SPECIAL TOPIC

Near Surface Geoscience

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Can you tell us about yourself and your team?
I am Alireza Malehmir, the scientific coordinator of Smart Exploration. I am also the task leader for providing the GPS-time transmitter system in GPS denied environments. My specific role is to develop solutions and formulate them with other partners. For some time, I have been calling for such a solution to be applied in the mineral exploration and tunneling industry.

Uppsala University and Mic Nordic have collaborated to develop the prototype. For the validation work we are working with partners such as Somincor-Lundin Mining and LNEG (Portugal). Three individuals form the team developing the prototype: Lars Dynesius and myself from Uppsala University and Tord Sjölund from Mic Nordic. We bring a wide range of expertise in electronics, design and manufacturing. For example, Mic Nordic specializes in indoor mobile signal technologies for hospitals, exhibition halls, shopping malls and tunnels. Their products include FM, Tetra/Rakel, GPS, 1G, 2G, 3G and 4G solutions. Uppsala University specializes in hardrock seismics and came up with the idea of this invention.

What was the motive of developing such a GPS time transmitter for time denied environments?
Many experts in the mineral exploration industry regard the future of exploration to be deeper mining at depths of 800-2500 m. It is believed that the majority of shallow and giant deposits have already been explored and exploited. To sustain operating mines, avoid new environmental footprints and for financial reasons, brownfield and near-mine exploration is where exploration expenditure will be focused. Technical challenges (e.g., logistics and infrastructure and operational noise) around an operating mine limit the exploration techniques that can be used. For this reason, in-mine exploration becomes in most cases limited to mainly drilling and based on drill core observations. To improve exploration at depth and in operating mines, improved geophysical solutions are needed. Exploration should also help exploitation to be done effectively to avoid ore block loss and possible geological surprises during the mining operation. Mining and exploration infrastructure such as tunnels and boreholes can be used to partly tackle these issues.

As an example, most underground mining operations in Scandinavia are carried out using the block (sub-level) caving or cut and paste (or cut and filled) mining methods requiring many parallel mining and exploration tunnels (usually 50-100 m apart at the same level as ‘drift’) and also at different levels (50-100 m connected through access tunnels or ramps). Such tunnel layouts are ideal to set up a network of seismic sensors for an underground 3D seismic survey that can image structures and geology under the mining tunnels, or between them or between different levels as well as the hanging-wall. When combined with surface seismic recorders that are synchronized in time, this can allow us to capture the seismic wavefield between the tunnels and the surface and what happens to the seismic wave (e.g., amplitude and velocity) as it travels between the surface and the tunnels and vice-versa. In such circumstances, imaging vertical or very steep dipping structures would be possible (like half MRI scanning) by utilizing the underground space where synchronized receivers and sources are used.

When a full-scale experiment is conducted, for example using 100-1000s sensors on the surface and similarly in the underground space (simultaneous recording) one can (1) delineate the extension of existing ore bodies, (2) map fracture and fault systems, (3) study seismicity in deep stressed mines, (4) time calibrate existing mine seismometers, (5) study anisotropy due...
to mining-induced fracturing (unloading), (6) characterize ore quality, (7) optimize blasting, (8) explore ahead of mining and tunnelling and (9) perform 4D imaging and characterization (e.g., time-evolution of various mining blocks).

**How long did it take the team develop this prototype?**

We had the idea for this development work from an earlier survey where we were able to transmit GPS-time signals using cables (see Brodic et al., 2017). However, we knew this would not be possible everywhere hence a mobile system had to be developed to work at different depth levels or connecting one tunnel to another. It took 12 months before our first in-house test was successful. Within 14 months we were able to validate the system for an upscaling survey set-up at the Neves-Corvo mine in Portugal.

The task team met and worked together from the planning stage, design and tests. We made the system for the Neves-Corvo survey more robust, which was essential given the humidity and extreme conditions at 650 m depth.

