Technical Innovations in Management of Spatial Data

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FIG Commission 3

Technical Tools

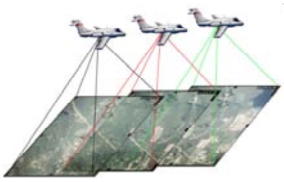
- Rapid urbanization processes ➔
  - Updated, precise and continuous representation of our environment
- In the last decades major technological developments in:
  - Data collection
  - Data integration
  - Data analysis
  - Building of sophisticated GI databases
- The surveying and mapping community has to give answer to:
  - Rapid/frequent updating, integration and analysis of existing GI databases
  - Deal with huge data volumes, resolution levels, and accuracies

Data Collection Technologies

- Traditional techniques
  - Photogrammetry
  - Field surveying (Total Stations and Global Positioning Systems)
  - Cartographic digitization and scanning (raster vectorization of existing maps)
- New techniques
  - Radar based systems (radargrammetry techniques & Interferometric Synthetic Aperture Radar - IfSAR – imaging
  - Laser scanning (LiDAR - Light Detection and Ranging)

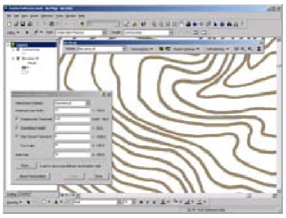
Photogrammetry

- Using stereo pairs of aerial or space imagery
- Based on strip or block adjustment
- From manual up to fully-automated collection techniques
  - Relative/absolute orientations
  - Feature extraction , etc.
  - Accuracy in the range of centimeters to meters
- Toward autonomous solutions



Cartographic Data

- Scanning and vectorization of existing maps
- Fast and relatively inexpensive solution
- Applicable to establishing geo-spatial databases of large areas
- A semi-manual process
  - Quality assurance is required (more than in other techniques)
  - Available in many of the on-the-shelf GIS packages



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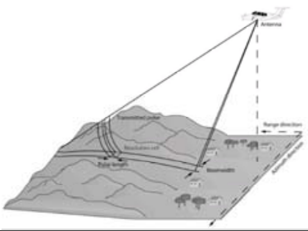
Radar Based Systems

- Using radargrammetry techniques and IfSAR imaging
- Efficient for acquiring data of large regions
- Not affected by the lack of sun light and extreme meteorological conditions
- Accuracy/resolution which was until recently limited, is being improved



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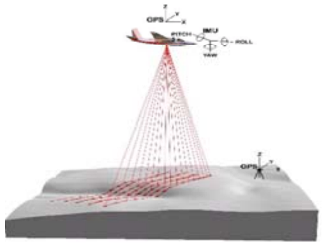
Laser Scanning (LiDAR)

- Using laser ranging techniques (together with INS and GPS) to producing dense 3D points cloud
- Efficient for acquiring data of large regions
- Collecting up to 100,000 points/second
- Collecting up to 18-20 points/sq.meter
- Vertical accuracy up to 10-20 cm.



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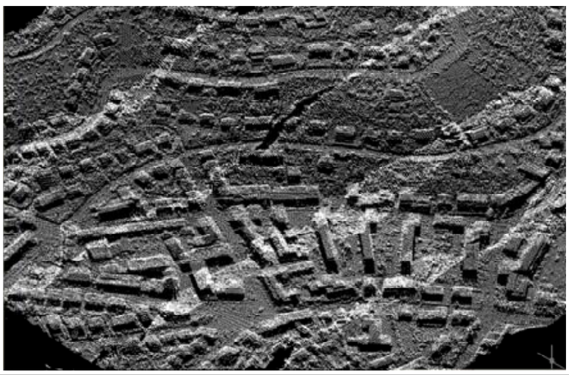
Laser Scanning (LiDAR)



