NATIONAL TECHNICAL UNIVERSITY OF ATHENS
SCHOOL OF RURAL AND SURVEYING ENGINEERS
LABORATORY OF PHOTOGRAMMETRY

Development and implementation of a Multi-dimensional Land Information System for Urban Re-adjustment

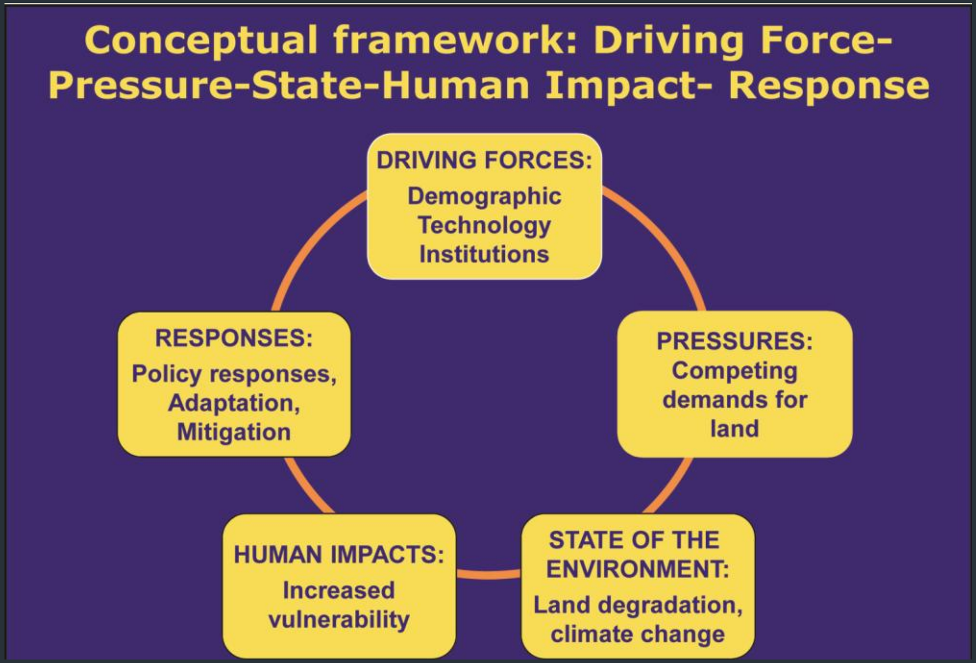
Развитие и внедрение многофункциональной земельной информационной системы для целей реорганизации городских пространств

Prof Dr Chryssy Potsiou, Prof Dr Charalabos Ioannidis

ЧЕТВЕРТОГО ВСЕРОССИЙСКОГО СЪЕЗДА КАДАСТРОВЫХ ИНЖЕНЕРОВ
Иркутск, Россия , 15 июня - 18, 2015

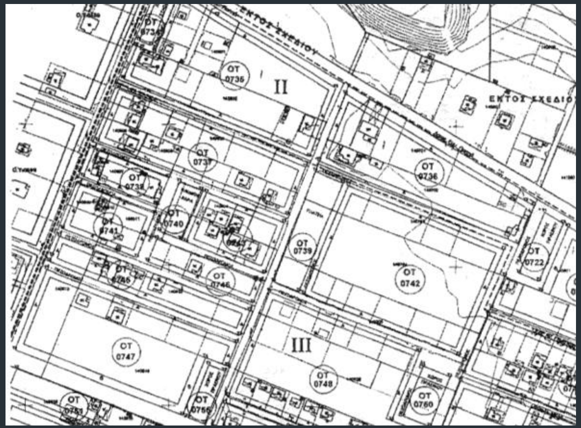
URBAN RE-ADJUSTMENT

- Good governance of the complex modern urban environment requires reliable, real-time, big geospatial data of various types
- Climate change requires energy saving policies
- People require sustainable prosperity for all
- Rapid increase of urban population and the need for compact cities require 3d LIS / 3D GIS



REDISTRIBUTION OF PROPERTY RIGHTS FOR AFFORDABLE HOUSING

- Sustainable property market
- Sustainable housing policy and housing rights
- Affordable planning
- Affordable housing



Housing of very low-, low-, or middle- income households

30% standard: to rent or buy a house for a cost of 30% of the household income

This means different things for different target groups in the various countries

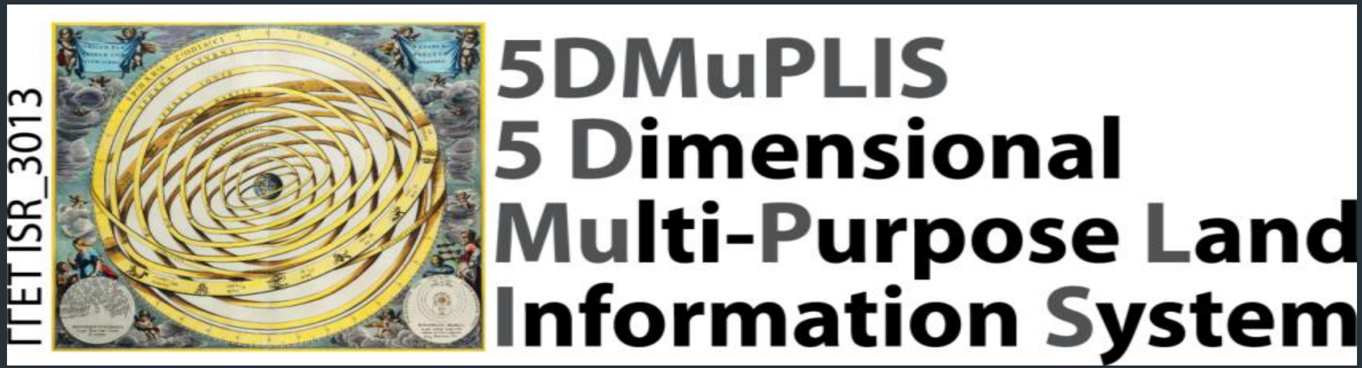
THE ROLE OF PUBLIC AND PRIVATE SECTOR

- Affordable housing policy requires a strong collaboration among the state agencies that are responsible for planning and the private sector that is active in the construction and property market
- The state should regulate (**quantity and price**) for an adequate number of beneficiaries
- To secure that an adequate number of new properties will be constructed and be available to the households in need

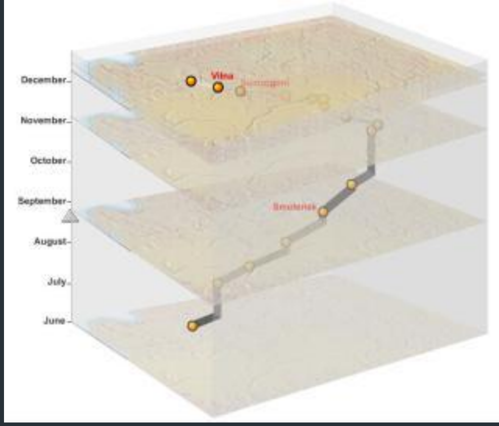
PROCEDURE TO PROVIDE PRIVATE OR/AND STATE LAND FOR A SMALL SCALE URBAN LAND RE-ADJUSTMENT

- Adjudication of existing property rights and rights to use
- 3D cadastre and planning at a certain time t_1
- Collection of all necessary spatial data about the valid land use regulations at t_1
- Estimation of the value of each property at t_1
- Implementation of new regulations and construction of new buildings
- Redistribution of property rights to the old owners according to their value plus a small ‘profit’ that will cover all type of costs
- The remaining of the new properties belong to the constructor to cover his expenses and profit and to provide a percentage of those for affordable housing according to an agreement with the state/regulations

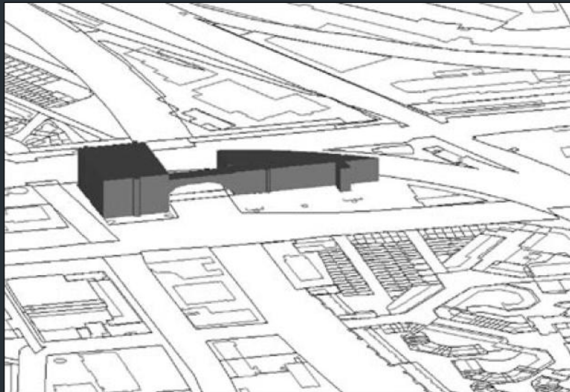
RESEARCH PROGRAMME



Development of a **5D multi-purpose LIS** , based on existing commercial software, for 3D management of various data types extracted from national, regional or local databases (architectural, surveying, cadastral, economic, property values, property rights, etc)



in **3 spatial dimensions** (ownerships & constructions) **+ time** (changes) **+ scale** (different Level of Details)



RESEARCH FIELDS OF THE PROJECT

- **Urban planning**

  LIS , Urban re-adjustment, Land policy

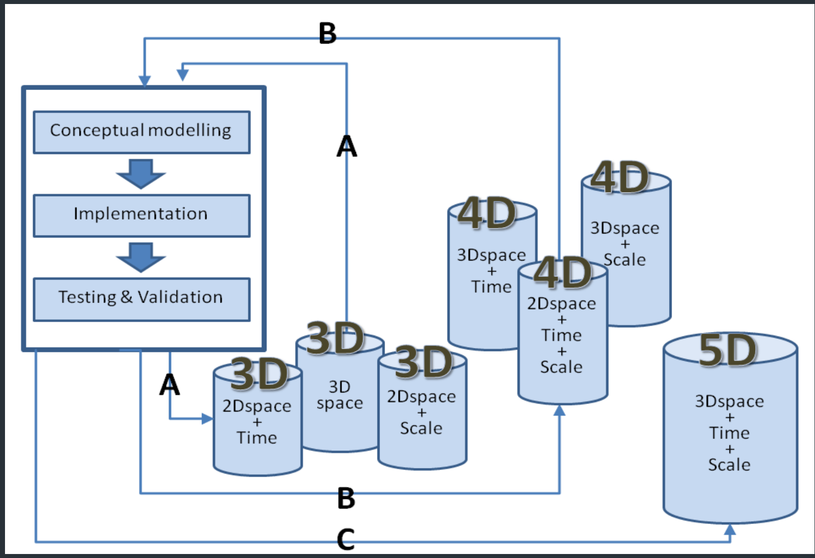
- **3D modelling**

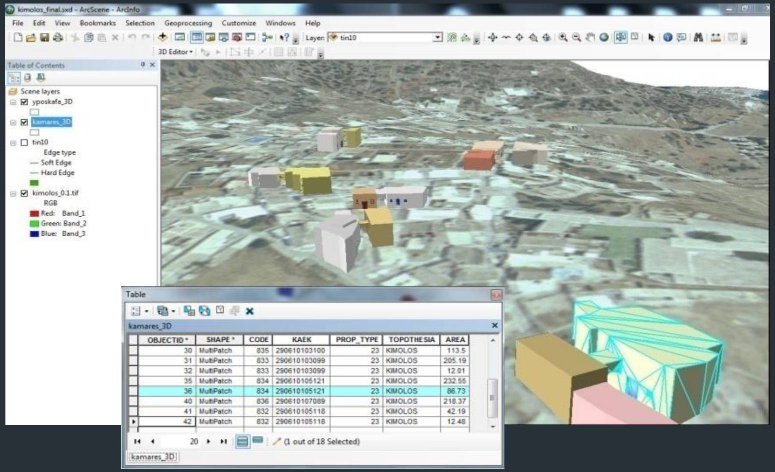
  3D models for urban planning,

  3D topologies, Visualization

- **4D/5D modelling**

  Creation of 4D and 5D, Tools for 3D image analysis, Dense image matching, Scale generalization





