Geometric Modelling of a Large Dam by Terrestrial Laser Scanning

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Terrestrial Laser Scanning and Large Dams

TLSs are instruments capable of acquiring 3D models of large objects in relatively short times

TLS are then suitable for applications involving large dams due to:

- large size of dams
- presence of sub-vertical faces requiring terrestrial surveying techniques
- classical geodetic techniques (total station measurements) are too slow
- difficulty on the use of digital photogrammetry
    - poorly textured surfaces for image correlation algorithms
    - insufficient accuracy

Two kinds of possible applications:

- geometric surveying
- monitoring of the structure's displacements

Advantages offered by TLS in Geometric Surveying of Large Dam

When is required the geometric surveying of a dam?

- for mathematical modelling of dam's static behaviour
- for evaluation of surfaces (e.g. for estimation of works)
- for derivation of drawings and plans

Laser scanners are highly productive with respect to other topographic and photogrammetric techniques, considering the huge amount of data to be acquired

In particular the use of Long-Range TLS is interesting, featuring a nominal measurement range up to 1000 m (however in practical applications limited to 500-600 m)

Limitations: the morphology of the dam site may prevent to find positions for TLS stand-points

The Cancano Dam (Bormio, Sondrio)

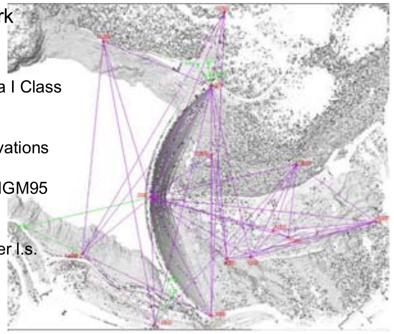
Location: Alta Valtellina (Lombardia)
Type of dam: arc gravity
Owner: Azienda Energetica Municipale (Milano)
Max. water volume of the basin: 124 mil m³
Size of the dam:
- height: 136 m
- lenght of the arc on the top: 381 m

Two projects:
- geometric surveying of the dam (Sept 2005) for deriving:
    - a 3D model for finite-element analysis
    - drawings of the dam
- monitoring of dam displacement (ongoing, first results presented at ISPRS/V Symp. In Dresden)

Layout of Cancano Dam and Geodetic Network

Geodetic network features

- Measurement by a I Class total station (Leica TCA2003)
- Redundant observations
- 11 main verteces
- 3 points linked to IGM95 GPS network
-Accuracy of point measurements (after l.s. adjustement):
    - E-N: ± 2 mm
    - h: ± 3 mm



Geometric Surveying: Adopted TLS

Laser Scanner: Riegl LMS-Z420i
Main Technical features:
- Time fo Flight mirror scanner
- max range measurement: 800 m (r > 80%)
- realistic range measuremnt: 500 m
- range accuracy: ± 10 mm at 100 m (then about linear)
- Field of View:
    - H: 360 deg
    - V: 80 deg (TLS can be tilted in calibrated positions)
- possibility of multi-scan
- angular resolution: 0.002 & 0.0025 deg (H & V), i.e. 3.5 & 4.5 mm at 100 m
- diameter of laser beam-width: 0.014 mgon, , i.e. 25 mm at 100 m
- integrated calibrated camera Nikon D100 (6,1 Mpx), with 28 mm lens
- control via PC
- power supply by a portable electric generator Honda EU 10i, 0.9 kW, 13 kg weight

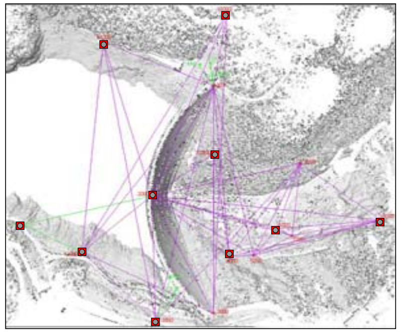
Riegl LMS-Z420i in Action at Cancano Dam

Scans' Features

# of TLS stand-points: 10 main scans + some details
# of scans (included tiltet scans): 36
Mean acquired point density: 1-4 point/100 cm^2
# of points in each scan: 2.8÷11.6 mil
# of total measured points: 58.6 mil

TLS stand-points	# of scans	scanning time (min)	# of points (mil)	point step (cm)
2000	3	7	2.8	10
4000	2	10	5.2	5
6000	1 multi-scan	26	11.6	5
8000	1 multi-scan	19	10.2	5
10000	2	9	3.9	5
11000	3	23	3.6	10
12000	2	15	3.7	10
13000	3	12	4.4	10
14000	1	2	0.7	10
15000	2	8	1.3	10
details	16	33	11.2	10

Scan Stand-points



Scan Georeferencing: on the field procedure

Computed by measurement of retro-reflective targets as GCPs:

