ΓΓΕΤ ISR_3013

5DMuPLIS
5 Dimensional
Multi-Purpose Land
Information System

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Ταμείο
Περιφερειακής Ανάπτυξης

ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη

Selective 4D modelling framework for spatial-temporal Land Information Management System

A. Doulamis, S. Soile, N. Doulamis,
C. Chrisouli, N. Grammalidis, K. Dimitropoulos
C. Manesis, C. Potsiou, C. Ioannidis

Third International Conference on Remote Sensing and Geoinformation of Environment
16-19 March 2015, Paphos, Cyprus

THE EVOLUTION OF LIMS

***L**and **I**nformation **M**anagement **S**ystem*

Traditionally, the parcels of a LIMS are 2D spatial objects

advances in computer vision and photogrammetry

3D-LIMS

manipulates, stores, queries and analyzes 3D land properties, rights and spatial restriction

spatial-temporal alterations of the land resources and the respective rights

3D geometry plus time

A 3D LIMS need to be extended towards a **4D representation**

even the 4th dimension is not enough for urban management, since such systems integrate various types of information, of quite different type and detail

5D multipurpose LIS → time-scale 3D model representation

MULTI-DIMENSIONAL MODELLING
STATE OF THE ART

3D Modelling

- ❑online virtual globe viewers
- ❑V-City project
- ❑3D maps enhanced with video
- ❑ companies working on developing 3D cadastral applications
- ❑ considerable research on 3D reconstruction algorithms

4D Modelling

- •capturing of the dynamic nature of land information
- •independent 3D modelling processes are needed
- •handling of heterogeneous types of data

⇩

arduous and cost demanding process

❑4D-CH-World

▪Currently, 4D modelling is implemented by a simple aggregation of independent 3D digital models at different time instances → not suitable for large-scale cases

▪Currently limited to the display of different static configurations of geospatial datasets → not appropriate for land management

AIM OF THE RESEARCH

The proposal of a selective (predictive) multi-dimensional modelling framework

The 4D modelling framework (3D geometry plus time) is proposed for:

- ✓ improving the automation and cost-effectiveness of 3D capturing of land parcels and
- ✓ provisioning new personalized tools and services to different actors involved