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

time and cost demanding process

- handling of heterogeneous types of data

- 4D modelling is implemented by a simple aggregation of independent 3D digital models at different time instances → not suitable for large-scale cases
- Limited to the display of different static configurations of geospatial datasets → not appropriate for land management

5D VISUALIZATION

Regarding the 4th dimension (time):

•Buildings that undergo changes between two consecutive time instants 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 →

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

Regarding the 5th dimension (scale):

•Automatic display of the 3D model of the appropriate level of detail (LoD), while the user zooms in and out

5D VISUALIZATION

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

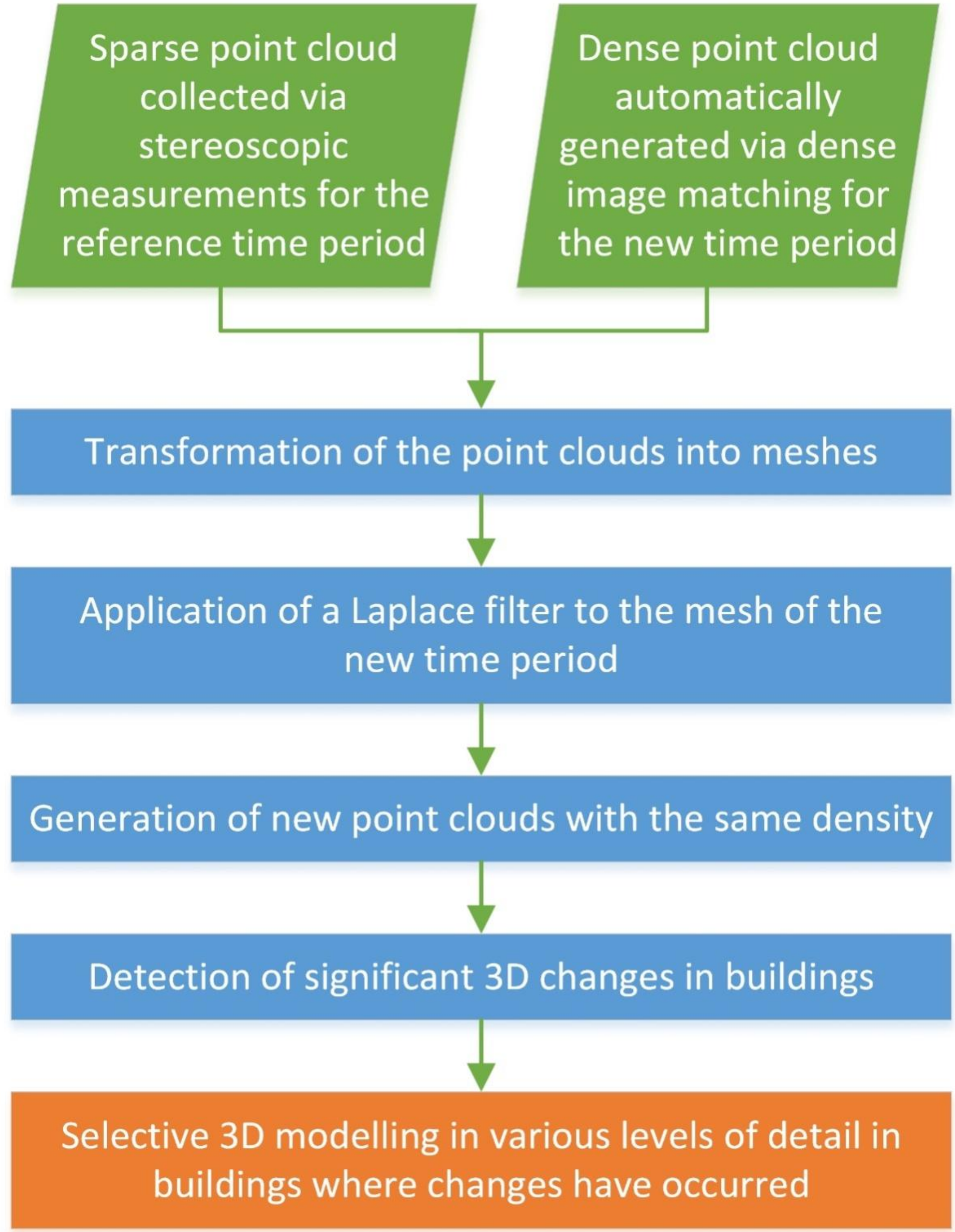
- direct visualization of the geometry of CityGML
- transformation of CityGML to a more efficient file format

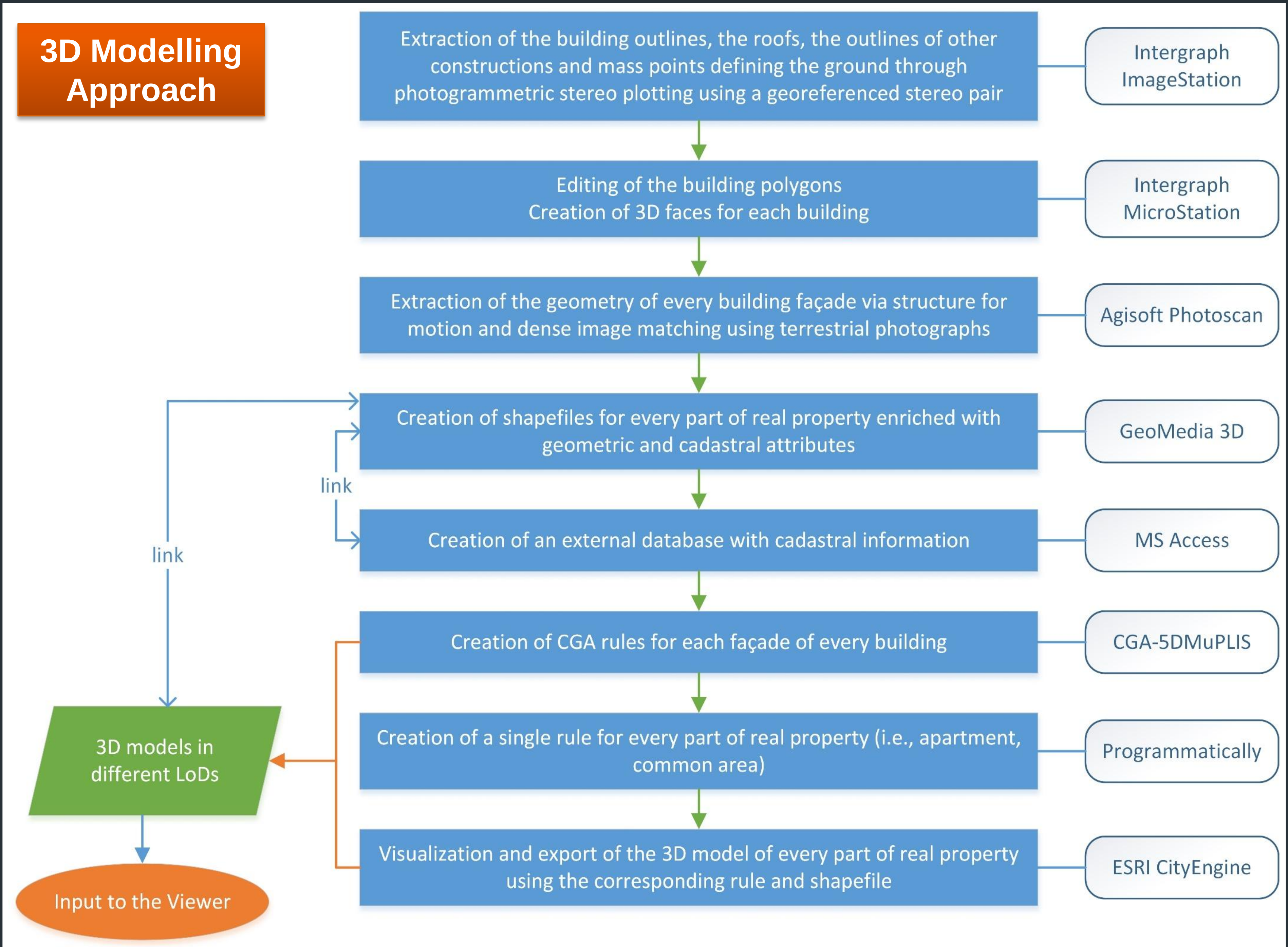
KML/COLLADA file formats

X3D file format

suitable exporters of data in these formats can be developed

Selective 3D modelling approach in areas where changes have occurred




3D Modelling Approach
Extraction of the building outlines, the roofs, the outlines of other constructions and mass points defining the ground through photogrammetric stereo plotting using a georeferenced stereo pair
Intergraph ImageStation
Editing of the building polygons
Creation of 3D faces for each building
Intergraph MicroStation
Extraction of the geometry of every building façade via structure for motion and dense image matching using terrestrial photographs
Agisoft Photoscan
Creation of shapefiles for every part of real property enriched with geometric and cadastral attributes
GeoMedia 3D
link
Creation of an external database with cadastral information
MS Access
link
Creation of CGA rules for each façade of every building
CGA-5DMuPLIS
Creation of a single rule for every part of real property (i.e., apartment, common area)
Programmatically
3D models in different LoDs
Visualization and export of the 3D model of every part of real property using the corresponding rule and shapefile
ESRI CityEngine
Input to the Viewer

