TERRESTRIAL LASER SCANNING
AND
APPLICATION IN GEODE蒂IC ENGINEERING

Marko Pejić
University of Belgrade, Faculty of Civil Engineering

TLS method and data workflow

- Realistic and accurate 3D model $\rightarrow$ reverse engineering, architecture, civil engineering, urban planning, heritage documentation, etc.;
- Terrestrial laser scanner $\rightarrow$ very high spatial density of the acquired data and very high geometric accuracy;
- TLS workflow involves: measurement planning, setting up a survey reference frame, scanning, registration and/or georeferencing of scans, point cloud 3D modelling and analysis;
From scanning to information...

• Point cloud
  
a. Range and directions measurements → 3D information;

b. + intensity → 4D information;

c. + RGB value of 3D point
From scanning to information...

• Registration and georeferencing;
• 3D model;
  a. Parametric surfacing,
  b. 3D meshing.

Pruga Nikšić-Podgorica railway, 2012.

Lola, 2014.
CAD products (3D models, intersections, views) and analysis.

Oil reservoirs, Smederevo, 2010.

Mratinje Dam, 2010.

Nikšić-Podgorica railway, tunnels, 2012.
TLS over traditional surveying instruments and methods
The main features of the commercial TLSs for use in architecture

<table>
<thead>
<tr>
<th>Manufacturer / Model</th>
<th>Precision</th>
<th>Resolution</th>
<th>Speed [pts/s]</th>
<th>Field of view [°]</th>
<th>Range [m]</th>
</tr>
</thead>
</table>
| Leica Scan Station P20      | 3D position: 3 mm/50 m  
Linearity: < 1 mm  
Angular: 8"  
Targets: 2mm                                                                  | up to 0.8 mm/10 m  
up to 1 million                                                   | 360/270  
360/200                                                      | 120       
| Rieg VZ-400                  | 3D position: 5 mm/100 m                                                  | 1.8"                                                   | 360/200  
42000  
122000                                                   | 600       
| Zoller+ Fröhlich IMAGER 5010 | Range: 1.2 mm/50 m, 3.8 mm/100 m  
Angular: 25"  
Model: 2 mm  
V: 1.4"  
H: 0.7"  
1.016 x 10^6                                                   | 360/320  
360/300                                                      | 187       
| Trimble CX 3D                | Position: 7.3 mm/50 m  
Range: 2 mm/50 m  
Angular: 15"/25"  
Model: 3 mm                                                            | 7"                                      | 360/300  
54000                                                  | 80        
| FARO Focus3D                 | Range: 2 mm/25 m                                                         | 30"                                      | 360/305  
0.976 x 10^6                                                  | 120       
| Optech ILRIS-3D              | Range: 4 mm/100 m  
Angular: 16.5"                                                              | 4"                                      | 40/40  
1200                                                   |          |
Typical TLS engineering application
Landslide monitoring

2013-2014.

Landslide, road M-22, near Ljig.
Geometry analysis, Saint Anthony of Padua Church, 2015.
Geometry inspection of tower

Cylinder Fit Quality:
(Derived from cloud with 213 304 075 points)

Standard Deviation (1σ) = 5 mm
Cylinder Diameter = 8,962 m
Height = 42,999 m
Total height = 47,393 m
Tilt = 1° 27’ 40"
Tilt in horizontal plane = 1,208 m
As built geometry analysis of crane, Lola, 2015.

Mechanical engineering, Point cloud, XYZ+I
Tolerances and „as built“

Lola, 2015.
Railway tunnels - geometry inspection, 2012.

Design and optimization of laser scanning for tunnels geometry inspection

narrow and elongated objects \(\rightarrow\) unfavourable case to provide geodetic measurements of a sufficient **accuracy** and **reliability**

Design factors:
- incidence angles
- tunnel geometry
- georeferencing approach

The criterion of variance component significance:

\[
B^2 \leq \frac{2\alpha - \alpha^2}{(1 - \alpha)^2} \cdot A^2 \quad B \leq \frac{1}{3} \cdot A, \: \alpha = 0.05
\]

Position of the control points \((S_t, M \text{ and } K)\) and scanner positions \(S_c\) in a section of example tunnel.
(a) tunnel surface, (b) expanded profile of the train, (c) estimated clearances and failures and (d) 1 m cross sections; The tunnel mesh is created from the scan data. The expanded profile of the train is modelled in respect to the surveyed positions of the rails.

Geometry and clearances of a tunnel and expanded profile of the train. Detected contact of the expanded profile of the train with tunnel sheeting.
Revitalization of the facade, Požarevac district office, 2014.

Architectural drawings
Ore smeltery, RTB Bor, 2015, Parametric model
Medieval monastery reconstruction

Kasteljan, Kosmaj 2016.
XYZ+RGB
Re-emerging from ash...

<table>
<thead>
<tr>
<th>a) INTERIOR CONCEPT OF THE CHURCH</th>
<th>b) EXTERIOR CONCEPT OF THE CHURCH</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Interior concept diagram" /></td>
<td><img src="image2" alt="Exterior concept diagram" /></td>
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</tbody>
</table>

**Exterior and interior concept of the church**
Spinix statue,
Faculty of civil engineering,
Belgrade, 2014.
• Technological innovations are pushing the feasibility boundaries, while basic engineering approach remains the same;
Technology of the future generations
MORE FROM SCIENTIFIC POINT OF VIEW:

Thank you for your attention

Zlatibor, 2014.

Zlatibor, 2015.