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Terrestrial Laser Scanning

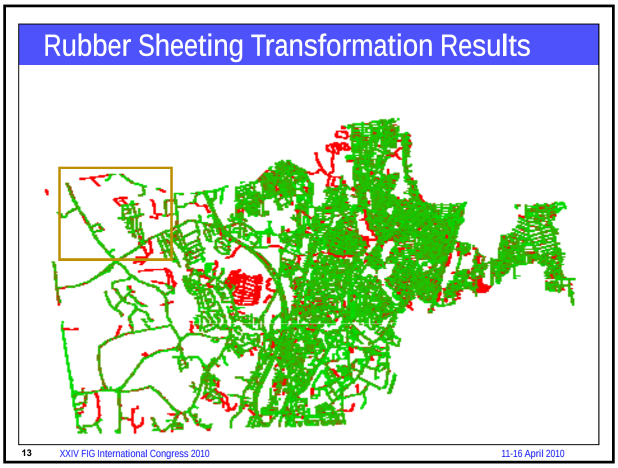
Available Approaches

- An architecture of wrappers and mediators
  - Creating an intermediate dataset
- Map conflation based on:
  - Rubber sheeting transformations
  - Non-Linear transformations
  - Delaunay triangulation
- Data fusion
  - Refers usually to locally solutions – matching feature by feature, or
  - Integrating raster data from multiple sources

Why Data Integration Is Needed

- Digital maps and datasets are:
  - Collected by various institutions
  - Collected by different mean
  - Representing different disciplines
  - Kept in different databases
  - Usually maintained separately
- There is an urgent need to:
  - Use data from diffrent sources
  - Merge them together (by applying an integration process)
  - Implement interoperability applications

Geometric Coordinate Based Overlapping


Rubber Sheeting Transformation Results
13
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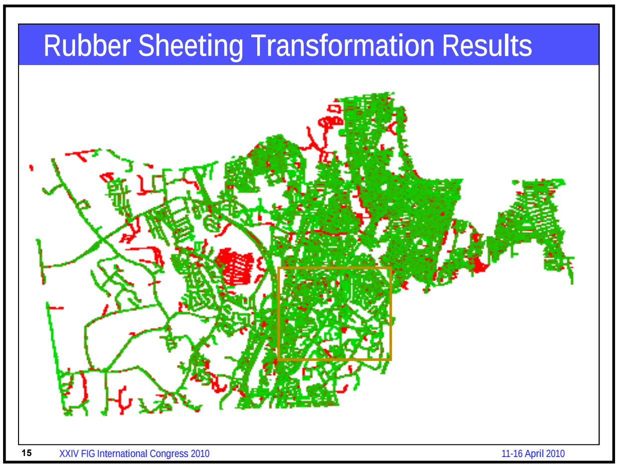
Rubber Sheeting Transformation Results
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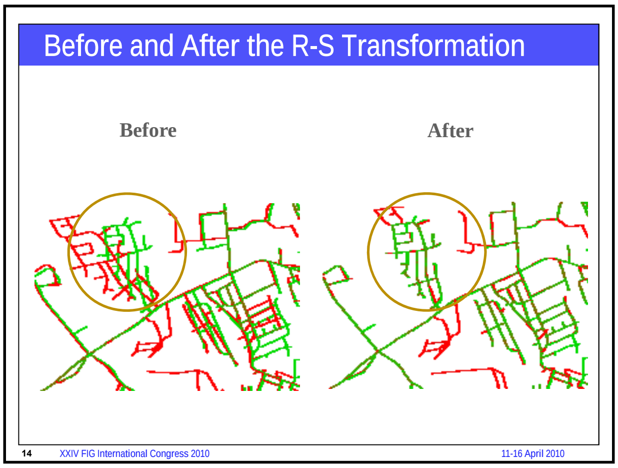
Before and After the R-S Transformation
Before
After
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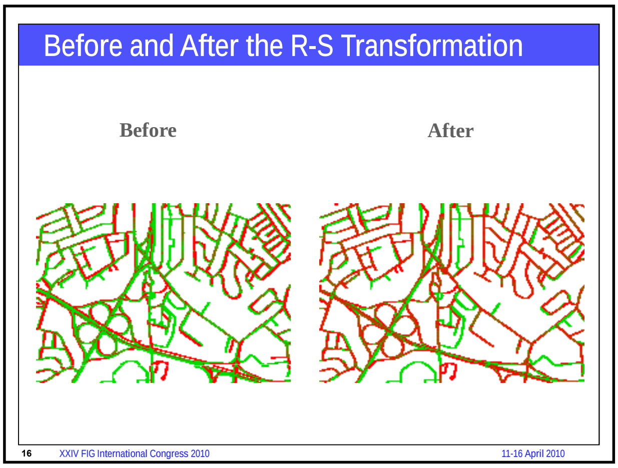
Before and After the R-S Transformation
Before
After
16
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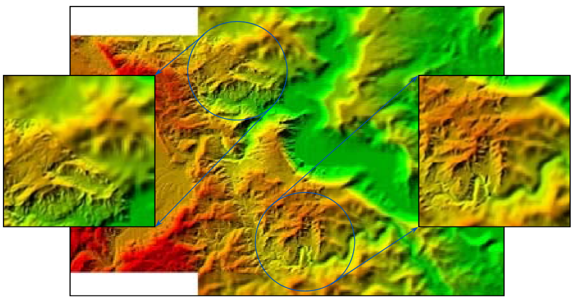
3D DTM/Raster Integration