CASE STUDY

- Study area: A region consisting of 10 urban blocks in a suburb in the eastern part of Athens, Greece
- Data used for the creation of the 3D models:

  Two stereo pairs of aerial images, at a scale of 1:7000,

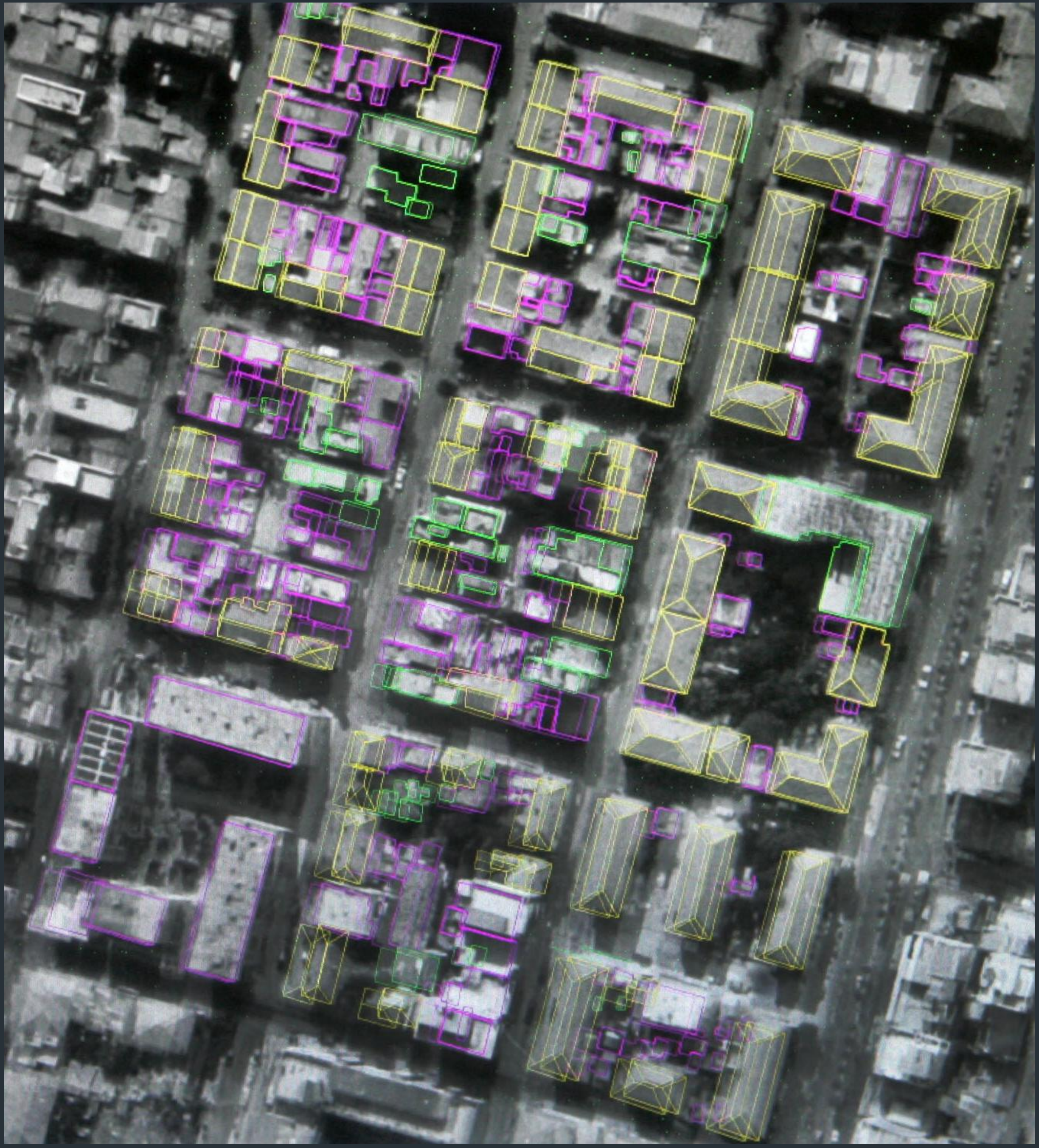
  taken in 1983 and in 2010
- 12 GCPs were measured

CREATION OF THE 3D MODEL FOR THE REFERENCE TIME PERIOD (1983) & LoD1

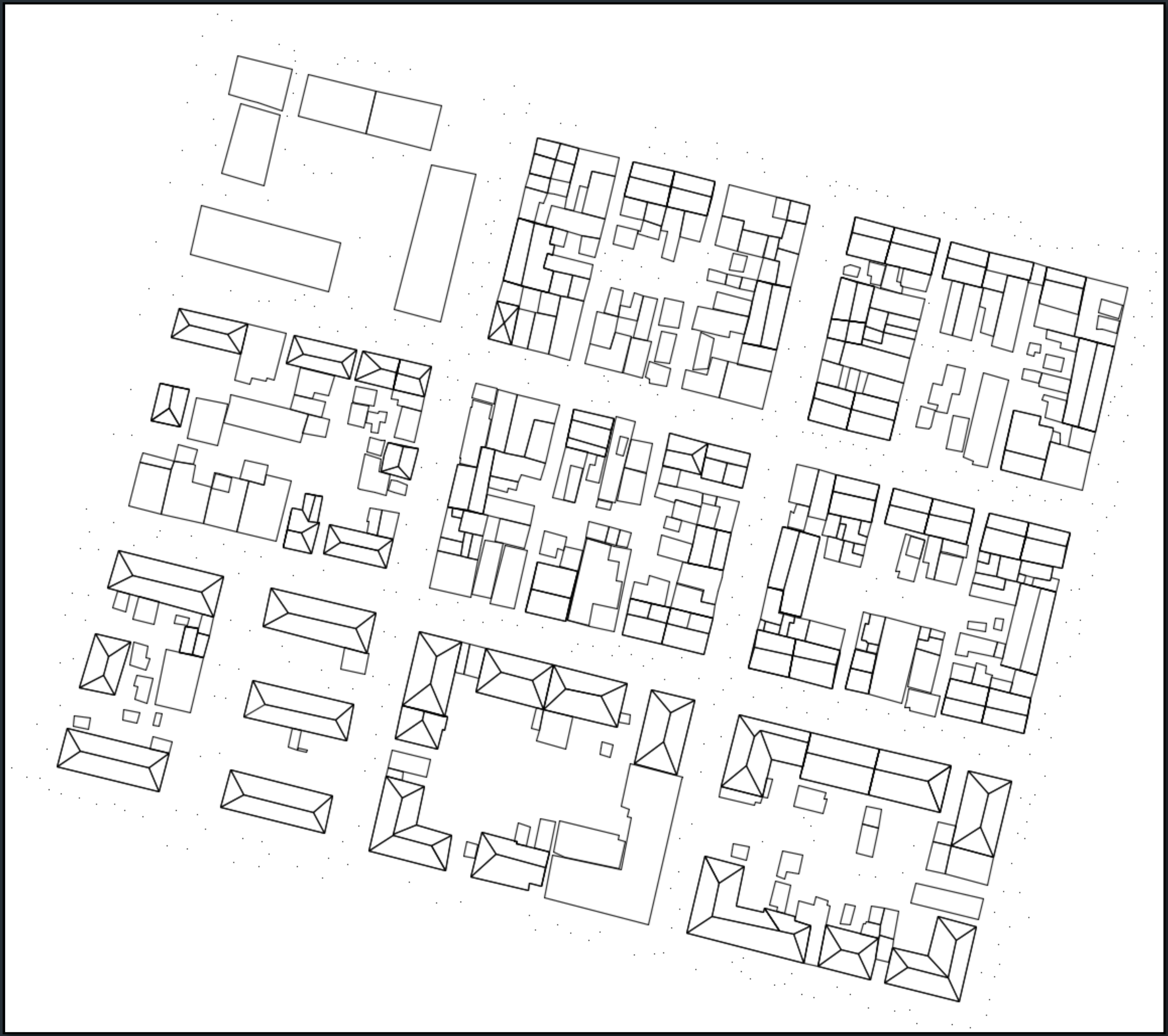
- The building outline, the roofs, the outline of other constructions, as well as mass points and lines defining the ground were stereo plotted using the stereoscopic models in ImageStation Digital Photogrammetric Workstation
- A geo-database was created, with the buildings, the ground points and the 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 were 3D polylines and shapefiles