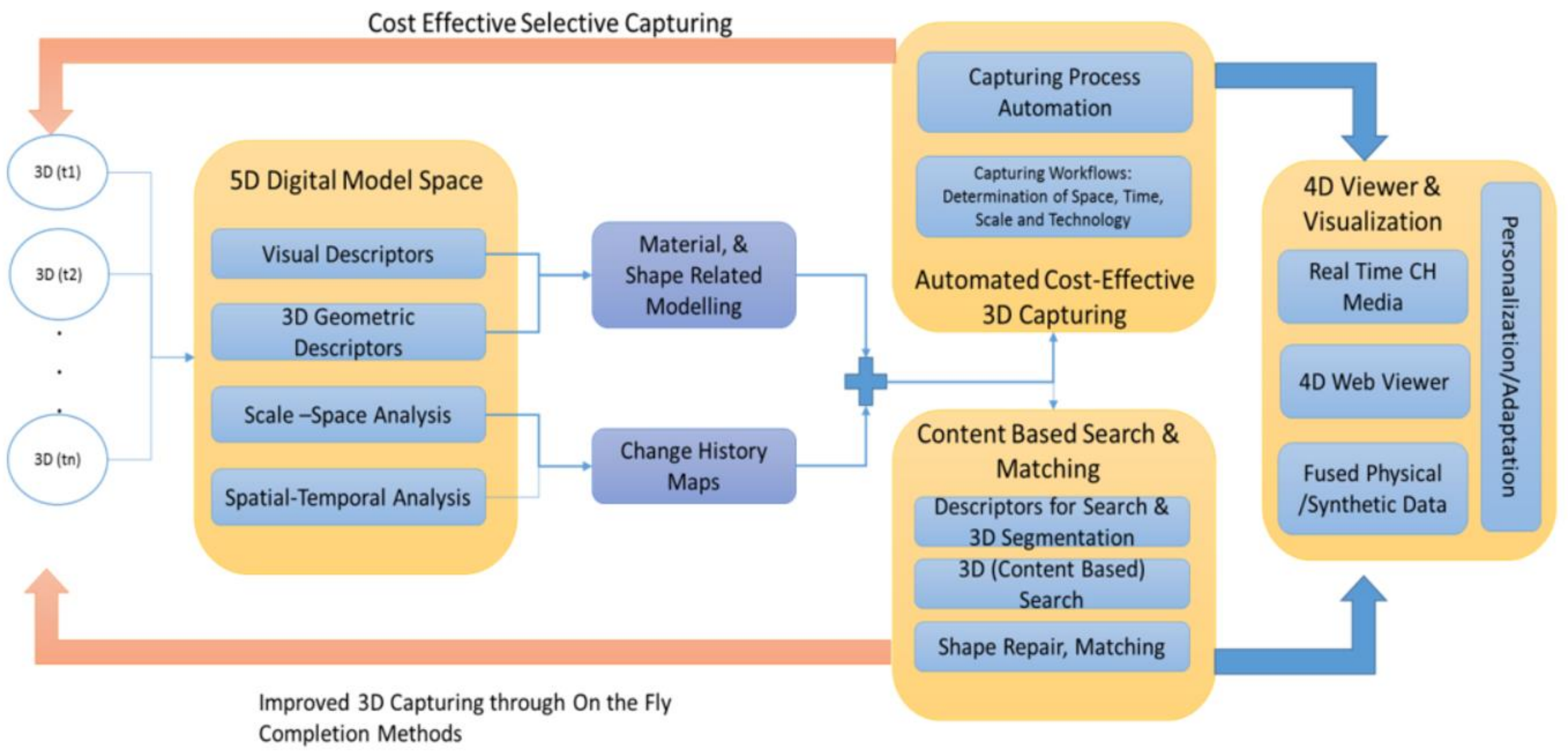
SELECTIVE 3D MODELLING

- Only regions that undergo a significant spatial-temporal change are 3D modelled at the next time instances
- Regions of insignificant change remain intact
- For this reason, a spatial temporal analysis is initially applied to the 3D models to indicate the regions of changes
- The results are change history maps that indicate the regions where spatial-temporal changes occurred
- Scale-space analysis is adopted to reduce the computational time
- The outcome of this analysis is used for determining the most appropriate photogrammetric method for the next 3D modelling

✓ **Regions of insignificant changes can be captured with less precise 3D scanning methods, avoiding computational complexity**

✓ **Regions of significant changes are 3D scanned with precise methods, since no significant information is available from previous 3D modelling processes**

