STRUCTURAL MONITORING USING GNSS TECHNOLOGY AND SEQUENTIAL FILTERING

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Introduction

Structural monitoring → great interest in Italy

↓

classical topographic techniques

Great improvement GNSS technique performance

+

lower equipment costs

↓

GNSS for structural monitoring

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Introduction

GNSS station - rooftop - important historical building in Bologna (Italy)

The Garisenda tower

Bologna's cultural heritage
Two towers:

- Asinelli
- **Garisenda (leaning)**

stability problems

✓ height = 48 m
✓ overhang = 3.22 m

foundation consolidated 1995 ca

The Experimentation

- GNSS station - BOGA
- installed October 2, 2013
- mobile-phone connection
- data continuously sent
- analysis center
- School of Engineering of Bologna

Dataset

automatic data processing:
- daily positioning
- kinematic solutions

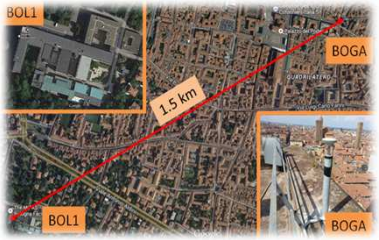
short baseline
- Rover Station: BOGA
- Master Station: BOL1 stable a

15 days of RINEX data

Software set up

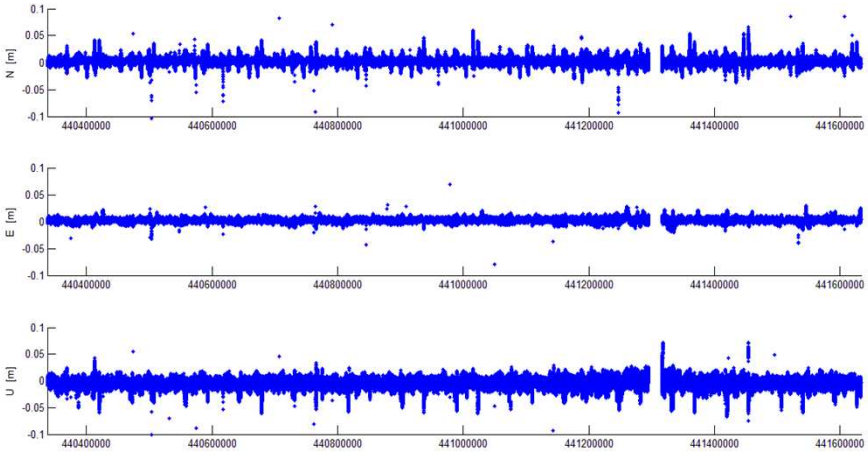
SOFTWARE:

- **RTKLIB** ver. 2.4.2
- Observable: Carrier Phase
- Frequencies: L1+L2
- Data sampling: 1Hz
- Constellations: GPS+GLONASS
- Satellite Ephemeris/Clock: IGS Precise



Data processing of kinematic solution (1Hz)

Full raw solution

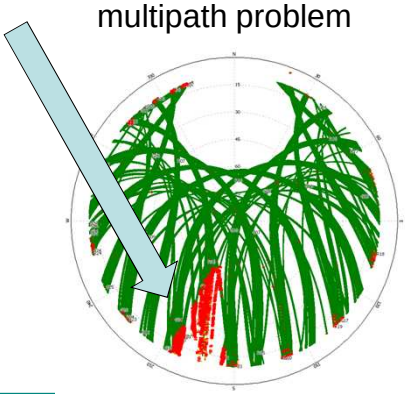


Precision of GNSS survey

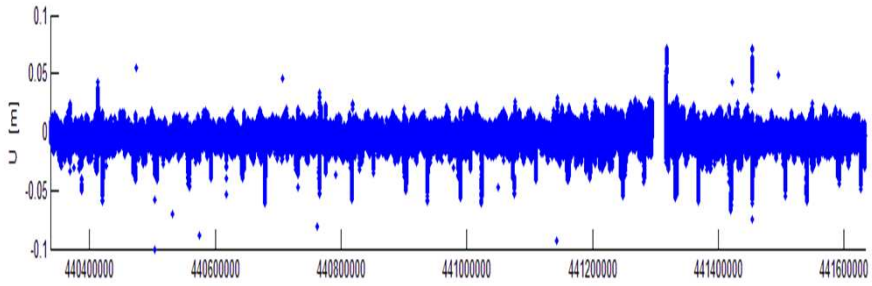
- baseline length ⇨ modeling of the atmosphere
- **multipath ⇨ nearby obstacles**
- **constellation geometry**

Example of GNSS problems

adjacent Asinelli tower
obstacle for satellite signals
multipath problem



Why a filter?

