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The ROBOMINERS mineralogical sensors: spectrometer prototypes for autonomous in-stream, in-slurry geochemical diagnostics.

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ROBOMINERS (Bio-Inspired, Modular and Reconfigurable Robot Miners, Grant Agreement No. 820971, http://www.robominers.eu) is an European project funded by the European Commission's Horizon 2020 Framework Programme. The project brings roboticists and geoscientists together to explore new mining and sensing technologies and demonstrate a small robot-miner prototype designed to exploit unconventional and uneconomical mineral deposits (technology readiness level 4 to 5). This approach could change the current mining paradigms dictated by larger existing machines, while reducing mining waste and environmental footprint (Lopez and al. 2020).

One of the key function of ROBOMINERS is the “selective real-time mining”, in other words the ability for the miner to choose an optimal progression path while mining in a particular orebody geometry (inspired by the petroleum industry geo-steering technique). This will be done by a continuous monitoring of the surrounding rock properties (hardness, abrasivity, electrochemistry, thermal conductivity, 3D electrical/induced polarization tomography), and by a “digestive mineralogy” unit, performing on-board mineralogical/geochemical diagnostics of the extracted material.

After an extensive review and tests on existing sensing techniques, the consortium selected a few sensing methods, based on the considered environment (underground gallery drilling, mud/slurry-filled environment with very limited to no visibility) and the opportunity to test proven techniques as well as original methods that can be distributed on and in the miner body.

Mineralogical sensor prototypes on ROBOMINERS are articulated on 3 techniques : multi/hyperspectral reflectance, UV fluorescence and Laser-induced breakdown spectrometry (LIBS). The first two techniques are well established and easily integratable on a robotic platform. ROBOMINERS will demonstrate how miniatirization/distribution of these sensors on and in the robot can yield fast diagnostics from the excavated material. LIBS is a very interesting atomic emission technique for real-time monitoring of slurries with fast multi-element detection and low detection limits, even on light elements. It has been already used as a competitive approach to monitor slurries using flow cells in mining (Khajehzadeh et al., 2017) and inside molten metals in metallurgy applications (Moreau et al., 2018). LIBS typically achieve fast and sensitive analysis in a

few micro- to milli- seconds. While true quantitative measurements remain a challenge outside a controlled lab environment, qualitative and semi-quantitative measurements are possible and is very relevant for ROBOMINERS selective mining application.

The work presented here deals with the conceptualization of the spectrometer suite. Tested slurry analogs include mixtures of lead-zinc sulfides, copper cobalt oxides, phosphorites and oil shales. Once an fixed instrumental setup is selected, the next development steps include retrofitting for testing in an industrial scale slurry circulation system at the K-UTEC facilities (Sondershausen, Germany) and, after validation of all components, integration on the ROBOMINERS prototype for the field demonstrations planned in 2023.

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