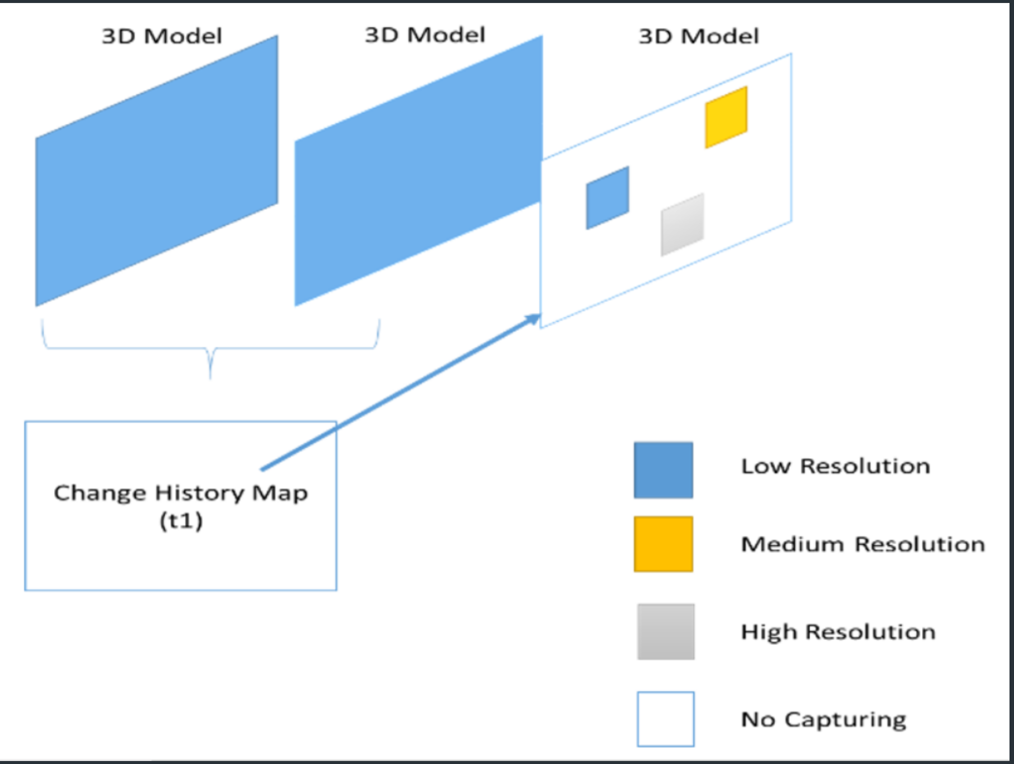
ARCHITECTURE OF THE SELECTIVE 3D MODELLING SCHEME



CHANGE HISTORY MAPS (1/3)

Change history maps detect regions of interest in the 3D space by combining multiple instances of a 3D model

The change history maps determine the regions that need to be reconstructed more precisely than others due to temporal changes



CHANGE HISTORY MAPS (2/3)

Geometric History Changes

- Initial smoothing of the 3D models by the application of a Gaussian pyramid filter
- Creation of the change history maps directly from the filtered 3D models
- The ICP algorithm is applied between the two examined 3D models in order to align the point clouds of the two time instances

