Example of Use of GNSS and Laser scanning for Dams monitoring

Mourad BOUZIANI
Department of Geodesy and Surveying
ESGIT, IAV Hassan II, Morocco

Coordinator of GNSS Master Curriculum
CRASTE-LF, Affiliated to the United Nations
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1. Activities of CRASTE-LF on GNSS

2. GNSS and Laser scanning : Application Example
1. Activities of CRASTE-LF related to GNSS
The CRASTE-LF has been established in Rabat on October 23, 1998. Initiative of the UN-OOSA.

Education and training on Space Science and Technology for sustainable development


Building of CRASTE-LF

CRASTE-LF

CRASTE-LF
Education Programmes

- Remote Sensing and Geographic Information Systems,
- Satellite Communications,
- Satellite Meteorology and Global Climate,
- Space and Atmospheric Sciences

Global Navigation Satellite Systems

Education Curricula established and Published by UN-OOSA
Training Course on GNSS

“Satellite Navigation and Location Based Services”, 28 September – 24 October 2009, with participation of 35 trainees from 19 Countries & from 32 different organizations and supervised by 10 experts.

Trainees supervised by METIS project team attending the demonstration at Mohamed V Airport, Casablanca, Morocco.
Regional Training Workshop

24 trainees from 07 countries

- Datums: Ellipsoid, Geoid.
- Coordinate Reference Systems
- Cartographic Projections
- Satellite Orbits.
- Navigation Signal.
- Errors and Precision.
- Positionning Techniques.
- Laboratories.

« Global Navigation and Based Services on Satellite Positioning »
Lomé, Republic of Togo, 3 - 7 October 2011
Master on GNSS

Post Graduate training courses on GNSS, Nov. 2013 – Aug 2015
12 trainees from 6 member Countries & 8 different institutes

The participants have been supervised by Experts from 4 countries (Algeria, China, France and Morocco)

Training on Beidou: International Institute for GNSS Education, Beijing China.

This Master in GNSS is recommended to candidates graduated in electronic engineering, telecommunication Engineering, civil engineering, forestry, geomatics and geographic sciences, mathematical sciences and physical sciences.
The Master programme in GNSS is divided into four parts:

- **Lessons organized in 9 modules** consisting of 690 hours.
  - Lectures, tutorials, practical works and thematic seminars.

- **Laboratory experiments, practical activities and projects** related to the applications of GNSS consisting of 200 hours.

- **A GNSS project** realized in 12 weeks corresponding to 360 hours.

- **One year project** conducted by each candidate in his country on an issue related to the GNSS applications. The research project lead to the development of a thesis document presented in the CRASTE-LF centre.
Training Workshop on “Space Weather & GNSS Applications”, Feb 2015 with participation of 29 trainees from 13 Countries & 11 different institutes supervised by 8 experts.
The participation of Experts from Russia in GLONASS System is Highly recommended to support the CRASTE-LF centre: Training on Glonass, Practical works using Glonass receivers and softwares, development of applications.

13 countries will benefit from the training in order to promote the use of GLONASS in African countries and to encourage the interoperability with the GPS and other systems in this region.
2. GNSS AND LASER SCANNING: EXAMPLES OF APPLICATIONS
Monitoring of Dams in Morocco

- Morocco undertakes important actions in order to protect and save hydraulic resources.
- These actions include the monitoring of dams.

In Morocco the dams are mainly used:
1. To provide water for various needs (human consumption, irrigation for agriculture, industrial use).
2. In Hydropower to generate electricity.
3. To manage or prevent water flow into specific land regions, to avoid floods.
Monitoring techniques

Dam failures are generally catastrophic if the structure is breached or significantly damaged. Routine deformation monitoring is useful to anticipate any problems and permit remedial action to be taken before structural failure occurs.

Two types of measures to control and monitor the deformation of dams:

1. Geodetic or photogrammetric measurements:
   - provide the relative displacements as well as the absolute movement of objects relative to reference points considered as stable points.

2. Geotechnical and structural measures using extensometers, inclinometers and direct or inverted pendulums:
   - are typically used to determine the relative displacements within the structure of the dam
Geodetic monitoring

So far, geodetic monitoring is performed using the conventional method consisting of:
1. Spatial intersection with high precision theodolite instruments to monitor the dam in planimetry.
2. Geometric leveling instruments for the auscultation in altimetry.