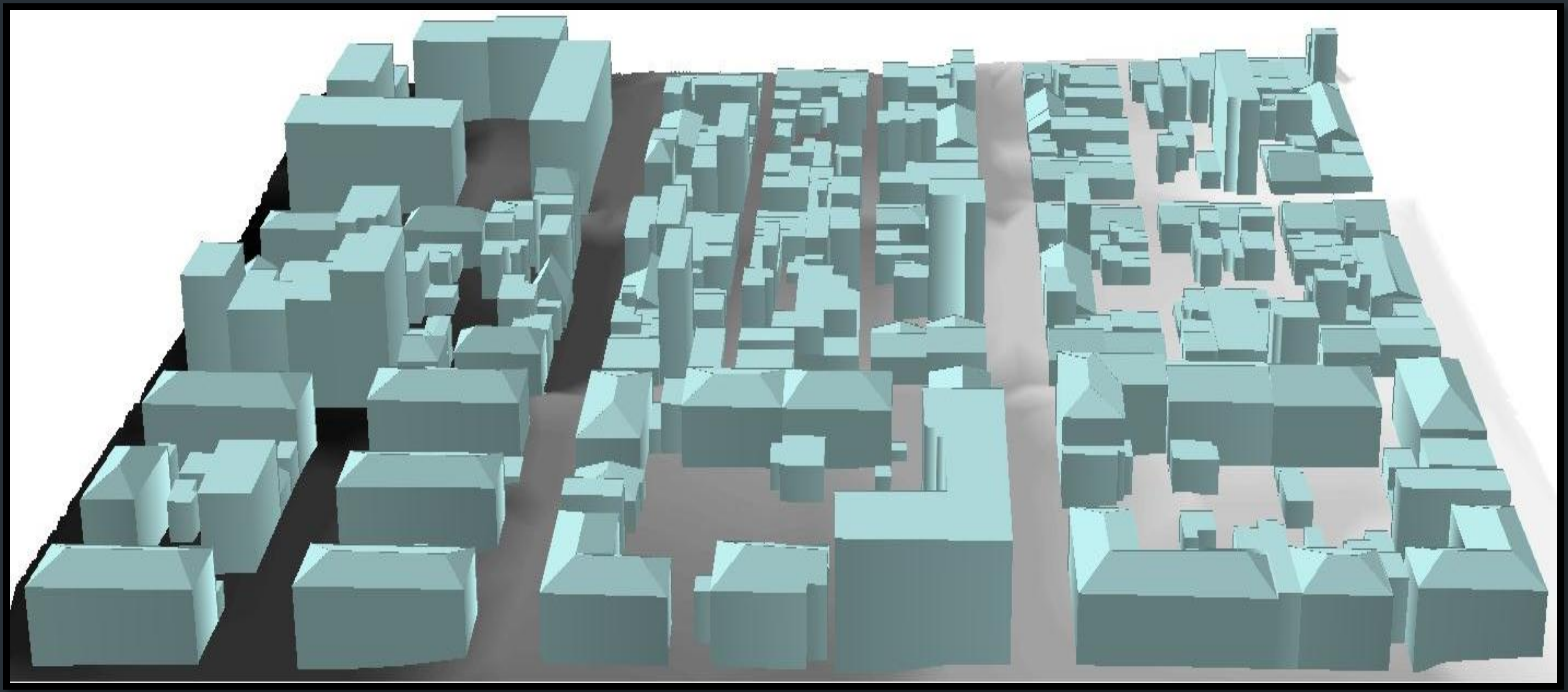
Level of detail: external volumes (LoD1)



Stereo plotting of the study area using the 1983 stereo pair



Top view of the 1983 drawing



3D model
(1983, LoD1)

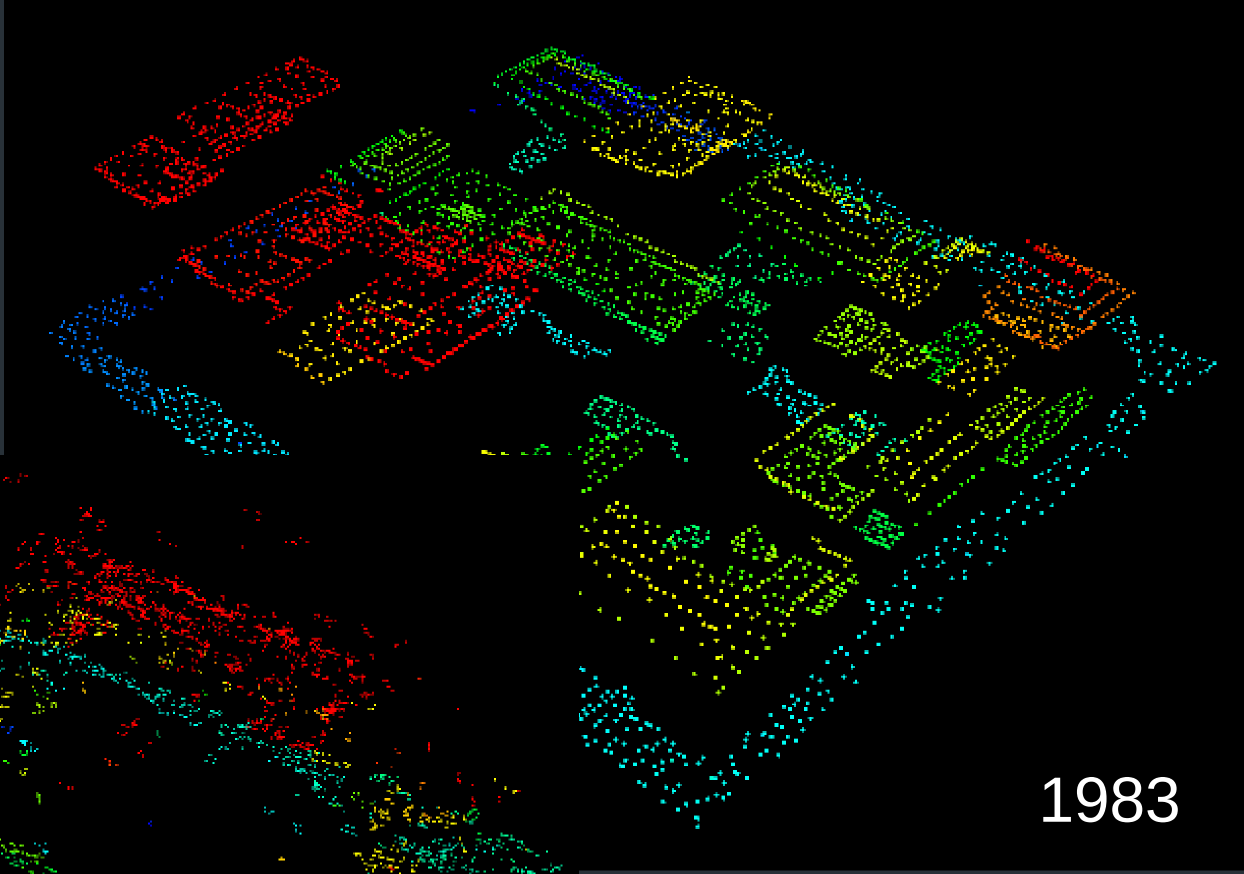
AUTOMATIC GENERATION OF DENSE POINT CLOUD FOR THE NEW TIME PERIOD (2010)

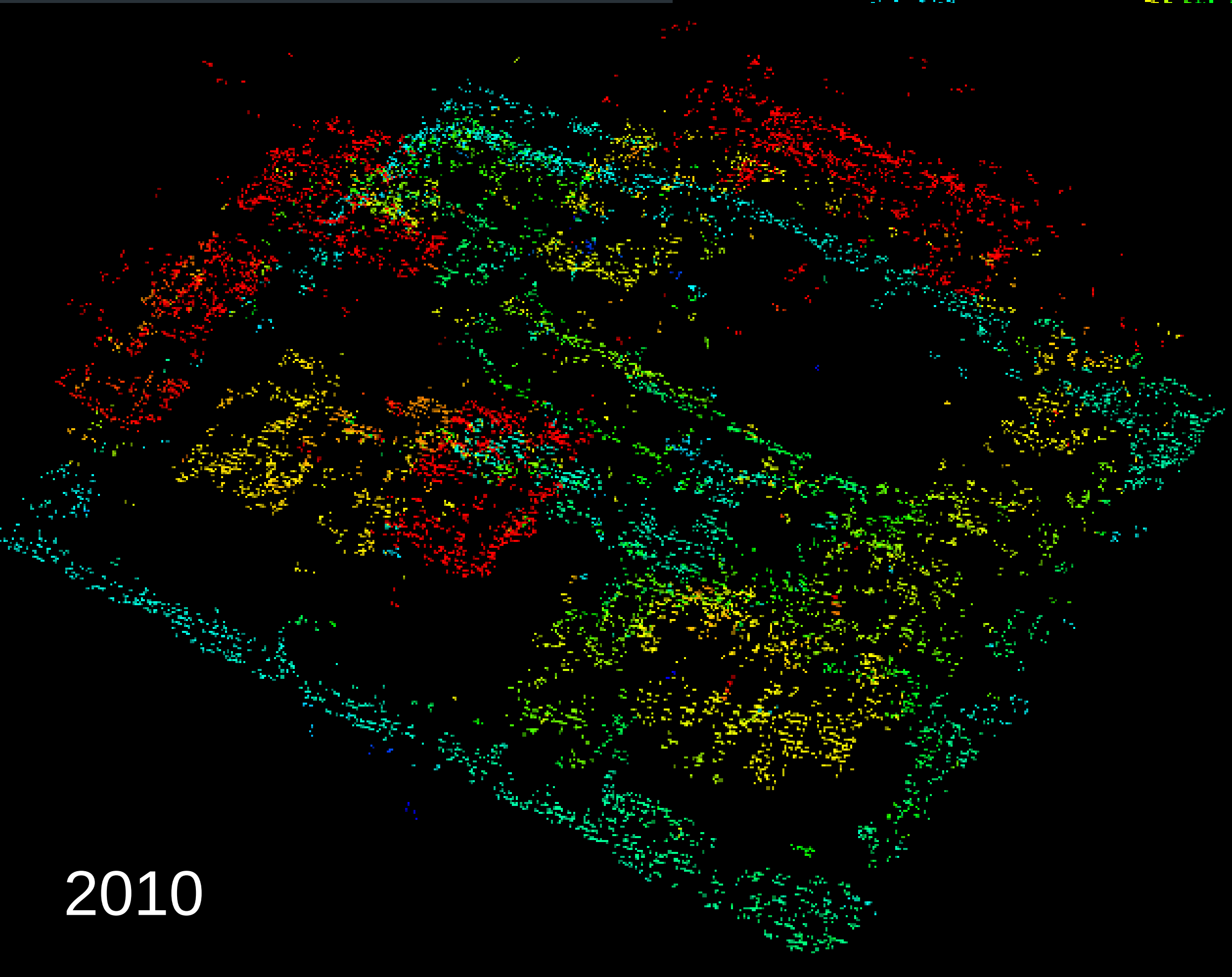
The eATE (enhanced Automatic Terrain Extraction) dense image matching module of Erdas Imagine 2015 was used