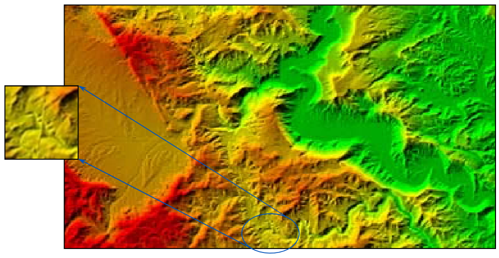
- Different data acquisition techniques affect the produced DTM/raster and can vary by:
  - Model (structure)
  - Data-density
  - Level-of-detail
  - Accuracy and resolution
- A need to overcome geometric discrepancies and inconsistencies
- Standard coordinate based overlapping algorithms are insufficient
- Feature based and/or topographic characteristics approach is required

Example of Overlapping DTM Databases



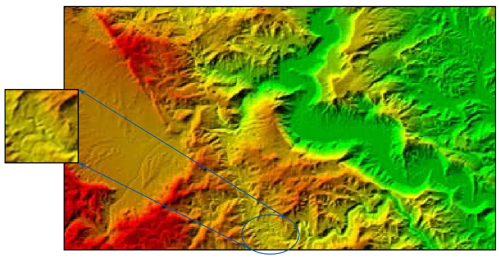
- These two adjacent DTM databases are of different densities.

Result of the "Cut and Paste" Algorithm



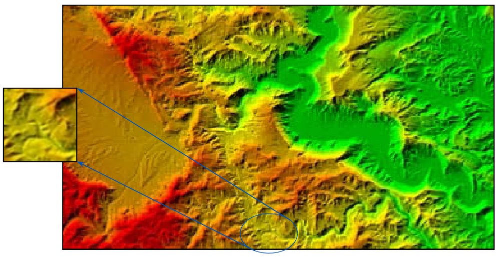
- The seam line is clearly seen as a line of discontinuity.
- Terrain structures within the band surrounding the seam line may appear more than once in the merged DTM.

Result of the "Height Smoothing" Algorithm



- The seam line is hardly visible.
- Terrain's topology and morphological structures are not preserved.

Result of a Rubber Sheeting Algorithm



- The seam line turns out to be a line of continuity in the merged DTM and it is invisible.
- Terrain's topology and morphological structures are preserved.

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3D City Modeling

- Extremely important in many areas of the urban environment:
  - Municipal management, planning, communications, security and defence, tourism, etc.
- Until recently, input data was collected manually - "point by point" - on Photogrammetric Workstations
- Nowadays, extensive research dealing with 3D building extraction is carried out:
  - From aerial images – by semi/full automatic algorithms
  - From LiDAR points cloud – by automatic algorithms

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Semi-Automatic Solution from Photographs

1. Isolating the window round the pointer
2. Finding the edges, enlarging and inserting them
3. Finding the pixels with values similar to those round the pointer
4. Region growing
5. Morphologic operations (Open & Close)
6. Raster to vector
7. Simplification

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Photograph to Photograph Shifting

- Transferring the initial pointer
- Extracting the Right polygon (in the same way as in the Left image)