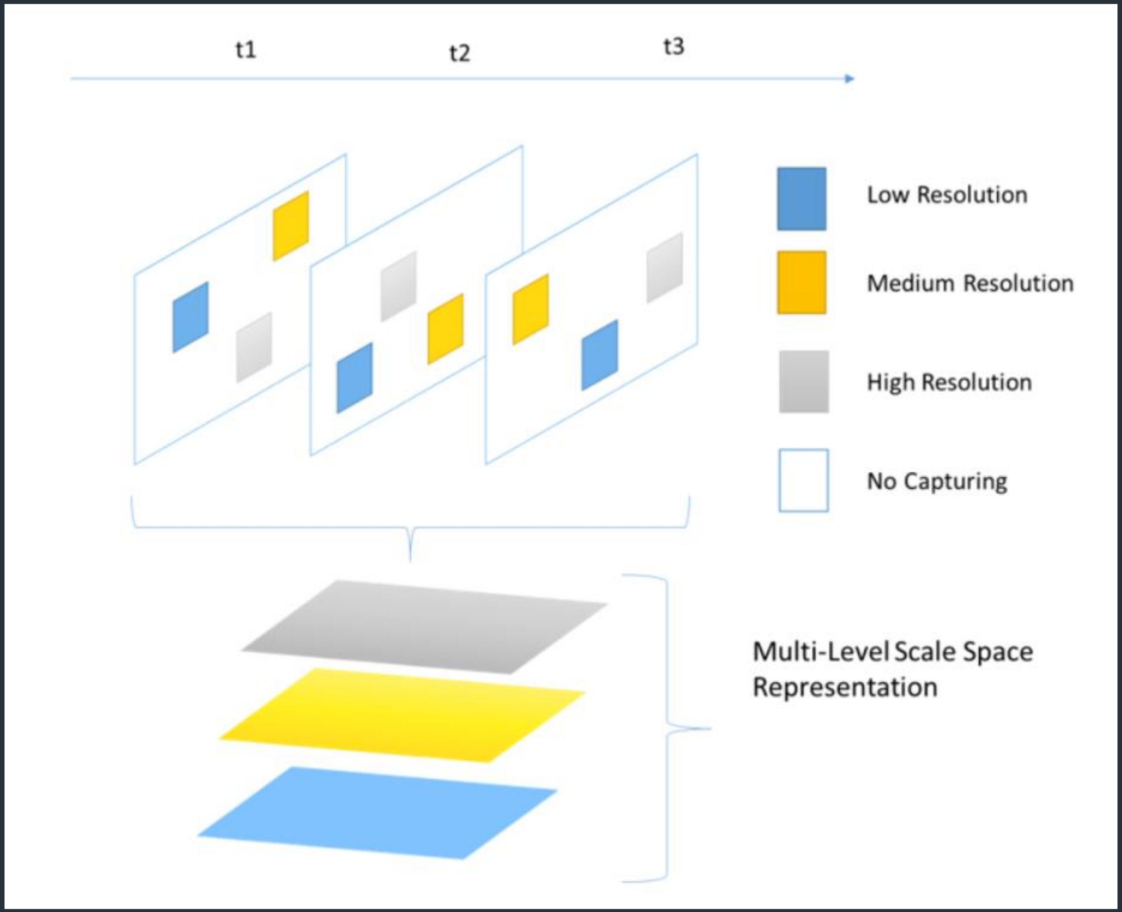
Semantic History Changes

- Use of the metadata information embedded on the 3D models
- In case that the geometric properties of a building have not been changed but the semantic information connected with a part of this building has been changed, a change history map is also created

CHANGE HISTORY MAPS (3/3)

Scaled History Maps

- Another important aspect is the scale of representation
- Creation of multi-level scale resolutions from partial reconstructions
- Reconstruction of a multi-level resolution pyramid from the low to high resolution scales



DATABASE STORAGE

Heterogeneous data associated with different time and scale information will be collected

- raster files
- vector files
- additional information

Transformation to an extended-CityGML format
Semantic enrichment

CityGML objects and metadata from the Greek cadastre

Data storage to a PostgreSQL/PostGIS database

open source software of 3DCityDB

provides

the geo-database, the relational schema, tools to import and export CityGML documents and other tools

4D VISUALIZATION (1/2)

Regarding the 4th dimension (time):

- Buildings that undergo changes between two consecutive time instances will be associated with two different IDs
- A single ID will be used if no change occurs
- The additional time will be added as an external reference in the database in order to encode changes in the time dimension

Features of the viewer for visualization of GityGML models →

- Controls allowing to interactively visualize different time instances and scales of a model
- Option to display (or highlight) the changes between two models
- Display of additional information

4D VISUALIZATION (2/2)

Regarding the input data formats a number of visualization approaches are available:

- direct visualization of the geometry of CityGML
- transformation of CityGML to a more efficient file format

KML/COLLADA file formats

X3D file format

suitable exporters of data in these formats can be developed

APPLICATION CASE STUDY

- Study area: a region consisting of 10 urban blocks in the municipality of Kessariani, a suburb in the eastern part of Athens
- Data used for the creation of the 3D models: 2 stereo pairs of analogue aerial images, at a scale of approx. 1:7000, taken in 1983 and in 2010
- 12 GCPs were measured