georeferenced dense point cloud of the study area

Dense image matching

Detection of significant changes in 3D buildings





COMPARISON OF THE TWO MODELS

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

They are transformed into meshes

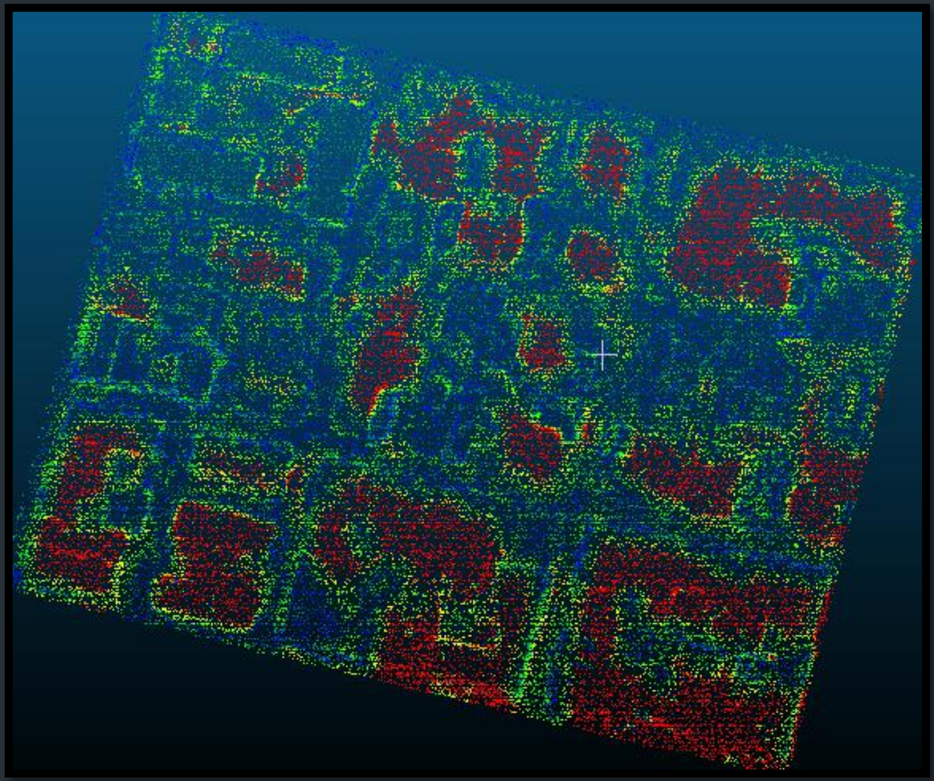
- For the mesh of 2010 the application of a Laplace filter is implemented

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

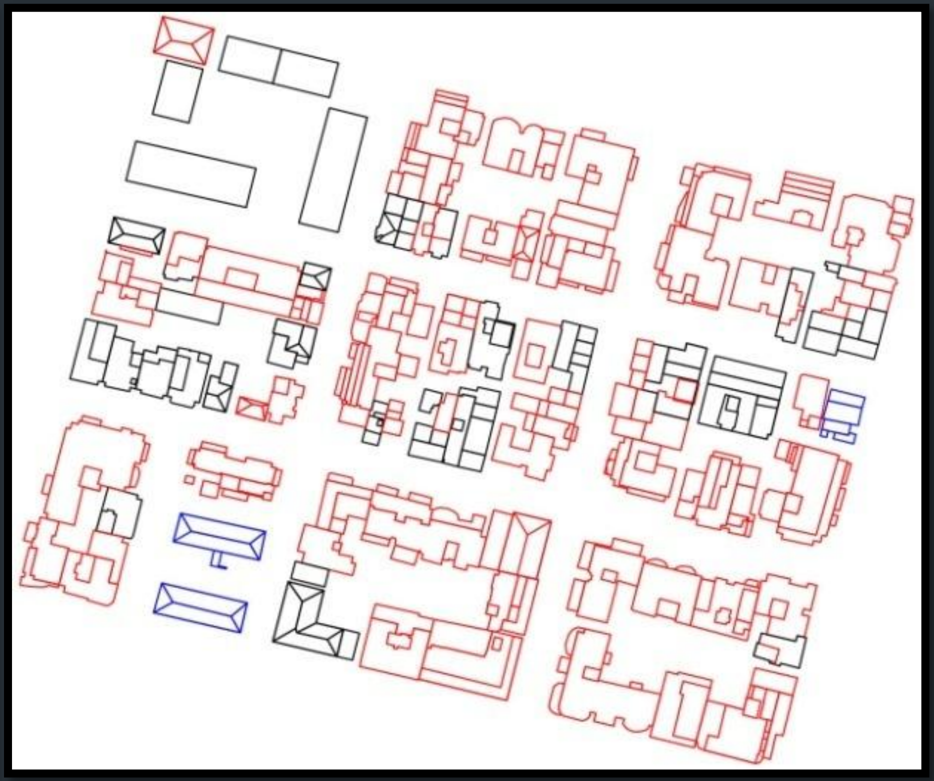
Using a comparison test the areas with changes (a new building or a new floor) are located, using thresholds to avoid cases of low vegetation and structures, cars, etc.

cloud to cloud (C2C)-point to nearest point approach using CloudCompare software

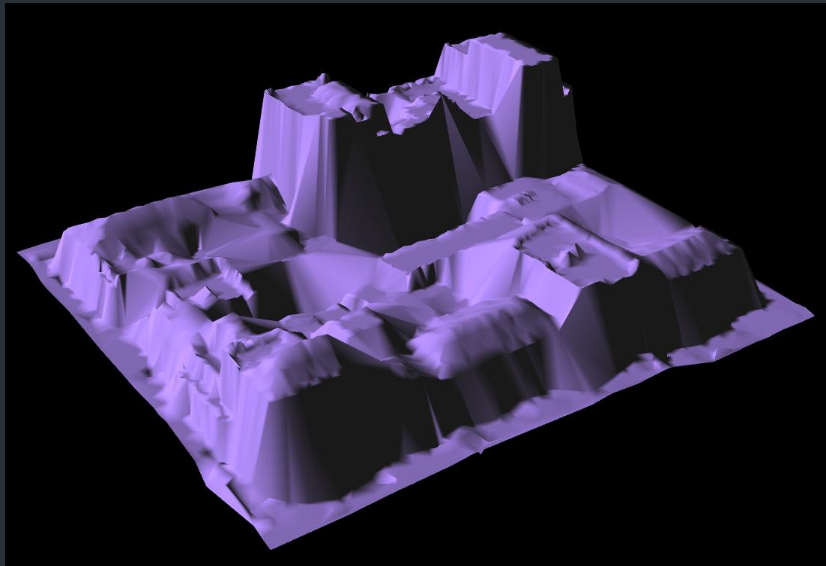
CHANGE HISTORY MAP



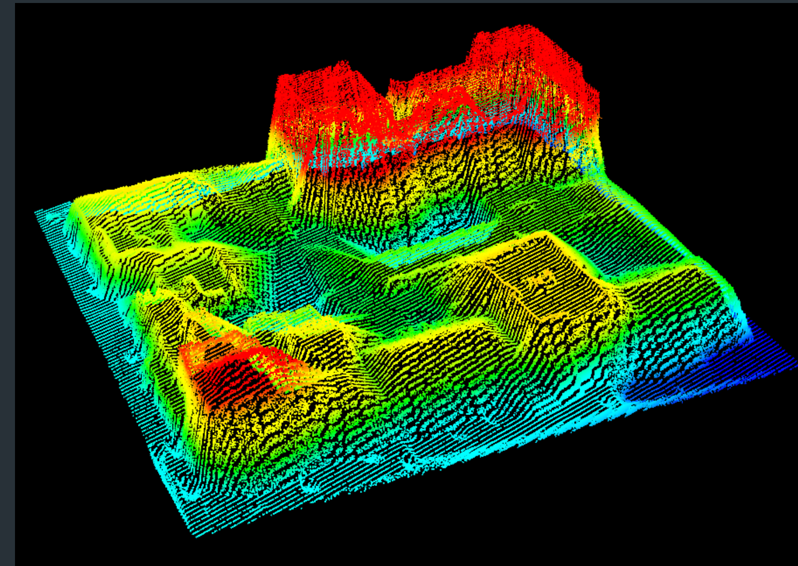
Colored point cloud according to the detected height differences



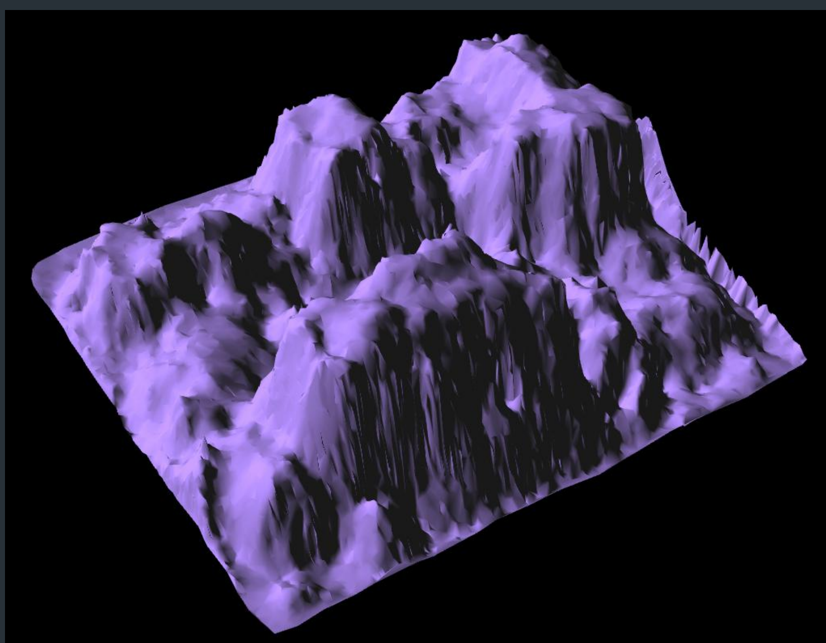
Drawing of the differences as they are derived from the visual control