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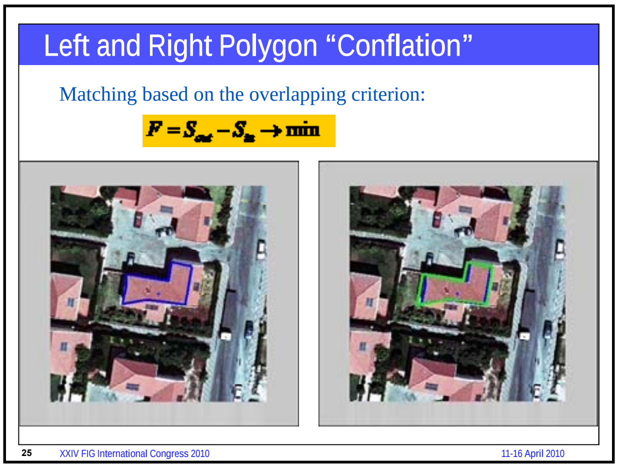
Left and Right Polygon "Conflation"
Matching based on the overlapping criterion:
$F = S_{out} - S_{in} \to \min$
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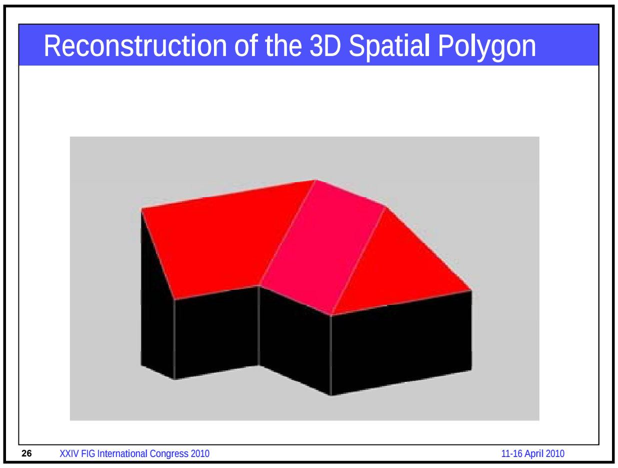
Reconstruction of the 3D Spatial Polygon
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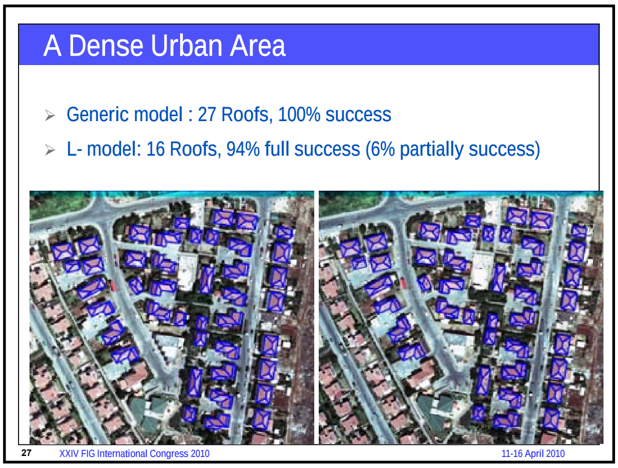
A Dense Urban Area
Generic model : 27 Roofs, 100% success
L- model: 16 Roofs, 94% full success (6% partially success)
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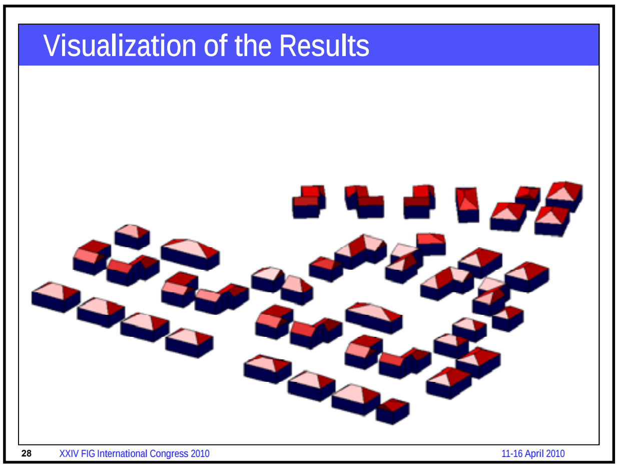
Visualization of the Results
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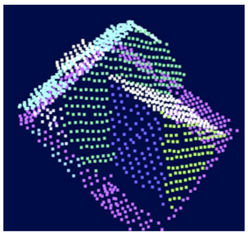
LiDAR Points Cloud – a Segmentation

- Cluster based
- Creating feature vector (slope & height diff) for each point.
- Cluster analysis in feature space
- Grouping in object space
- Validation and refinement follows



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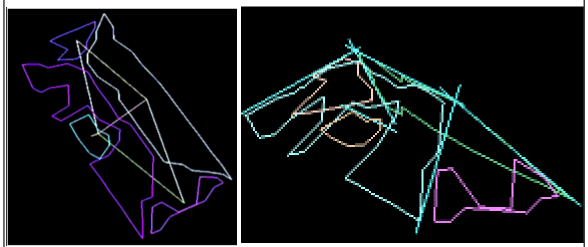
Analysis of Roof Topology



a) adjacency graph b) the crease edges for resulting from it.