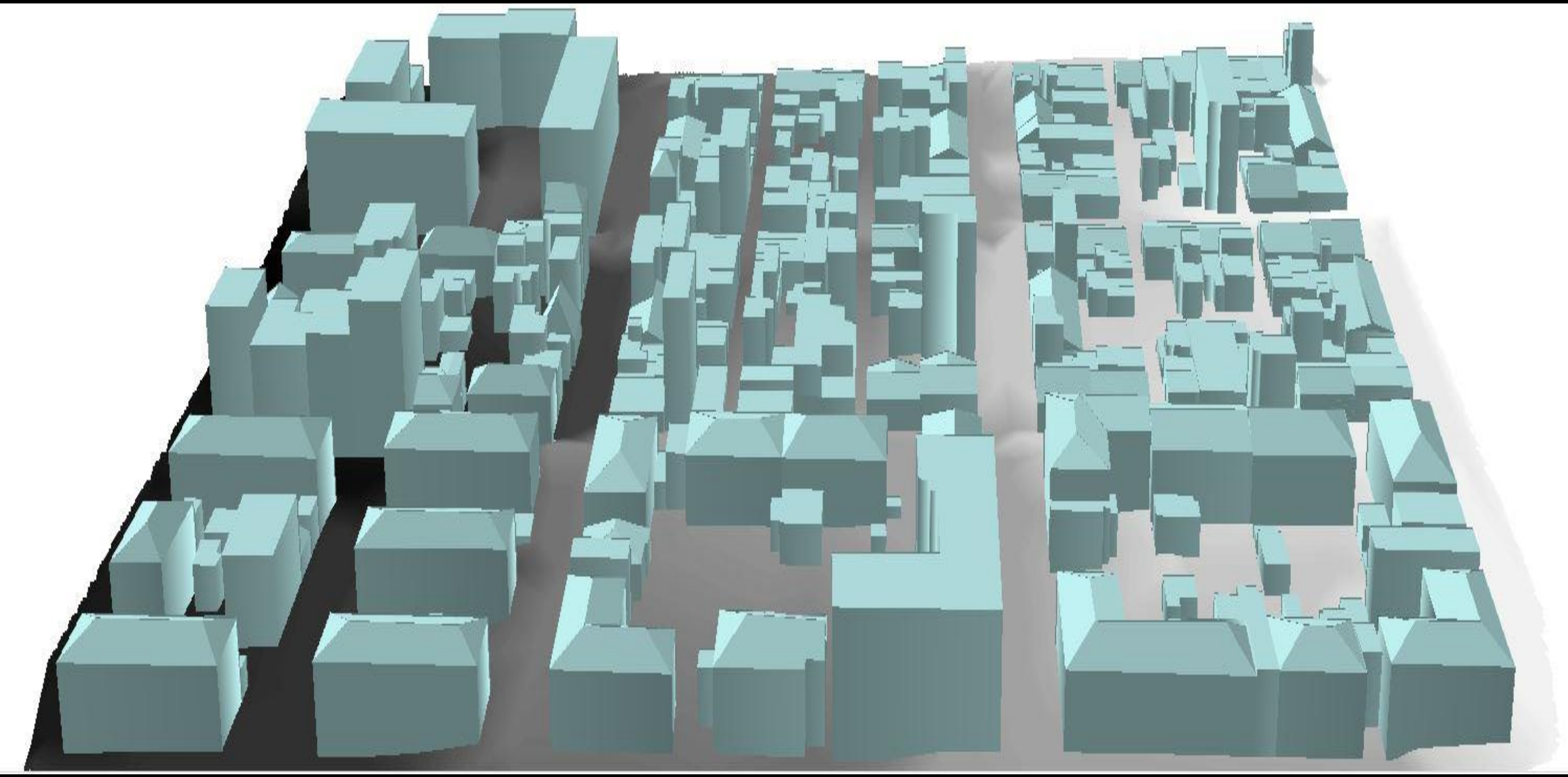
CREATION OF THE 1983 3D MODEL

- The building outline, the roofs, the outline of other constructions, as well as mass points and lines defining the ground were stereo plotted using the 1983 stereoscopic model in ImageStation Digital Photogrammetric Workstation
- A geo-database was created, with the buildings, the ground points and the lines as feature classes.
- TIN surfaces were constructed and were then converted in raster DTMs which were inserted in the geo-database
- The buildings were extruded to the DTM