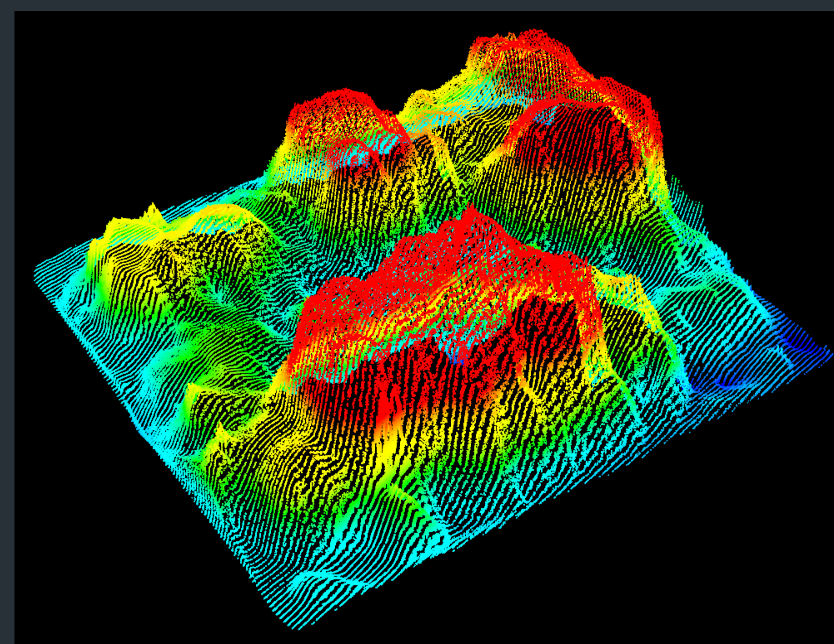
Mesh of an urban block of 1983



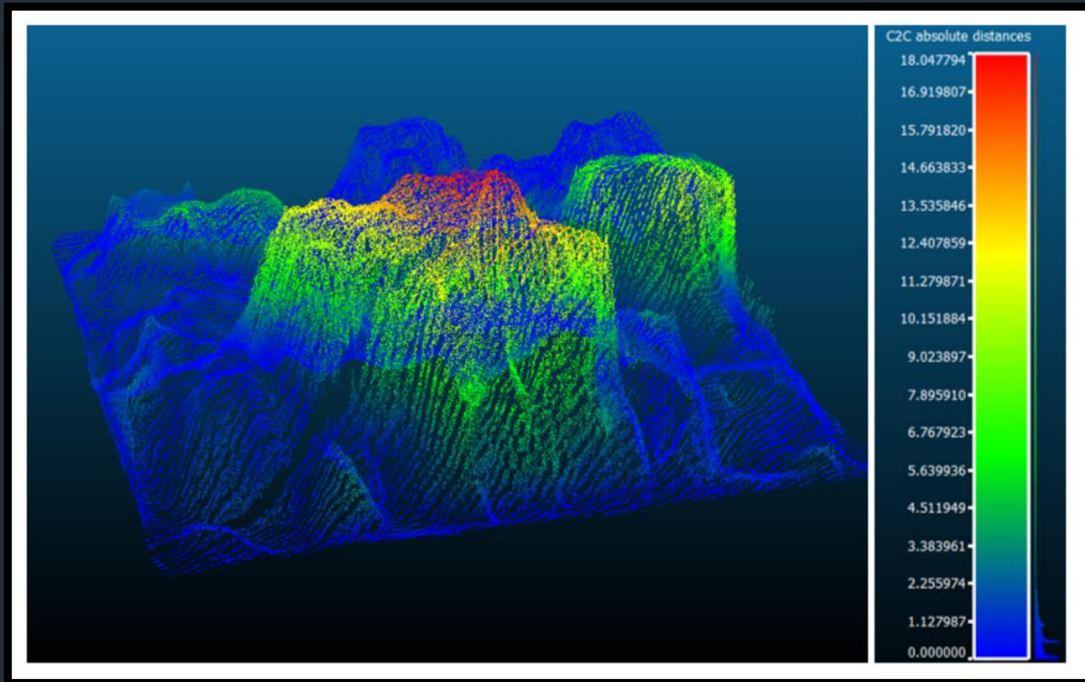
Final point cloud of a urban block of 1983



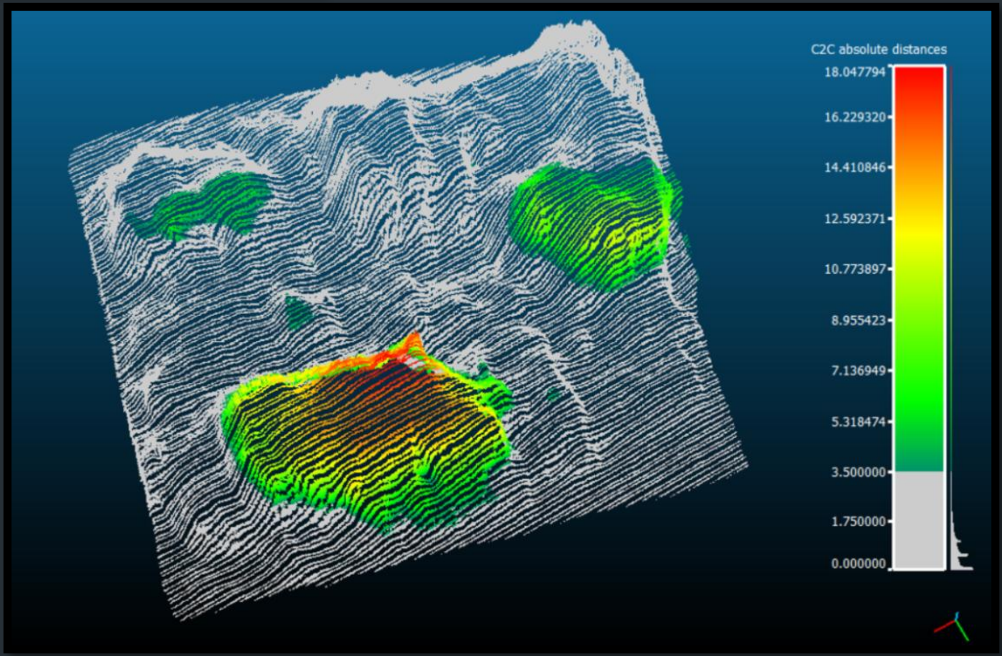
Mesh of an urban block of 2010



Final point cloud of a urban block of 2010



Building change detection results using the C2C-point to nearest point approach



Detection of significant 3D changes applying the distance threshold

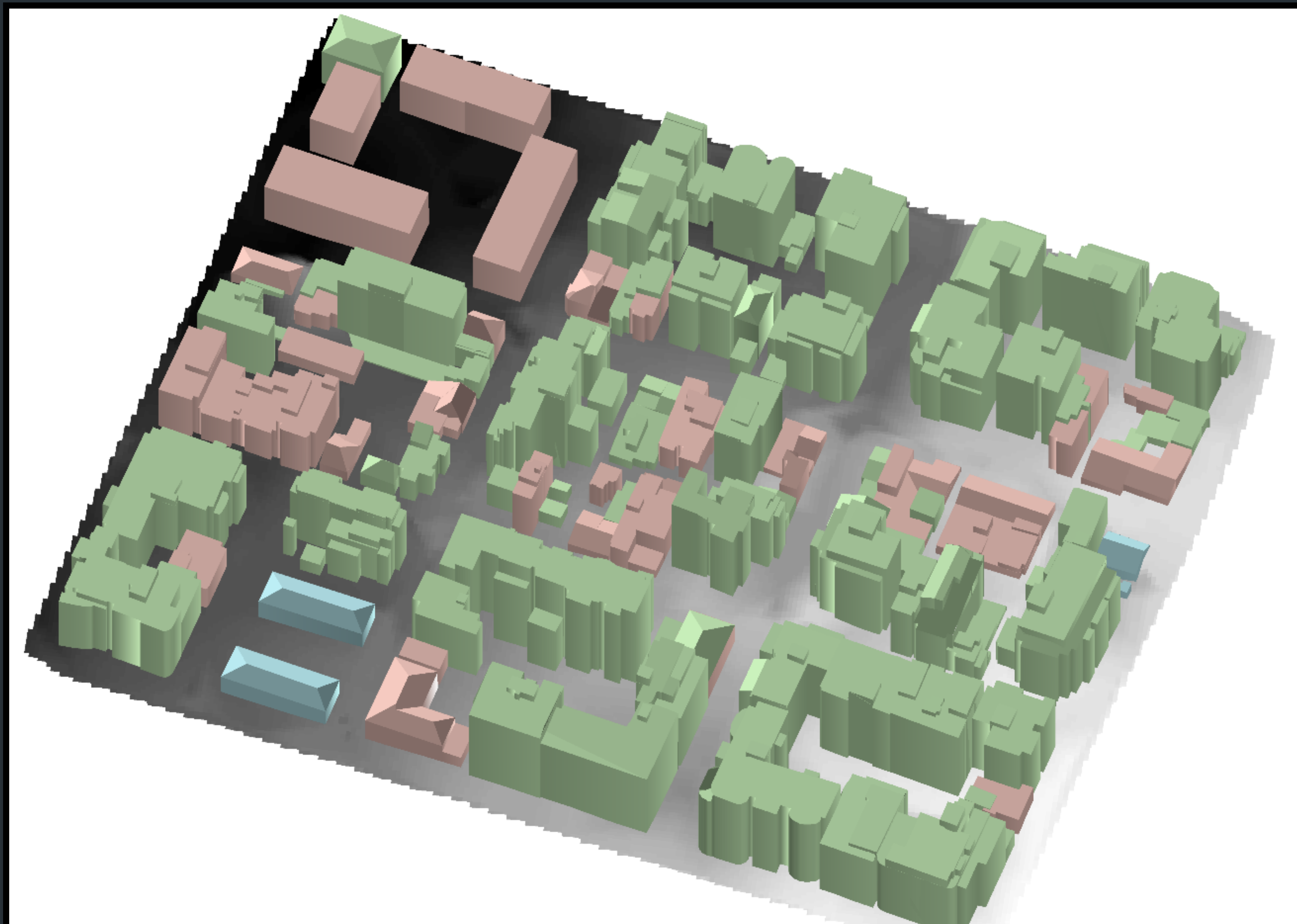
SELECTIVE 3D MODELLING IN AREAS WHERE CHANGES HAVE OCCURRED (LoD1)