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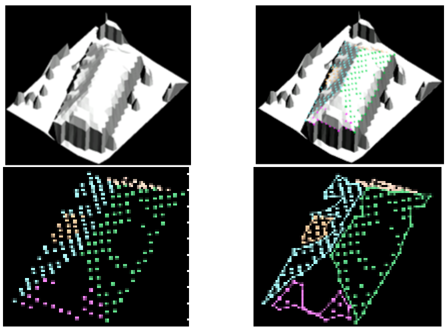
Data Segmentation

(resolution 1.2 p/m2)



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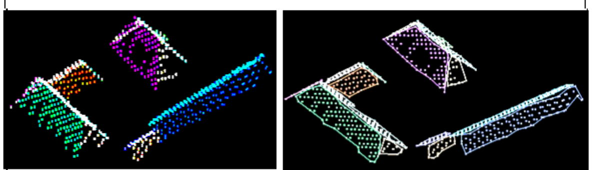
Result of the Segmentation of Buildings

(resolution 1.2 p/m2)



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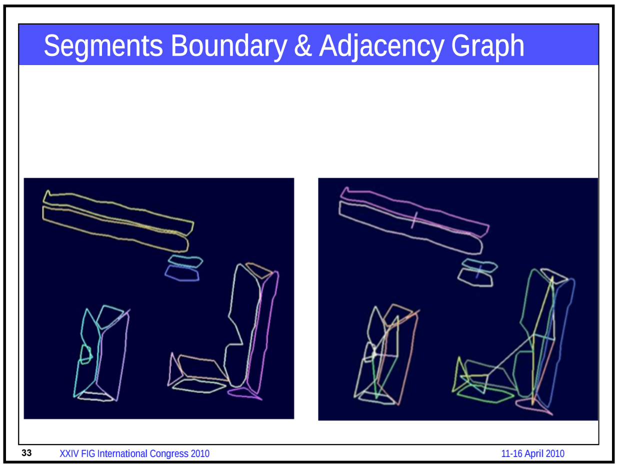
Segments Boundary & Adjacency Graph
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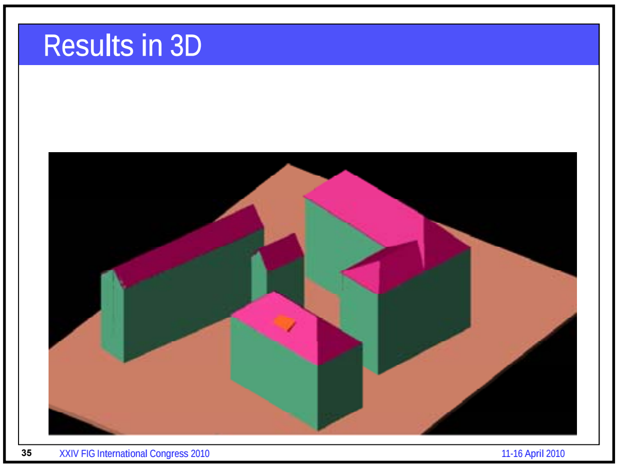
Results in 3D
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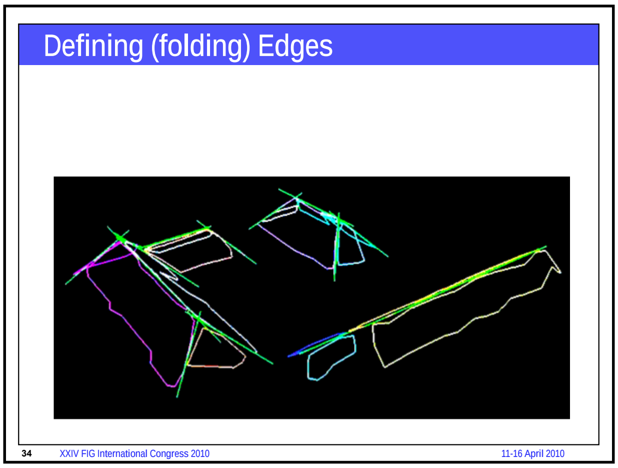
Defining (folding) Edges
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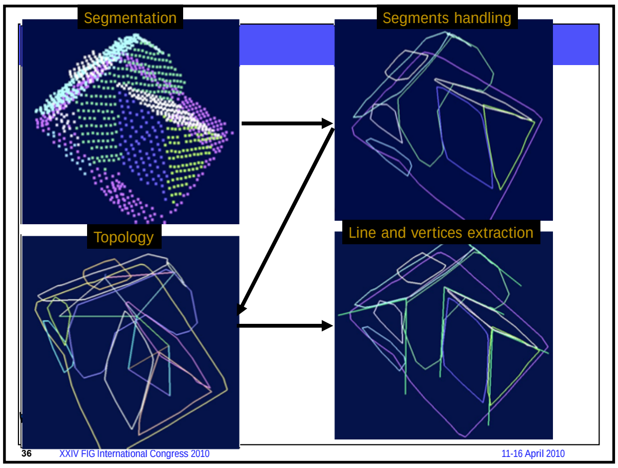
Segmentation
Segments handling
Topology
Line and vertices extraction
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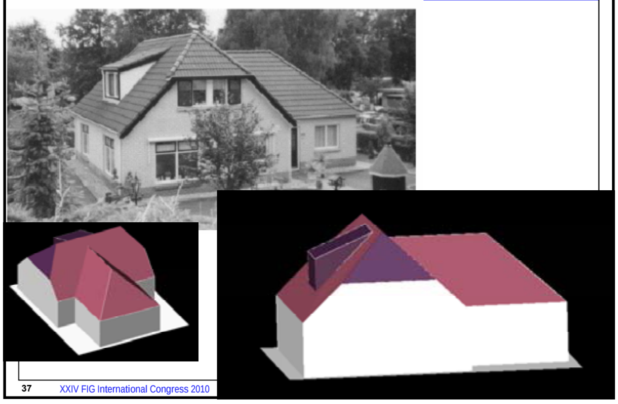
Results Verification



