Contribution ID: **42** Type: **Plenary talk**

Thoughts about an ideal validation environment for muography applications

Friday 26 November 2021 09:00 (20 minutes)

Muography has many possibilities ranging from imaging volcanoes to observing civil infrastructures or even small scale objects. G.F. Knoll has laid out the fundamentals of radiation detection and measurement. However, what is still lacking is the testing and verification environments for muography detectors. In this work, we will present a few thoughts on such a possible muography test and method validation site.

As the target sizes for muography vary drastically, there is a need to have different detector technologies and assemblies. Most known applications of muography are linked to observing unknown (e.g., archaeological or geological target) or temporally changing (e.g., volcano monitoring) targets. There are also a lot of well-known but deteriorating targets within civil infrastructures. Data gathered from an alternative source(s), e.g., topographic maps, gravitational data, conductivity or magnetic field data, or seismic reflectivity data, to name a few, are used as reference material for the muography analysis. With Monte Carlo simulations, the muon background can be simulated and compared with the measured muon statistics to get a glimpse of what might be within the observed target.

For the data and method validation, an entry-level test environment is needed. It would be the most beneficial if it would be located on the surface, or at least relatively close to it, so that the muon flux measurements would be quick to carry out. Also, targets should be of high contrast compared with the surrounding environment, and the targets should be well-known objects what comes to their internal density profile and outer dimensions. For example, air against any liquid or solid target would create high contrast object and hence an ideal target for validating and testing muography detectors and imaging software. Using artificial targets such as 1 m3 concrete blocks or similar-size industrial containers filled with water, gravel, sand, or perhaps refined ore would provide an ideal object in size, cost and mobility. Additionally, a series of targets could contain integrated density anomalies (voids, denser structures) to enhance the validation tests related to contrast separation, angular resolution, inversion methods, and reconstruction of density profiles and tomographies. This could be called a micro-level validation environment.

At the macro level, the validation environment should be as authentic as possible. It should, for example, have access to a subsurface facility and known geological and infrastructural environment (e.g., a former underground mine with flat overburden would include all these qualities). In such a setting, the underground galleries, workings, and the tunnel network itself would make excellent muon radiography and muon tomography targets. Similarly, a micro-level validation environment would guide the validation process for testing the detector systems and the data reconstruction capabilities of the software. Additionally, it would be beneficial if there would be stockpiles of sand, gravel, etc., on the surface, and these would have variable sizes, or some of them could be reshaped or changed in terms of size. They could be used to validate both the spatial resolutions of the chosen detector assemblies and the threshold limits for observing the temporal changes.

We propose that the Callio Lab, a science and R&D site located at the 1.5 km deep Pyhäsalmi mine, Finland, offers an excellent opportunity to establish a micro and macro scale validation environment for the muography community. The underground mining is ending soon at this site, subsequently giving room for even 24/7 underground operations for other types of operators. However, the surface operation continues. The flat local overburden is ideal for both surface and underground validation tests for muography instruments. Geology and the mine infrastructure are well-known and documented. From the infrastructure point of view, the underground has even a 1 Gb internet connection, and with secure remote access, long-term remote tests are also possible.

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Session Classification: Applications

Track Classification: Applications