- Geodetic monitoring is an unavoidable method for monitoring the behavior of the dams.
- Periodic operations are launched twice a year that are executed by surveyors and controlled by DHA.
- The reports allow decision-makers to ensure the functioning of the dams and its security and stability.
GNSS and Laser Scanning

Laser scanning offers the advantage to acquire dense data quickly. The result shape almost perfectly the form of objects which allows a full three-dimensional reading. The problem is the level of precision and reliability that this technique can guarantee.

The Global Navigation Satellite systems are widely used in many areas of positioning but it is necessary to study this technique to see to what extent it can replace the conventional method in monitoring of dams.
Case study: Rabat & Assfalou Morocco

Methodology

Preliminary mission

Homogeneity test (Pillars)

Spatial intersection

GNSS Relative Positioning

Terrestrial Laser Scanning

Comparison
Targets

Experimentation 1
Equipments and base points
Spatial intersection

- Measurement of horizontal and vertical angles
- Angle accuracy: 0.5 ”
- 08 measurements per roundel
- Intersection of 18 roudels from 02 Pillars
- Least-squares adjustment
- Determination of positions in 3D
GNSS receivers

GNSS Characteristics

- 75 channels:
  - GPS L1 C/A L1/L2 P-code, L2C, L1/L2 full wavelength carrier
  - GLONASS L1 C/A L1/L2 P-code, L1/L2 full wavelength carrier
  - SBAS code & carrier
  - Low-signal acquisition and tracking engines for signal detection in difficult environments

- Fully independent code and phase measurements
- Advanced multipath mitigation
- Update rate: Up to 20 Hz position and raw data output
Relative Precise Positionning

- Post-Processed Static
- Two frequencies (GPS, GLONASS)
- 01 hour observation / session
- 02 reference points, 18 survey points (Roundels)
- Recording Interval : 1 s
- 04 Receivers used : 02 Bases & 02 Rovers
Terrestrial Laser Scanning

- **Measurement Accuracy:**
  - Angle: 10’’
  - Distance: 3 mm

- **Range:** 300 m

- **Field of view:**
  - Horizontal: 360°
  - Vertical: 270°

- **Scan Rate:** Up to 50,000 pts/sec

- **Scan of 18 roundels from 02 Pillars**
# Intersection Results

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<th>N° Roundel</th>
<th>$\sigma_X$ (m)</th>
<th>$\sigma_Y$ (m)</th>
<th>$\sigma_H$ (m)</th>
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Comparison with reference survey

Results:
- Spatial Intersection : 1 mm
- GNSS : 5 mm
- TLS : 1 cm

Conclusion:
- GNSS recommended for monitoring.
- Use of GLONASS and GPS is a necessity to improve the geometry of positioning.
- TLS could be used with some arrangement: If Pillars are close to the structure (<60 m)
Experimentation 2
Results

- Angular Intersection: 1 to 3 mm
- GNSS: between 5 mm and 1 cm
- TLS: > 1 cm
- Monitoring of the hall structure by TLS:
  - detection and monitoring of cracks
  - surfaces comparison between two dates
- Conduct experimentation using Permanent GNSS Stations.
School of Geomatic sciences and Surveying Engineering, IAV H2, Rabat, Morocco

TLS Products

Ongoing Experimentations
Monitoring the silting of dams using GNSS, Laser scanning and Inertial sensors

• Multibeam Echosounder

• TLS

• MMS

• GNSS RTK

• Data acquisition in two periods

• Periodic Change detection: Bottom and shores of the dam

F., Boucht & F., Nouri (2015)
Monitoring the quality of the pavement for urban roads

- Equipments: GNSS & LS & IMU
- GNSS: RTK
- Methodology: determination of optimum parameters
- Comparison between design and scanned models to detect Pavement degradation

M., Benmira & B., Condé (2015)
Conclusion

- Promote GNSS use (interoperability between GLONASS and other GNSS).

- Precision and Rapidity of use of new technology are big advantages.

- Use of GLONASS and GPS improve the geometry of positionning.

- GNSS and TLS can be Used together. Their integration will improve Monitoring Operations but:
  - Design of Pillars, Roundels and Targets must be adapted
  - Methodology required by DAH has to be modified
• THANK YOU FOR YOUR ATTENTION