Towards improved alignment of TRI and TLS data for geomonitoring with increased resolution

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Fusing Terrestrial Radar Interferometry (TRI) and Terrestrial Laser Scanning (TLS) offers a powerful tool for geomonitoring by leveraging their complementary strengths. While TLS provides high-resolution 3D point cloud data for comprehensive site mapping, it is limited to centimeter-level precision in many outdoor applications and thus often not sufficient to detect displacements in the millimeter range, even exploiting redundancy. In contrast, TRI has the potential of detecting sub-millimeter deformations but poses challenges in image distortion and interpretation. Combining the two enables precise localization and quantification of motion/deformation of small geological features, for example, related to landslides, rockfalls, or permafrost-induced debris flows, while also simplifying the interpretation through 3D mapping.

In a preliminary study (Schmid et al., 2023), we investigated the accuracy of TRI-to-TLS mapping using a common workflow. With height differences up to several hundred meters and distances up to about 1.5 km between the instruments and the monitored surfaces we found systematic misalignments on the order of several tens of meters. This level may be acceptable for globally monitoring deformation processes like the sliding of an entire slope, but is not adequate for precise localization of individual events or local variations of a deformation process. To tap into this unused potential, we are investigating methods for better alignment of TRI data with TLS point clouds.

We pursue two approaches: (i) a data-driven approach relying on corresponding features automatically detected within the point clouds and radar images of the monitored scene; (ii) a more controlled, but labor-intensive approach using in-house developed collocation targets. The data-driven approach is based on the co-registration of topography features with low angles of incidence (AOIs) from the TLS point cloud and high amplitude pixels from TRI observations. So far, we achieved a mapping uncertainty of TRI data onto a TLS point cloud on the level of the median projected TRI pixel resolution (4.8 m @ 900m) using this approach.

The uncertainty can be further reduced using the collocation targets each of which consists of a radar corner reflector and a glass prism. Estimating the center of these targets independently from the TRI and TLS observations provides well-defined tie points between the datasets, enabling accurate co-registration and georeferencing. Using data from a field experiment with such collocation targets, we show that the target centers can be detected with a resolution on the level of a few centimeters at the present distances between 1200 and 2300 meters using both technologies. Compared to the resolution of the TRI images used herein, this is approximately 36 times better than the range resolution of 0.75 m, and 20 times better than the cross-range resolution.
of 0.1°. For TLS, the above resolution of the target centers is better than the chosen point cloud resolution and equals 10 to 30% of the laser footprint diameter (0.15 mrad).

Herein, we demonstrate the successful application of both georeferencing methods to real-world datasets, compare their advantages and shortcomings, and discuss possibilities for future improvements. Moreover, we show the advantage of the technological synergy of TRI and TLS with improved alignment precision in a monitoring use case of detecting exfoliation sheets (Guerin et al., 2020).

REFERENCES