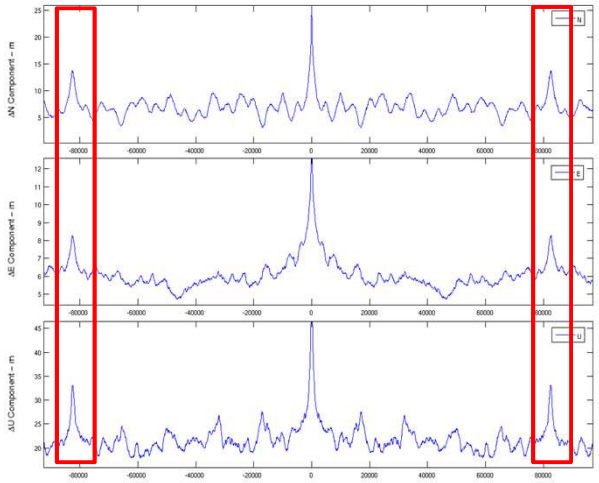


recurring spikes are evident

model in order to **eliminate**

improve precision

Statistical Analysis



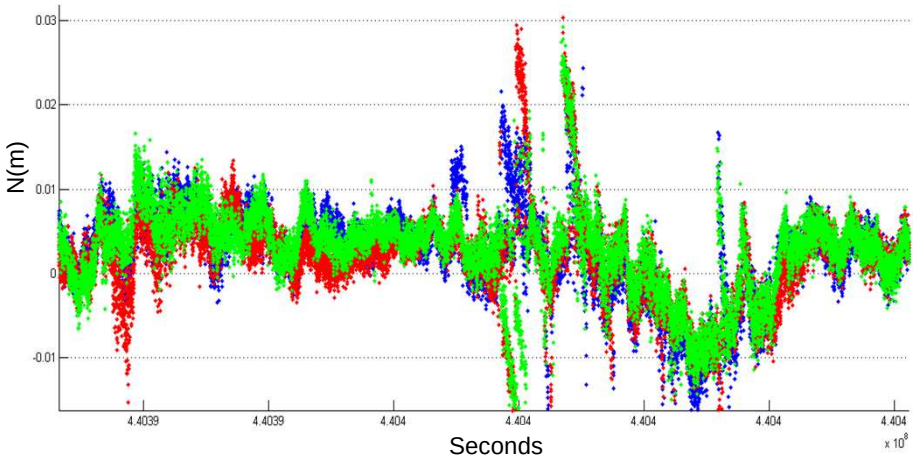
Autocorrelation function

$$R_x(\tau) = \sum_{t=-\infty}^{\infty} X(t) * X(t+\tau)$$

Peak about every 86164 s

Sidereal day

Comparison of three solutions



What can we do to improve the solution?

General idea

Estimation of a model generated from past solutions

- Cleaning of daily solution from outlier Preserving medium frequencies
- Generate a daily model
- Generate the final model using several days

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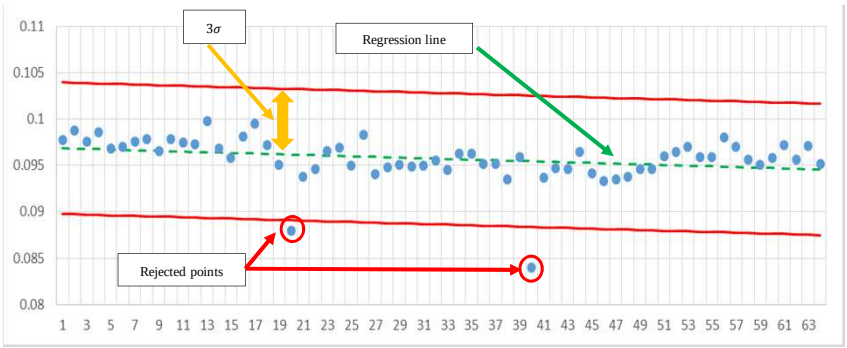
Cleaning of daily solution