Stereo plotting using the georeferenced 2010 stereo pair

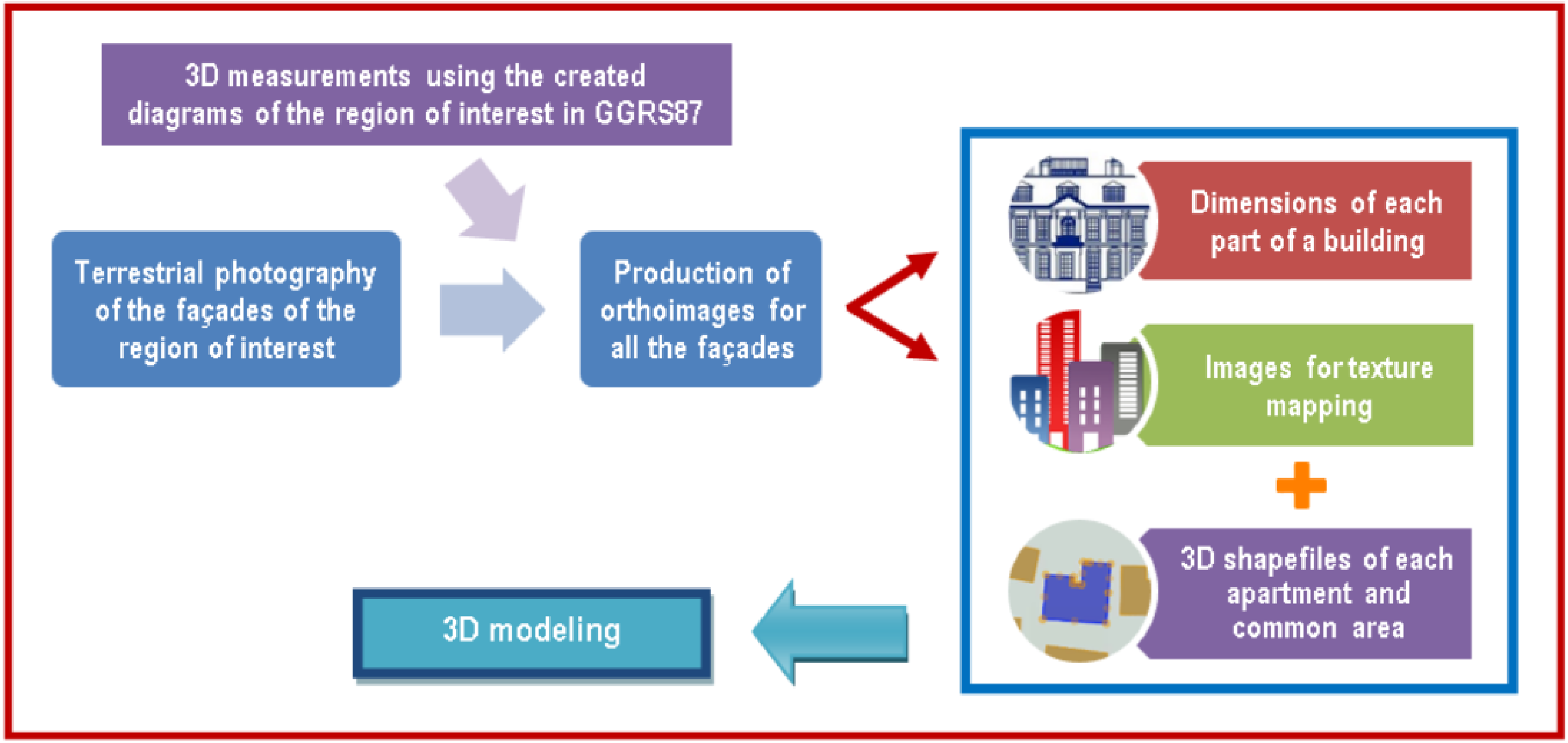
+

Same procedure as applied in the 1983 model for the buildings which have changed

Different 3D views of the region illustrating the changes that took place in the period 1983 - 2010



3D MODELLING IN HIGHER LEVELS OF DETAIL (LoD2, LoD3)



Methodology implemented for the creation of the 3D textured models of every building

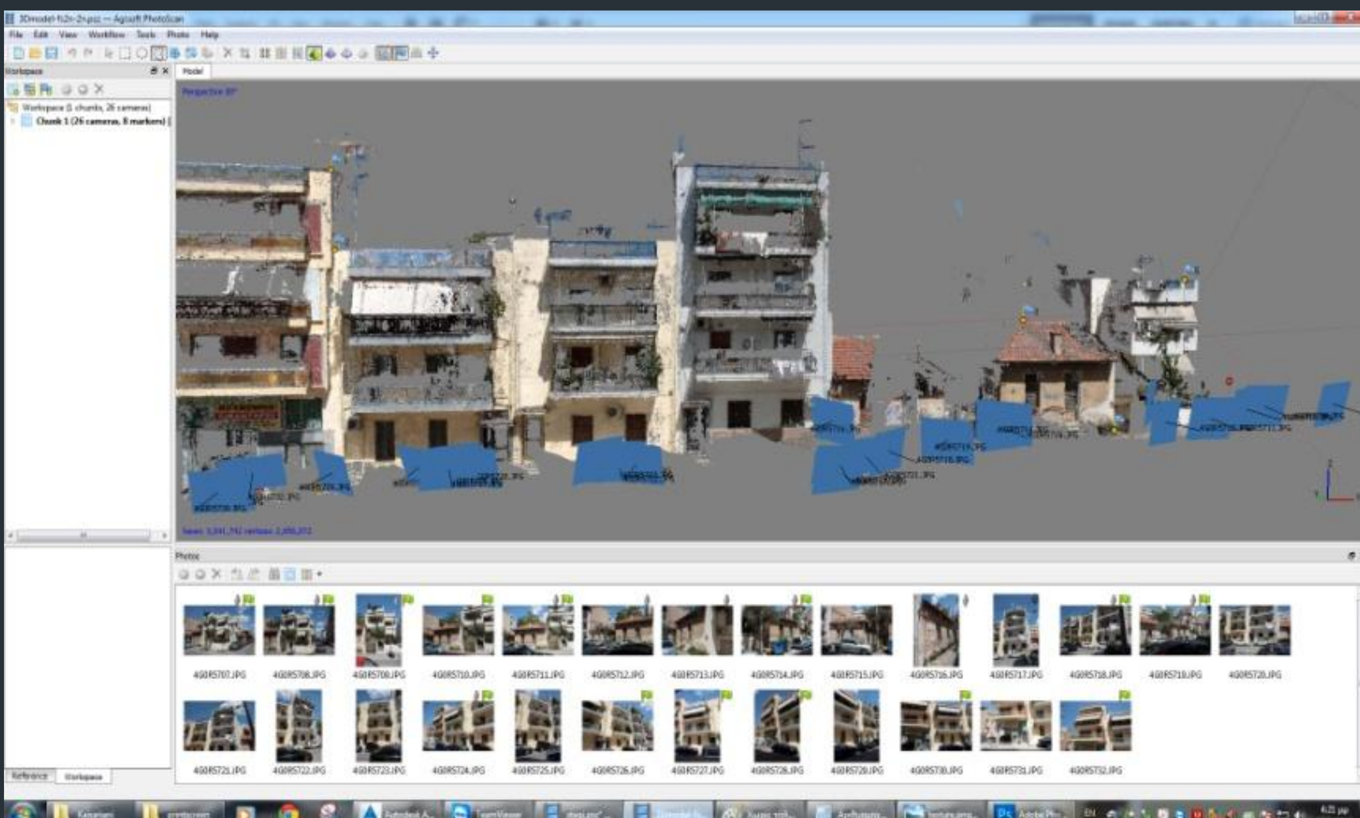
TERRESTRIAL PHOTOGRAPHY

- ~ 100 images per urban block were obtained using a metric calibrated camera
- Each building façade is depicted at 3 images of different views at least

EXTRACTION OF DENSE IMAGE MATCHING POINT CLOUDS

Agisoft PhotoScan was used for the creation of dense 3D point clouds from still terrestrial images

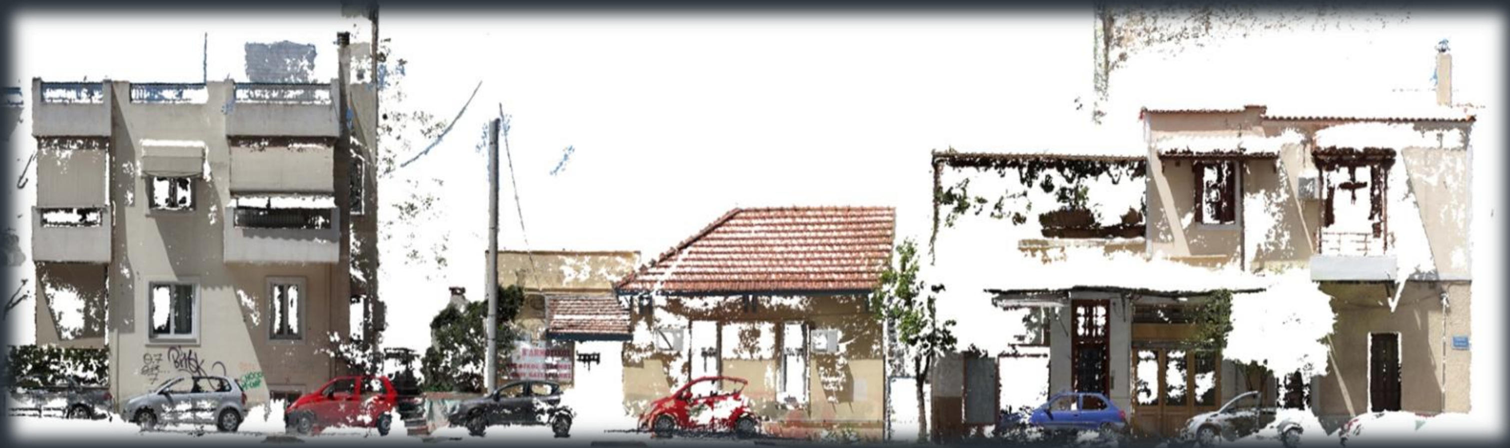
- **Structure from Motion**
- **Dense Image Matching**



Using this technique a dense point cloud can be extracted using multiple overlapping images taken by a single camera around the object of interest

