Derivation and Visual Exploration of 4-D Building Deformation from High-resolution SAR Data

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Outline

1. Background
2. D-TomoSAR and building deformation data
3. Visualization of building deformation
4. Summary

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Background

- Synthetic Aperture Radar(SAR) techniques in various application areas to monitor and detect potential damages
  - Natural Hazards, e.g. landslides, earthquakes
  - Transportation, e.g. roads and railways, bridges
  - Urban areas, e.g. groundwater extraction, flood defense
- Large amounts of raw data are difficult to interpret
- Visualization helps users to see, explore and understand numerous data

- Landslide detection
  - Each ground point identified (colored red to blue)
  - Orange line shows landslide outline

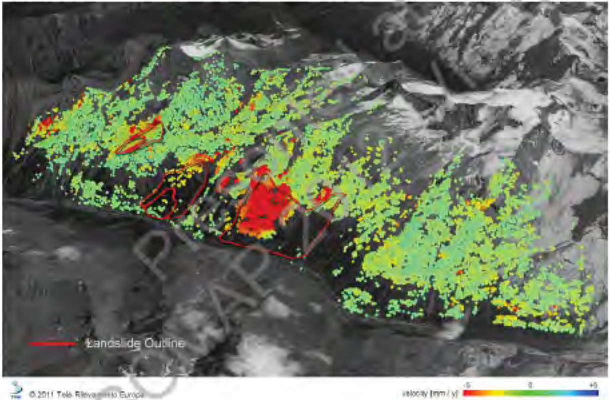

Figure: Landslide detection in Emarese, Italy

- Mapping land subsidence over wide area
  - Data presented is interpolated average velocity
  - Subsidence due to groundwater extraction

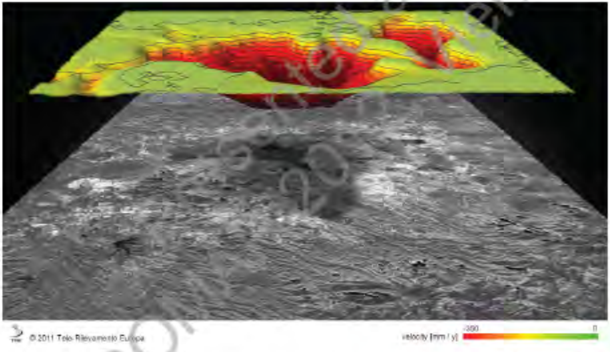

Figure: Subsidence Mapping over the urban area of Mexico City

- Mapping co-relatioinships
  - Surface subsidence to monitor reservoir depletion over time
  - Oil and gas production can cause wide area surface deformation

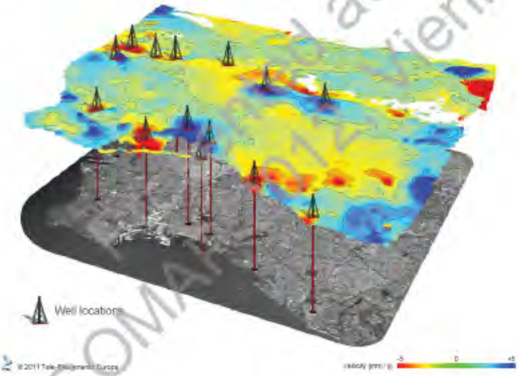

Figure: Ground Displacement due to Oil and Gas Extraction

- 4-D space-time visualization of InSAR data of volcano areas
  - Red and yellow indicate significant levels of eruption activity
  - Smooth geometric surface changes

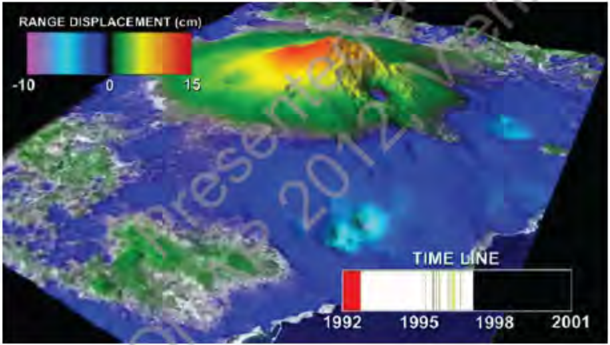

Figure: A time-series of ground deformation at Mount Etna Volcano 1992-2001 (http://www.etnatao.com)

- Individual building deformation detection
  - Monitor building behavior
  - Detect potential damage in urban areas.
  - Visualization of building deformation is not well-studied
    - difficulties of data acquisition; directional dependency

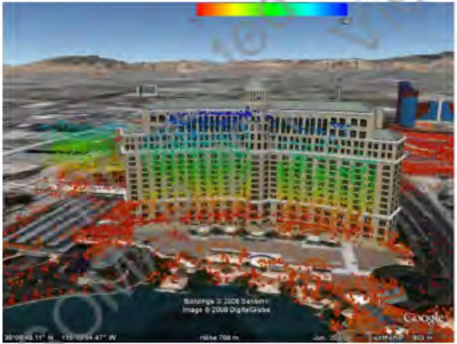

Figure: Color coded elevation for individual building. (Bamler, R., et.al, 2009)

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D-TomoSAR

- Synthetic aperture radar (SAR) imaging
  - Projection of the 3-D object reflection onto a 2-D azimuth-range plane
- SAR Tomography (TomoSAR)
  - Use data stacks from slightly different viewing angles
  - Reconstruct the reflectivity function along the elevation direction
  - Focused 3-D SAR images
- Differential SAR tomography (D-TomoSAR)
  - 4-D focusing, provides retrieval of both the elevation and the deformation information of multiple scatters inside an azimuth × range resolution cell
  - A 4-D (space × time) map of scatters

