Terrestrial Laser Scanning for Structural Health Monitoring

TLS is widely used for the digitization of the built world, especially for architectural purposes. However, the potential of such instruments is not fully exploited for structural engineering applications. Thus, the main idea is to integrate TLS within the most established procedures and tools of SHM.

Modern Total Stations
Total Stations are traditionally used for structural monitoring purposes. A few instruments with capabilities partly overlapping with TLS ones were recently introduced on the market (e.g. Leica MS50, Trimble VX), possibly enabling the application of TLS techniques for SHM.

Such devices can significantly simplify some steps of the acquisition and the processing phases. Advantages are:
- high angular accuracy of each single measured point
- good accuracy in measuring prisms (georeferencing)
- ensured verticality over time in case of continuous monitoring

Nevertheless, these devices have also some disadvantages with respect to a classical TLS:
- slow acquisition
- reduced density of the point cloud

Fibre Optic Sensors (FOS)
Fibre optic strain sensors are a good example of measurement devices that allow for distributed continuous monitoring of structures.

Indeed, Fibre Bragg Gratings (FOG) sensors allow for a wavelength-selective reflection of multiplexed signals. Typically, it is possible to measure up to 16 gratings on the same fibre.

FOS measurements of the interior of structures are increasingly getting widespread: the possibility to be integrated with surface TLS data should be investigated.

Finite Element Modelling
FEM is the most common method for numerically modelling the behaviour of structures.

In literature it is possible to find examples of:
- generation of a FEM model from TLS data
- retrieval of the stress distribution obtained by imposing the measured displacements to the FEM model

However, these techniques have never been combined yet.

Moreover, the physically rigorous modelling of complex buildings is a very challenging task.

Indeed, the procedure would particularly suit the monitoring of bare structures made of 1D homogeneous isotropic elements (e.g. steel or timber trusses).

First steps: the need for accuracy
Structural health monitoring often requires mm-level accuracies. Thus, the instrument has to be properly calibrated in order to retrieve meaningful data.

For example, a range dependent bias on range itself has been spotted when monitoring a wooden slab of the House of Natural Resources with a Faro Focus3D laser scanner. The scanner will now be calibrated for increased accuracy.

Figure 1: monitoring of the Kops dam with Leica MS50. Photographer: Stefan Leuenberger
Figure 2: TIN model of the Kops dam generated from the MS50 point cloud
Figure 3: a fibre optic sensor: bare (left) and as installed in the Kops dam (right). Source: Werner Lienhart, TU Graz
Figure 4: example of the results of finite element analysis on a dam (overtopping collapse). Source: www.stru.polimi.it
Figure 5: planar wooden slab: dependance of bias on range
Figure 6: planar wooden slab, spatial distribution of displacements