SAR Interferometry
and applications

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Interferometry
measurement of travel path differences
The target’s signature is removed

Short term  single pass, seconds, 30’, 1 day, weeks

- coherence  : Vegetation, surface properties
- parallaxis (baseline)  : Digital Elevation Models

Long term  months, seasons, one to several years

- co-seismic or volcanic motions (Line Of Sight, 2D, 3D)
- subsidence (mm/year); slow landslides (cm – mm/year)
- building pre-collapses, cracks, excavations effects
Summary

Interferograms, Wide Swath: Bam, Algeria

Wavevector length and revisiting times:
Digital elevation models and ground motion retrieval in Tokyo
Further analyses of the 3 days data in Rome

A simple model to evaluate the implications

Conclusions
Bam - Iran: Dec. 26, 2003 earthquake
Algeria

WSM - WSM seamless interferogram

400km

Coherence (forestry): the log histogram is superposed
VS (time-Varying Scatterers) and Permanent Scatterers that yield DEM, orbits, and motion
Digital elevation models
Old rivers in Istanbul (shales liquefaction)
Ground motion
Berkeley Hills: what goes up..
...then goes down: landslides in Berkeley
but faster when wet!
Ground motion

RADARSAT C-band HH pol.
- 30 images (ERS-like mode)
- 24 days revisiting period
- 2.5 years time interval

ERS1/2 C-band VV pol.
- 30 images
- 35 days revisiting period
- 10 years time interval

J-ERS L-band HH pol.
- 46 images
- 44 days revisiting period
- 6 years time interval
Accuracy of the measured orbits

Normalized baseline corrections

Time [yr]

SAR Interferometry, Polinsar Meeting, January 17, 2005
Precision of C band measurements: ~ 3mm

- Radarsat
- ERS
- JERS

SAR Interferometry, Polinsar Meeting, January 17, 2005
Precision of C band measurements: ~ 3mm
3 days data in Rome
ERS: 3 vs 35 days revisiting interval - PS elevation

3 days

35 days
ERS: 3 vs 35 days revisiting interval - PS motion

3 days

35 days
DEM (estimated precision: 2 m)
Tau = 46.75 days, $g_0 = 0.65$
JERS: Coherence Vs baseline
JERS 300 days
The model
Temporal behavior of the scatterers

- Nugget
- Time constant $\tau$

Revisiting time (days)
nugget
\[
\gamma(\lambda, M) \approx \frac{SNR}{1 + SNR} \exp\left(-\frac{M}{M_C} \frac{\lambda_C^2}{\lambda^2}\right)
\]

\[
\sigma_\varphi = \sqrt{\frac{1 - \gamma^2}{2 \gamma^2}} \\
p = \text{erfc}\left(\frac{\pi}{\sqrt{2} \sigma_\varphi}\right)
\]

\[
\sigma_m = p \sigma_n \frac{\lambda}{4\pi} + (1 - p) \sigma_{\text{apriori}}
\]

\[p = \text{Probability of phase shifts greater than } \pi\]
SNR=10dB
SNR = 0dB
Optimal wavelength

SNR = 0dB
SNR = 10dB

Revisiting time (days)
New missions

**C band** yields sub-millimeter motion and sub-meter elevation accuracy in populated areas.

**L band** revisiting intervals may be much longer. However, a much lower noise level is needed to obtain small motion sensitivity; optimal for forest penetration.

**X band** has lower penetration; revisiting intervals should be short to keep coherence and avoid alias. Constellations will help to reduce conflicts.
Better ground motion monitoring

<table>
<thead>
<tr>
<th>Competing Techniques</th>
<th>TIME Presence</th>
<th>SPACE Location</th>
<th>TIME Continuity</th>
<th>SPACE Continuity</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS - Galileo</td>
<td>- after</td>
<td>+ at choice</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Interferometry</td>
<td>+ before</td>
<td>- random</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
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Improving interferometry

- Regular and frequent revisiting times
- Synchronized SCANSAR for wide areas monitoring
- Better artificial reflectors
- *Geosynchronous illuminator, geosynchronous or LEO receivers*
Better Digital Elevation Models

*Competitors:*

- Optical, high resolution (all times, everywhere ?)
- LIDAR (shallow penetration ?)
- Airplane, UAV interferometry (availability ?)

Satellite interferometry must achieve submetric precision to stay on the market

**Proposed Solutions**

Multistatic Configurations
- Tandem in X band,
- Cartwheel, Pendulum etc.
Conclusion

With more or better:

- Revisiting times, spatial resolution
- LOS directions, frequencies, baselines
- Multistatic receivers
- Stable artificial reflectors

SAR interferometry will even better fulfill its promises.

Many useful results have been achieved already; new services are operational throughout the world.