The outputs of the procedure are 3D polylines and shapefiles

Level of Detail: external volumes

THE 1983 3D MODEL

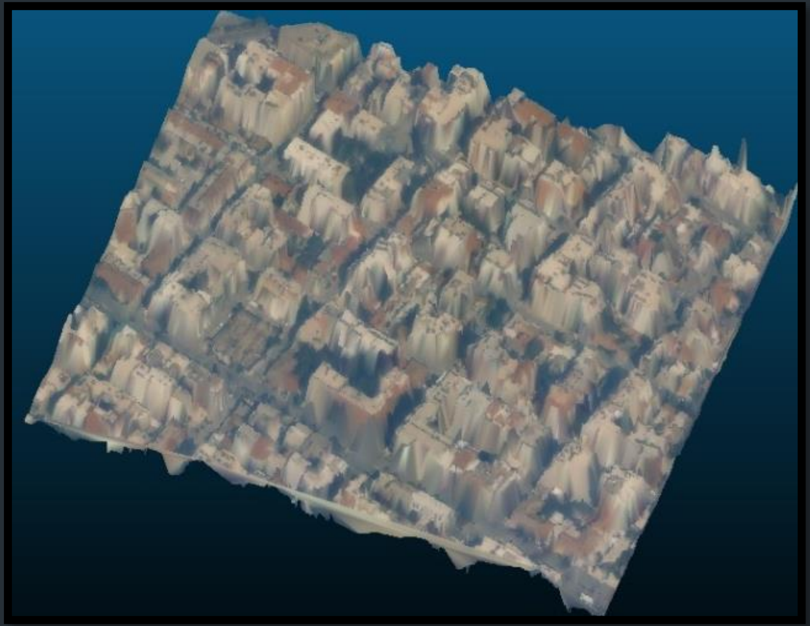


DENSE IMAGE MATCHING IN THE 2010 STEREO PAIR

The eATE (enhanced Automatic Terrain Extraction) dense image matching module of Erdas Imagine 2015 was used

georeferenced dense point cloud of the study area

POINT CLOUD



MESH SURFACE

COMPARISON OF THE 3D MODELS

The two point clouds (1983 and 2010) vary significantly in terms of density

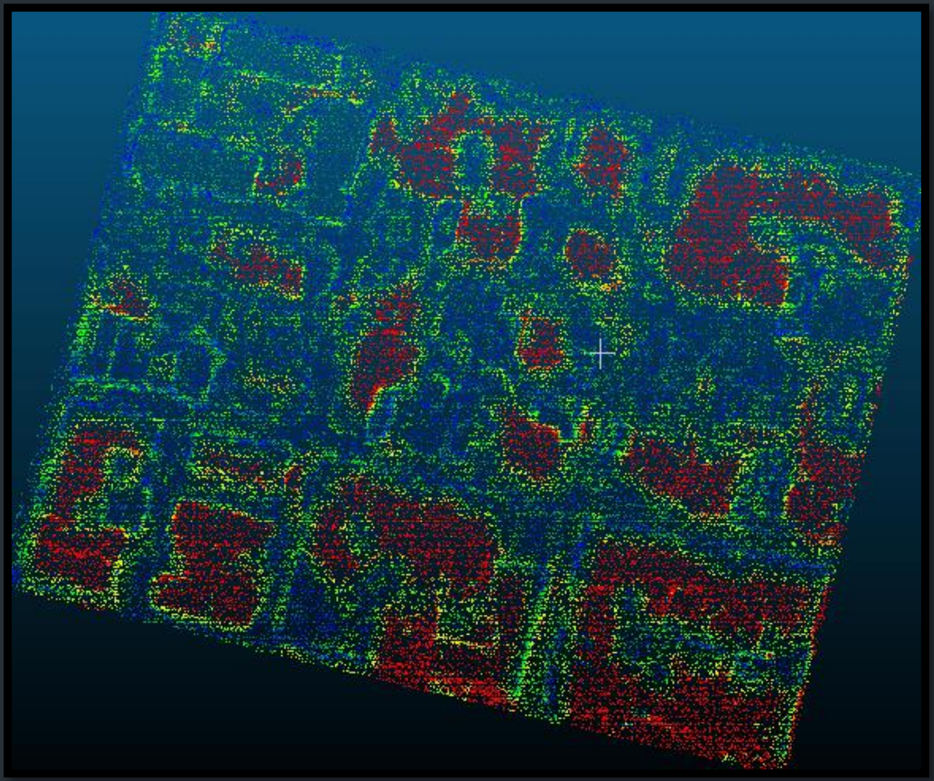
They are transformed into meshes

- For the mesh of 2010 the application of a Laplace filter is implemented

The two meshes are transformed into point clouds of the same density (approximately 0.30 cm)

Using a comparison test the areas with changes are located, with a threshold of 4 m so that changes like a new floor can be detected