Building deformation data

- Test area
  - the Bellagio hotel (36 floors, 151 m) area in Las Vegas
- Data source
  - 131,402 points (x,y,z,v) derived from D TomoSAR images (azimuth-range:1.5m × 0.6m)

Figure: Optical view of the Bellagio hotel test area in Las Vegas (©Google Earth)

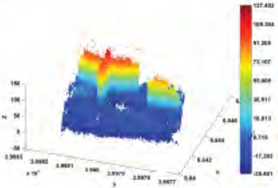

Figure: Test data set with 3-D coordinate information

Point deformation values

- range of the values: -19 to 19 mm/year
- actually line-of-sight directional measurements by satellites
- assume deforms in one of x, y or z directions

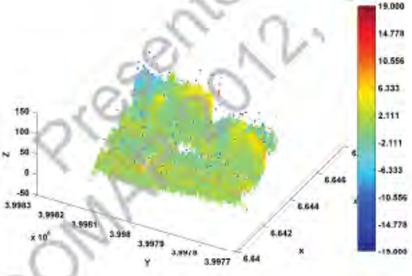

Figure: Color-coded deformation of the same point clouds

Problem statement

- Goal: design visualizations of building deformation for general users
- Drawbacks of color coded point clouds
  - Clustered points difficult to interpret
  - Building boundaries and shapes not obviously observed due to a missing building context
- Solution: Visualization based on 3-D building models
  - 3-D building models offer an intuitive organization of spatial objects
  - Thematic information can be integrated

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Building model extraction and data preprocessing

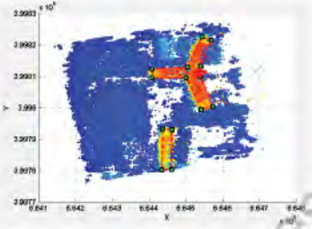

Figure: Turning points of two buildings

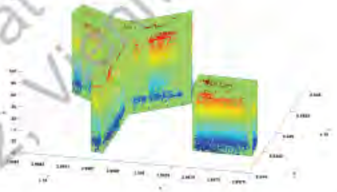

Figure: Projected points on the reconstructed buildings with color-coded height information

- Extraction of building contours
- Reconstruction of a simplified 3-D building model
- Projection of filtered data points onto the reconstructed facades and roofs

Scatter Plot

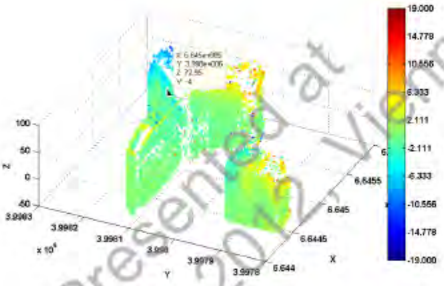

Figure: Scatter Plot

- Based on background knowledge, users may reason that building left sides deforms downwards, and the right sides upwards.
- Individual point information could be retrieved by clicking the point

Triangulation

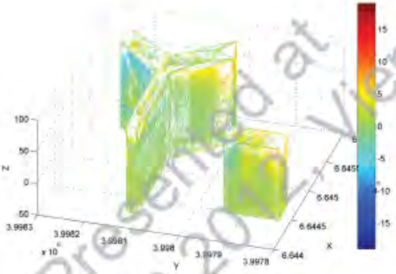

Figure: Triangulation of projected points on building facades and roofs

- Triangulate the points on facades and roofs to form continuous surfaces
- Facade triangulation and roof triangulation

Continuous surface motion

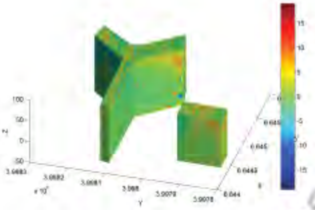

Figure: Deformation is color coded

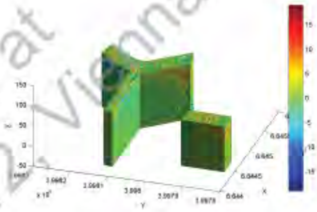

Figure: Deformation is color coded and the surfaces change dynamically according to the deformation values

- Deformation distributions over the whole buildings
- A time series of geometric changes: more intuitive impression of uneven surface movements caused by the directional dependent deformation

Isolines and Layered tints

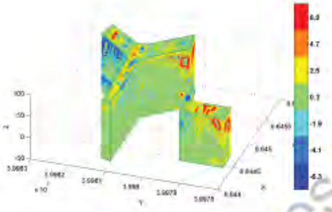

Figure: Deformation is illustrated by Isolines

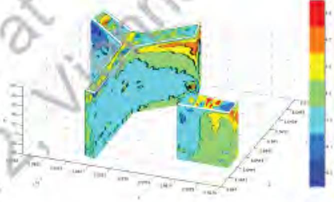

Figure: Deformation is illustrated by layered tints

- Deformation distributions over the whole buildings
- Y-shaped building deforms more than its neighbor building
- Hot spots: The locations of the maximum and minimum values are largely on the "shoulders" of the buildings

Outline

Summary

- Discrete points → Surface
  - Detailed information loss
  - Overview of the whole pattern
- Visualization techniques
  - Scatter plot
  - Continuous surface motion
  - Isoline
  - Layered tint

Future work

- Refinement of current methods
  - Color schemes, shading, lighting and viewing angle etc.
- Towards an interactive and adaptive visualization
  - Integration of more visualization techniques
  - Integration of building model at various levels of details
  - Design of adaptive map legends

Thanks