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State-of-the-art in 4D measurements

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Light detection and ranging (lidar) has become an essential tool in mapping and change detection in different environments over the last 20 years. Laser scanners capture point clouds to create accurate digital snapshots of their surroundings. These snapshots tell about the structural information in the scene and can be readily returned to again and again to detect and measure any changes with multi-temporal measurements. However, multitemporal measurements cannot typically resolve the change events nor can they resolve more high frequency dynamics that happen on daily or weekly basis in the scene. Also, lidar systems operate still mainly with single wavelength limiting their usability in classification tasks. First multi- and hyperspectral systems have been already demonstrated, but have yet to break through in wider usage. Finnish Geospatial Research Institute (FGI) has been prototyping with different 3D measurement systems for the last 10 years to improve multitemporal mapping (4D) solutions. The prototypes include both hyperspectral and long-term multi- and hypertemporal lidar systems, and their combinations in static and mobile configurations. FGI started early on to experiment with hyperspectral laser sources (2007) and successfully demonstrated the first hyperspectral laser scanner prototype in 2012. The system was later used in detecting intraday vegetation dynamics in 2015. Multitemporal multispectral ALS measurements have been conducted since 2015 in Evo and in Espoolahti. The first long-term multitemporal studies with FGI mapping platforms were started with ALS to monitor changes in forests (1998) and built environment (2001) and with mobile laser scanning in studying the erosion of an arctic river basin (2008) annually. Multitemporal ALS studies with vegetation started in 1998 in Kalkkinen and in 2007 in Evo followed with bi-temporal studies with TLS. Test Site Evo has been acquired with ALS. In 2020, Evo test site was granted Academy of Finland Research Infrastructure (RI) status. The RI will collect a 30-year-long time series with annual measurements using various laser scanning sensors for investigating single tree growth processes, forest dynamics, understanding cyclic forest while having variation at diurnal and annual scales and forest monitoring technologies. Vegetation dynamics monitoring was extended in 2020, when FGI started set up a permanent TLS measurement station in a boreal forest. The TLS station accurately detects structural changes of hundreds of tree crowns around it. The experiment aims to detect the changes of phenological state the trees and further link them with the environmental parameter variation. 4D measurements have successfully demonstrated their potential in extending the information available from laser scanning systems. To improve the

usage of these novel information, automated pre-filtering of the vast data amounts already at sensor level will be imperative. Different lidar platforms can operate throughout the spatial scale from millimeter precision all way to national coverage. Thus, development of new scalable lidar RIs open new possibilities to complement already existing infrastructures.