- 62 materialized over the dam and on rocks around (those used also for monitoring)
- cylinders over known points

All target have been measured from the geodetic network stations

Moreover several TLS stand-points have been placed over know points

# of GCPs per scan: 5-8

# of total GCPs: 25 (+ 62 monitoring targets)

In case of tilted scans, LMS-Z420i is georeferenced in vertical position and then inclined at calibrated steps of 5°

Scan Georeferencing and Data Processing

Computation of 6 georeferencing parameters of each scan by Riegl Riscan Pro SW

Mean residuals on GCPs: ± 2 cm

Subsampling of alla scans at a common resolution of:

- 1 point/100 cm^2 to derive drawings
- 1 point/400 cm^2 to derive 3D models for F.E.M.
- 1 point/10000 cm^2 to derive 3D models for global visualization

Derivation of TIN model by Riegl Riscan Pro SW

Derived Vector Drawings and other Products

Vector drawings:

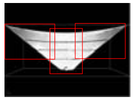
- General map at 1:500 nominal scale
- 3 horizontal cross-sections at different levels
- 10 vertical cross-section starting from the middle of concrete blocks
- 10 cross-sections following a mean line along concrete blocks
- Front and retro view of the dam

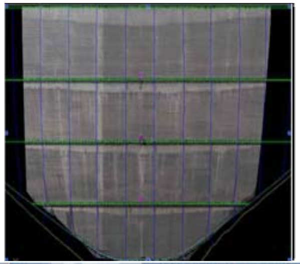
Other products:

- TIN models of concrete blocks
- Orthophoto of frontal view
- 3D global model for vizualization purpose

Dam Frontal View Generation Workflow

1. Subdivision od the whole cloud-point of the dam front in 3 portion
2. Triangularization
3. Photo-texturing
4. Ortoprojection generation
5. Vectorization

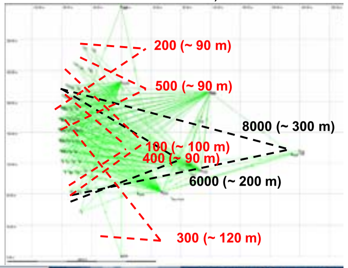




Monitoring of Dam Deformation: Scanning Stand-points

3 measurement campaigns (May05 – Oct05 – May06)

1. Riegl LMS-Z420 from 2 stand-points:
   - point 6000 (mean distance from the dam: 200 m)
   - point 8000 (mean distance from the dam: 300 m)
   - use of multiscan
   - expected accuracy on range: ± 5 mm
2. Leica HDS 3000 from 5 stand points (100-500) at mean distances ranging from 50-120 m:
   - expected accuracy on range: ± 6 mm



Monitoring of Dam Dislacements

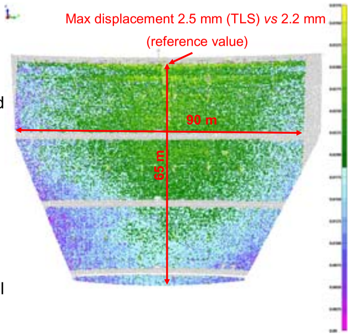
- The idea is to applied an “area based method”: displacements are not found by pair-wise point comparison, but by analysing surfaces interpolating corresponding portions of the dam downstream to reduce noise
- Point-wise analysis cannot be performed, due to:
  - Unperfect repositioning of scans
  - Effects of laser beam-width
- Currently this stage is a work-in-project and only some preliminary results are reported (see Proc. of ISPRS/V Symp. in Dresden, Sept. 2006)
- In particular the comparison between scans acquired from stand point 8000 in Oct05 and May06 has been carried out

Processing Workflow

1. Averaging of “multiscan” acquisition, and discarding points featuring a st.dev of range measurement > 10 mm
2. Resampling of both scans to a regular grid of 2x2 cm step
3. Interpolation of both resampled point clouds by two methods:
   - Triangular mesh
   - Polynomial 3D surface
4. Different combinations of interpolated surfaces have been tried on LMS-Z420i data

Comparisons: case 1

- Mesh (Oct05) *vs* resampled point-cloud (May06)
- # of points: 71758
- Displacement computed with the criterium of the shortest distance of each point from the surface
- Max displacement in the middle of dam crest according to that obtained from total station and from internal sensors



Final Considerations and Future Work

Dam surveying:

- the surveying project of the Cancano Dam has shown the feasibility of the operational use of TLS for deriving 3D data and drawings
- the density of TLS data allows to improve mathematical analysis of dam behaviour because models become more detailed
- however a better definition of technical specification of laser scanning surveying for structural analysis is required

Dam monitoring:

- first results have shown the possibility of applying TLS for monitoring long period displacement of a dam
- 3D data coming from TLS allow new kinds of mathematical analysis


Thank you for your attention
and enjoy the movie during
the final discussion!