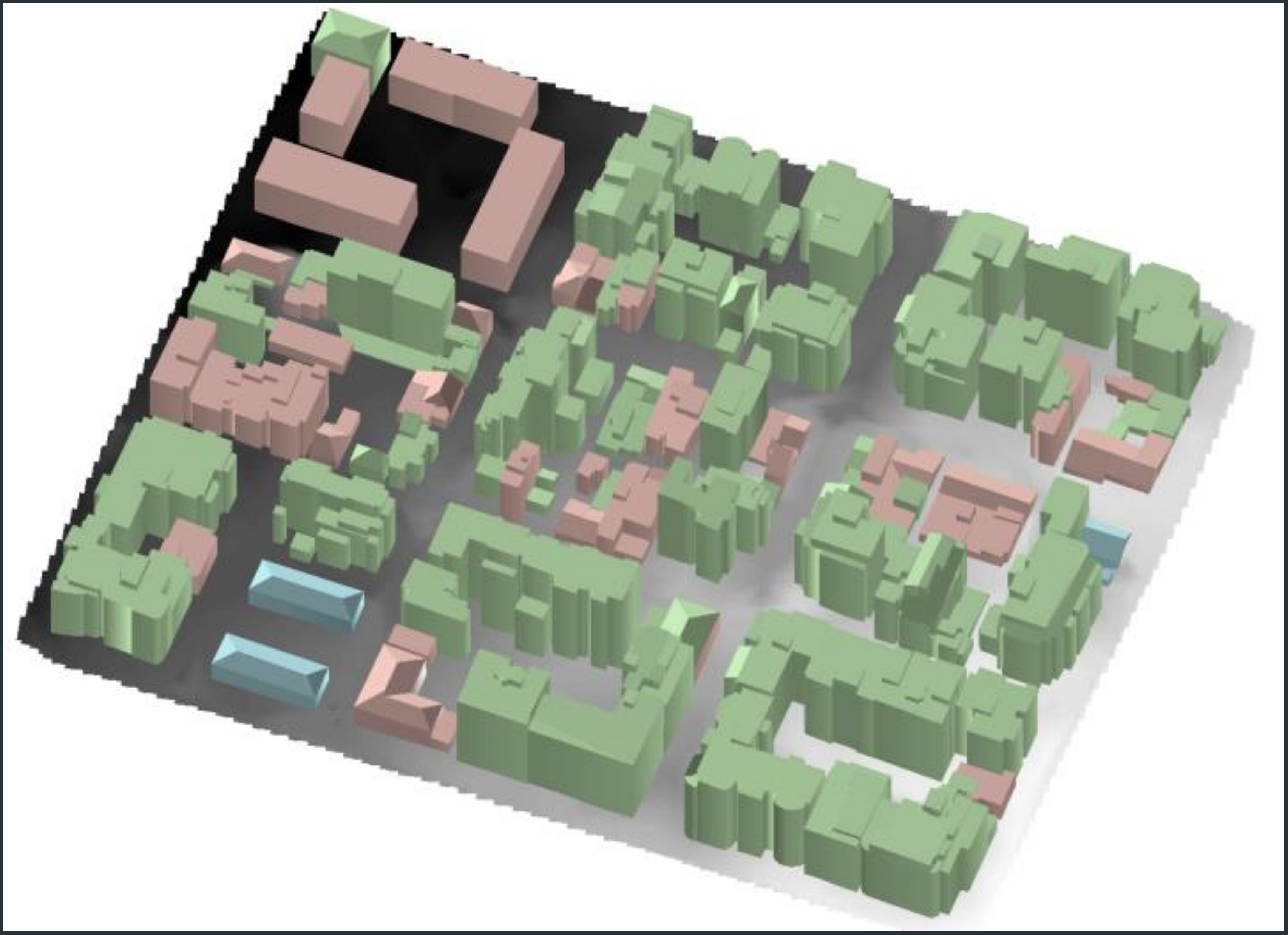
CHANGE HISTORY MAP



Colored point cloud according to the detected height differences

Drawing of the differences as they are derived from the visual control

FINAL 3D MODEL OF THE STUDY AREA



CONCLUSIONS

- The development of a 4D LIMS, may have multiple uses and applications
- A significant negative factor is the cost of the creation of accurate 3D models in various time instances
- The application of the proposed selective 4D modelling framework may improve automation and cost-effectiveness of 3D capturing of land parcels and constructions
- The use of dense image matching techniques gave satisfactory results according to the accuracy requirements
- The 3DCityDB geo-database incorporating with PostgreSQL seems appropriate to manipulate 3D data and their semantics
- The proposed implementation of the CityGML framework allows the description of the semantic metadata information and the visualization aspects for easy manipulation and representation of the 4D LIMS