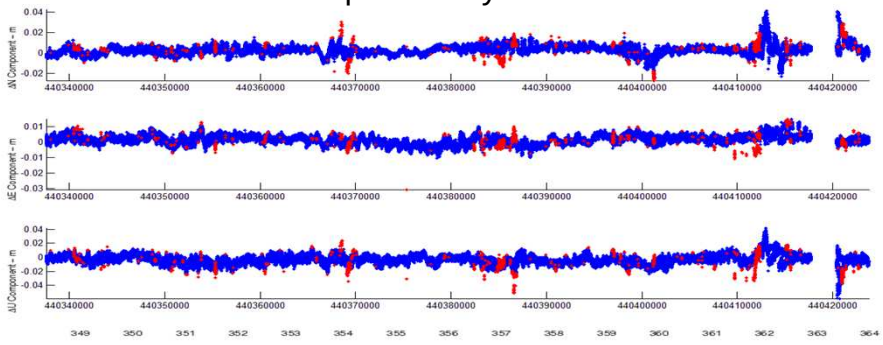


Split the series in 30 smaller blocks ⇨ prevent cutting the peaks

Cleaning of the solution:

rejection of outliers for each block

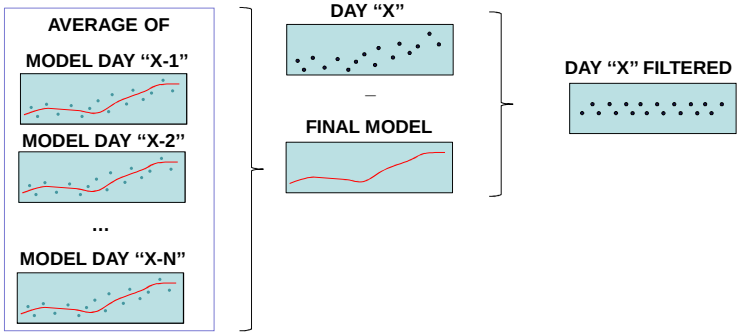
Example of daily solution



Regular peak

No real movement of structure ⇨ Need to model

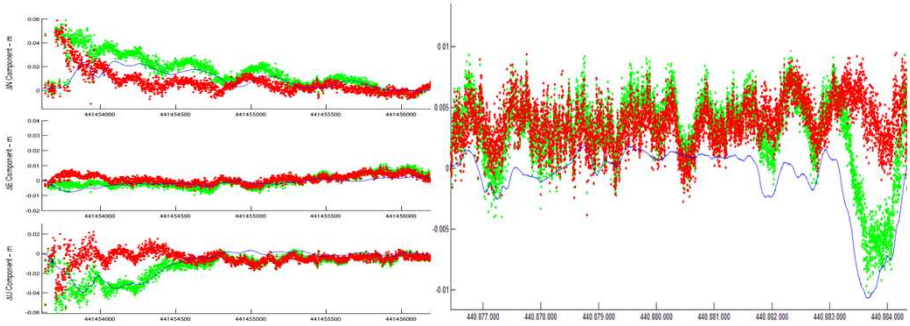
How the Sequential Filter works



1. Daily model: moving average - every solution
2. Final Model: Average of N previous daily models
3. Filtered solution: Application of Final model to the relative solution

Results

Clean solution – Model – Filtered solution



COMPONENT	σ^{CLEAN} (mm)	$\sigma^{FILTERED}$ (mm)	IMPROVEMENT %
N	4,8	3,8	**20,9%**
E	3,0	2,7	**10,1%**
U	7,1	5,8	**18,4 %**

Conclusions

- Structural monitoring - great interest in Italy
- Test **Garisenda Tower**
- Sequential filter on ***6* preceding solutions**
- **Improvement up to 20%** in terms of scatter
- Future development
  - Application of this filter in real time