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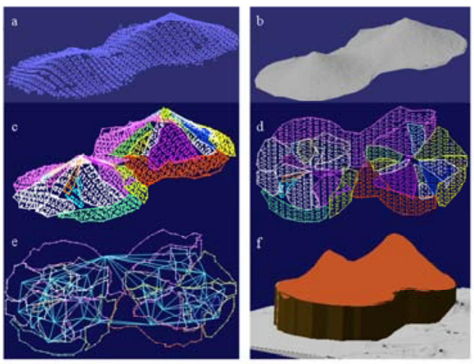
Reconstruction of a Complex Building



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Urban Sensing Technology (*)

- New citizen-activated sensors in the urban environment
  - Cellular phones
  - Radio Frequency Identification (RFID) tagged items
  - Urban observation sensors ("video recording")
- Active and/or passive collecting and managing a wide range of urban information
- Possibility to track movements of all citizens across a megacity
  - RFID like barcodes broadcasting their information
  - Everywhere surveillance through the use of mobile phones
  - Toll passes for vehicle tracking
  - Travel passes for individuals

(*) Thanks to Robin McLaren for his contributions on this topic

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Urban Sensing Technology (cont.)

- It is becoming passive sensors that silently collect, exchange and process information continuously
- In the future, cheap sensors will be added to detect some environmental variables such as:
  - Air pollution
  - Noise pollution
- Initial efforts to:
  - Improve traffic jams by using mobile sensors
  - Integrate location based services (LBS) and social networking to providing real time social interactions
- We are just at the beginning of this urban sensing era

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Urban Sensing Technology (cont.)

A sample of personalized estimates of environmental exposure

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Concluding Remarks

- There is a need for updated, precise and continuous representation of our natural environment / urban areas
- The technical tools required for the representation process of our natural environment - includes both discovery and quantification of the spatial information.
- The surveyors, computer experts and the mapping community at all has the responsibility to develop and implement these tools.

↓

We have the "mission" and we need to supply the vision

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Thank You

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