attributes and services/interfaces (UPM+INESC)
3.4 ATTITUDE CONTROL

• First 1:2 scaled prototype (30 cm diameter) realized

• Test attitude mechanisms (open loop)
  • Pendulum for pitch control
  • Spinning disc for yaw control

• Second scaled prototype with UX-1 manifolds system under construction
  • Pendulum for pitch control
  • Thrusters for yaw control
3.5 NAVIGATION

• Task started in advance w.r.t. scheduling

• Analysis of possible scenarios started already

• Creating virtual environment (in GAZEBO) for GNC simulations under development
AN AUTONOMOUS UNDERWATER EXPLORER FOR FLOODED MINES

Work package 4
Multi-robot platform development

(Swarm of robots (3 pcs.) working simultaneously and sharing data...)
DEMONSTRATION, PILOTS

- Kaatiala, Finland
  - Pegmatite mine
  - Open-pit and small underground part
  - Robot recoverable by divers

- Urgenicia, Portugal
  - Uranium mine
  - It is completely flooded
  - Water level 12–20 m below surface

- Idrija, Slovenia
  - Mercury mine
  - UNESCO Word Heritage site

- Ecton-mine, England
  - Cu – (Zn-Pb) mine (MVT type)
  - National monument site
POST-PROCESSING AND DATA ANALYSIS

- Data standards defined, documented, and agreed
- Database structure defined.
- Database management system selected (SQLite) and import data file formats and content defined for navigation and sensor subsystems
- Core point-cloud modelling and visualisation coding completed and demonstrated on a large sample data set
- Data conversion requirements for navigation and sensor systems agreed with consortium partners
- Post-processing applications requirements and specifications currently under review
Objectives:

✓ The identification of Stakeholders and the further extension of the Advisory Group
✓ To map, understand and process Stakeholder views and requirements
✓ Collection and analysis of Stakeholder requirements for creating an initial specification of UX-1
✓ Creation of **detailed stakeholder database** as well as a **database of flooded mines** (including contact details with ownership status) that will serve afterwards as a starting point for the commercial exploitation of the technology
✓ **Adaptation** of the robot design to Stakeholder needs and try to develop day-to-day working contacts with future customers.
**Task objective:** An on-line, public access inventory of potential target mines in Europe will be created

- focus will be on mines that cannot be surveyed by any other mean due to complex typology or a range of depth that is below the range of scuba divers (max 50 m)
- metallic minerals will be of primary importance, but others also
- existing databases will be reviewed (PROMINE & Minerals4EU) - **DONE**
- missing data will be collected from mine authorities covering at least 24 countries - **IN PROGRESS**

**Task timeline:**

- **Step 1:** Define relevant categories in the data collection template (End October, 2016 template prepared) - **DONE**
- **Step 2:** Data collection (start November 2016 – May 2017) - **IN PROGRESS**
- **Step 3:** Data compilation and preparation (June-July 2017)
- **Step 4:** Inventory online (October 2017)
- **Step 5:** Deliverable 5.4 ready (December 2017)
UNEXMIN DISSEMINATION CHANNELS AND MATERIAL

- Website developed and continuously updated
- Blog (News in the website – 2 per month)
- Brochures (First in 7 languages; Second in development)
- Press releases (three issued)
- Documents (images, deliverables, presentations) available for download
- Social Media: Twitter, Facebook, LinkedIn, Youtube
- Wikipedia: UNEXMIN, Mine dewatering, Flooded mines

Can be accessed through website

http://www.unexmin.eu/
UNEXMIN WEBSITE AND SOCIAL MEDIA STATISTICS – JANUARY 2017

- > 10,000 visitors
- > 44,000 visits
- 755 search engine referrals
- Top visiting countries: Spain, Portugal, United Kingdom, Hungary

Results surpassing expectations for first project year

- Facebook: 59 likes on page; 143 likes on publications; 16 shares on publications
- Twitter: 79 followers; 66 tweets; 32 retweets; 41 likes on publications
- LinkedIn: 31 followers; 11 likes on publications
- Youtube: 3 videos; 252 views
  (since (less than 2 months) 4 videos / 650 views!!)

Results meeting expectations for first project year

Raising awareness for stakeholders groups: Raw materials community; Technology developers for mineral exploration; ICT and robotics solutions providers; General public
TECHNOLOGY EXPLOITATION POLICY 1

- Raw materials exploration
  - Early stage of exploration (to continue with drilling, or no)
  - Proper calculation of reserves

- Water reservoirs
- Pipeline investigation
- Cavity measurement (salt mines)
- Cave system exploration
- Cultural heritage sites
- Rescue
- Ship-wrecks
- Ect…
Offering service with the developed equipment

- Further develop the existing instruments / sensors
- Develop new instruments
- Open-source platform for customer developed instruments
- Modification of the UX-1 series
  - Long-range version with extra batteries vs. scientific instruments
  - Ect…
- UX-2 series: sampling / drilling
- Other directions of development:
  - Bigger depth capability
  - Longer mission range
  - Smaller version for more confined spaces
  - Ect…
Partial utilization of the technology

- Sensors / instruments for regular and other underwater mining
  - Exploration, selective mining, innovative commodity processing
- Robotic control (automatic operation)
- Multi-robot platform adaptation
- Post-processing, data evaluation software
- Inventory of flooded mines
- Space applications
Thank you for your attention!

http://www.unexmin.eu/