**Can you explain how the system works?**

The GPS-time system developed here (Figure 1) is a hardware solution (physical prototype) that comes with a number of expert-knowledge experiments/surveys (how-to solutions). The system can transmit relative or real simulated GPS-time signals in closed spaces (e.g., tunnels) for several (10-1000s) readily available in the market sensors (e.g., within 1-3 days) in an easy and practical manner (1-2 persons and no requirement for extensive cabling from surface to the underground spaces).

As part of the development work, we also demonstrated why such experiments should be done and expanded to a different dimension than in the today’s exploration and underground mining/construction industries.

The solution is based on off-the-shelf components that are readily available in the market but not assembled as a whole for such a purpose. There are components in the development that are unique such as the ability to provide time signal for a distributed array of sensors (not only for a single point), practical in the sense that it does not need extensive cabling. Combined with fibre-optic technologies, attenuations of the GPS-time signal are considerably reduced for longer sensor arrays or going from one level of depth to another. If needed, multiple systems can be used in different depth levels independently without a cabling requirement at depth.

A great benefit of the system is that one does not need to modify existing recording sensors, which is a substantial saving.

**Are there any environmental or safety risks?**

Simplicity of the set-up and the lack of harmful components such as high-power electricity makes the system suitable for in-mine applications; limited set-up time and no need to stop any mine operation or access the mine communication or other cabling systems are other advantages in terms of safety. The system does no harm to the environment and is safe.

**Are there any other comparable systems available in the market?**

There are none available that provide a GPS-time signal in a modular manner to the same extent. Other GPS-time systems are only clock-based and in most cases can only feed one recording unit with true GPS-time or only relative time.

**Has the system proven to be successful?**

Laboratory tests (in Uppsala and using basement facility corridors/culverts) were first done (Figure 2), allowing us to GPS-time lock more than 20 wireless recorders/sensors (20 used here) in a pilot test examining the performance of the GPS-time system. Flashing green-red light indicator on the recorder means locking to GPS-time signal. The test was conducted in December 2018 in Uppsala using a long basement facility corridor. An accuracy of 10 microseconds was observed already at this stage.
What was the main challenge you faced during the development of this system?
Our main challenges were mostly technical in the sense that we did not know whether the signal strength and sensitivity would be sufficient. We worked quite a bit around this and made sure that we can adjust the signal level when needed using amplifiers. However, we had to make sure that the receiving units would not saturate if too strong a signal was transmitted. Other challenges were in obtaining parts and assembling them on time. The discussions among the partners were very useful in foreseeing risks and mitigating them as early as possible.

What difference can this solution make to the industry?
We think using a couple of case studies like the Neves-Corvo, more mining companies will realize how to use the system effectively for their exploration challenges. In fact, we recently leased the system for a survey using a simpler set-up than the Neves-Corvo but at greater depth for a deep underground mine survey in Sweden.

This system can be used anywhere where GPS-time for time-series analysis is required. We think besides the mining and mineral exploration industry, tunneling projects in urban settings, waste-storage monitoring and characterization can also benefit from this development work.

What is next step for this prototype? Will it be available in the market?
Given the broad application of the system and its commercial aspects in the mineral exploration and mining industry and for sensor manufacturers, through UU Innovation-Uppsala University and financial support, we were granted a Swedish patent for both the prototype and methods that the technology can cover. However, we feel that the system should be protected beyond Sweden and for this additional financial and market analyses are needed. During the patent application extensive search and review of existing technologies were carried out together with patent lawyers and UU innovation patent and IP experts to help us to better understand how to get the solution to the market.

The system has been leased for one commercial application so far and we hope for more. We have also met a few consultants and service providers. We have a market strategy and in the short term we are focusing on case studies and demonstration work.

Companies can rent, use our how-to solutions, but also buy. We have protected the IP through our patent application and PCT so this should be an incentive to people wishing to negotiate with us for various applications.

References