GENERATION OF ORTHOIMAGES

Orthoimages are generated (one for each side of an urban block) using the obtained optical terrestrial imagery, the GCPs and the generated dense image matching point clouds



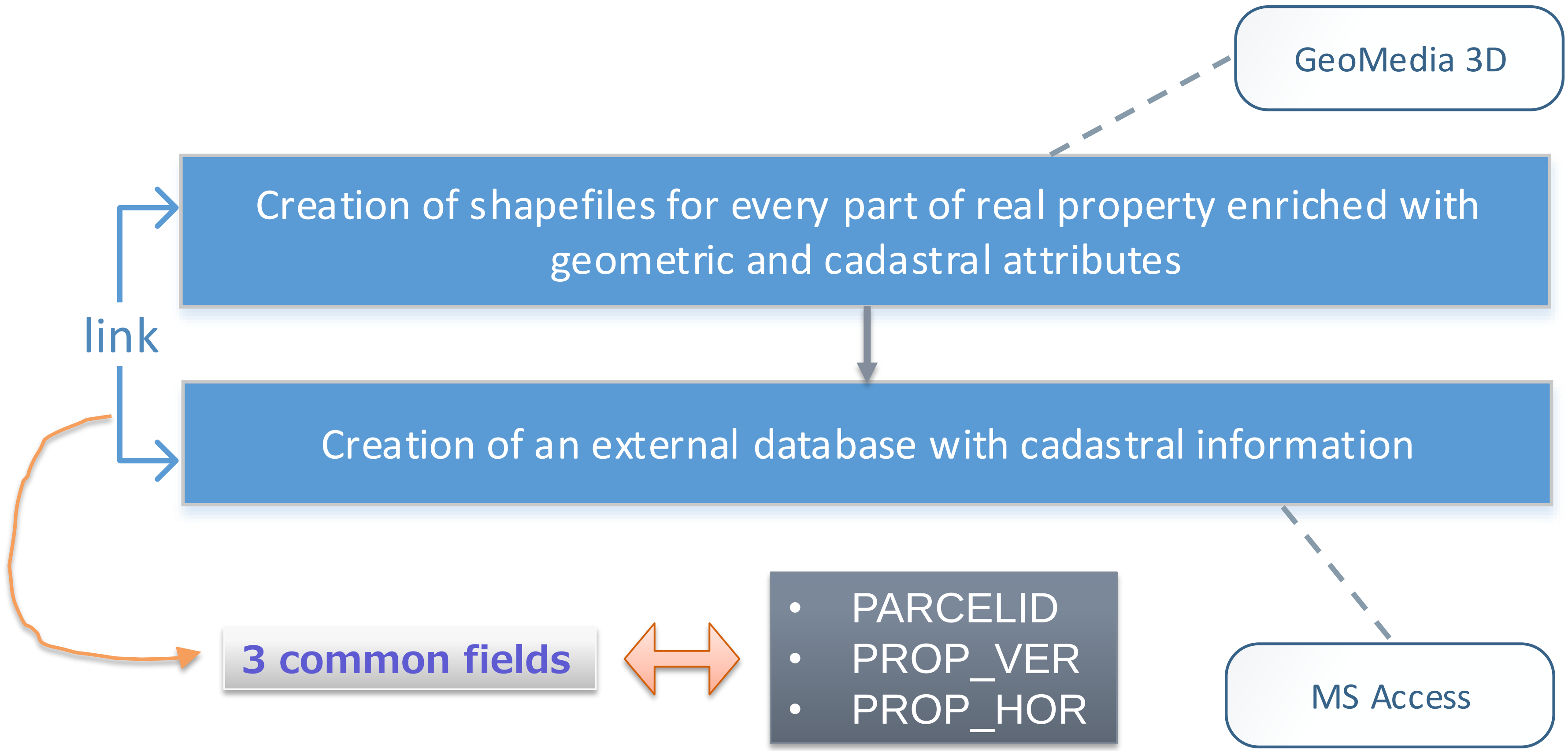
CREATION OF 3D SHAPEFILES FOR THE INNER AREAS OF BUILDINGS

- Information collected from the Greek Cadastre
- The areas described in the contracts + the acquired terrestrial photographs → guideline in order to create the inner areas apartments, parking slots, common used areas, etc
- Interior geometries → digitized as polygons using Geosystems’s Intergraph GIS tools
- In each polygon level, height and real elevation information were given, as well as various attributes along with a unique identifier
- Terrestrial photographs gave information regarding entrances, exterior parking slots, etc

Field Name	Field Description
Elevation	The real elevation of the footprint that was produced from the DSM
Height	The height from floor to ceiling of the volume
PROP_VER	The name of the relative Cadastral vertical property where applicable, zero otherwise.
PROP_HOR	The name of the relative Cadastral horizontal property where applicable, zero otherwise.
BLD_SN	The name of the relative Cadastral building structure where applicable, one otherwise.
Property_t	Description of the type of Cadastral property
Floor	Name of floor for the structure (e.x. -1, 1,2…)
Percentage	The percentage, in terms of ownership, regarding the parcel as was described in Greek Cadastre.
USE_TYPE	Type of Usage. Can be one of the following values: a. = APARTMENT b. = VERTICAL RIGHT c. = RESERVED FOR FUTURE USAGE d. = COMMON AREAS e. = ROOF STRUCTURE
USE_DESC	Usage Description. The description of the Use_type Field as mentions above
USE_AA	Unique number starting from 1 that identifies all the structures in a building
PARCELID	Twelve digit alphanumerical text that uniquely identifies the parcel. If Cadastral information exists then parcelid equals to KAEK otherwise it is unique number starting from one.
ID	Unique twenty one digit alphanumerical text that identifies each structure among all other structures in Greece. It is a composite key that consists of: PARCELID[12] + PROP_VER[2] + PROP_HOR[2] + USE_TYPE[2] + USE_AA[3]

Fields of the attribute table of each inner area

CREATION OF AN EXTERNAL DATABASE AND CONNECTION TO THE SHAPEFILES



PROCEDURAL MODELLING

- The models are automatically generated through a predefined rule set

  computer code which generates 3D content

- Procedural modelling techniques use programming languages for the textual semantic description of a building

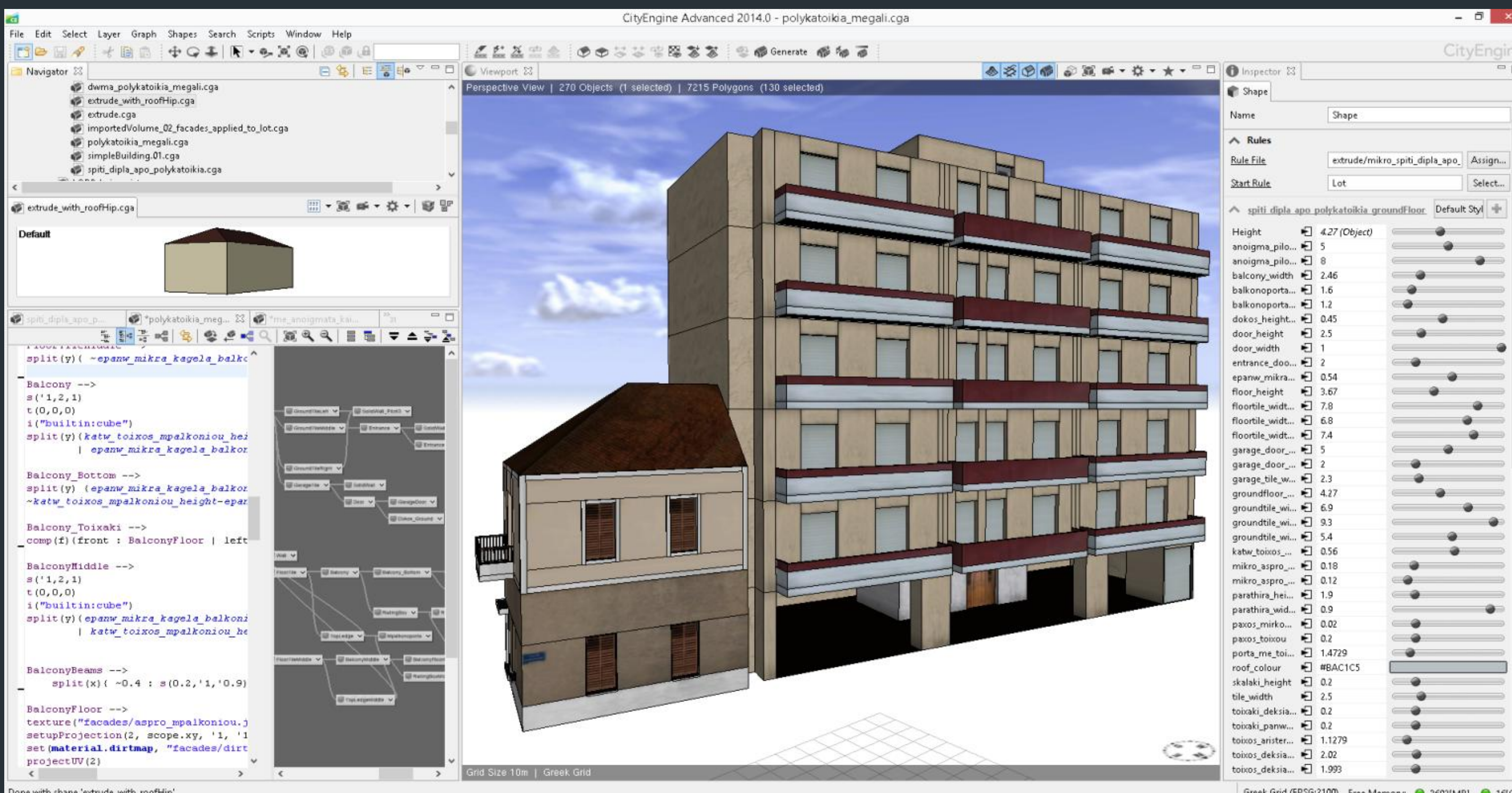
  rapid and interactive updating of a model

- The use of attributes and parameters enables the visualization of change over time and the representation of different scales, through the introduction of the various levels of details of the 3D content

- The programming code used for the generation of 3D models is based on CGA (*Computer Generated Architecture*) shape grammar, a context-sensitive grammar

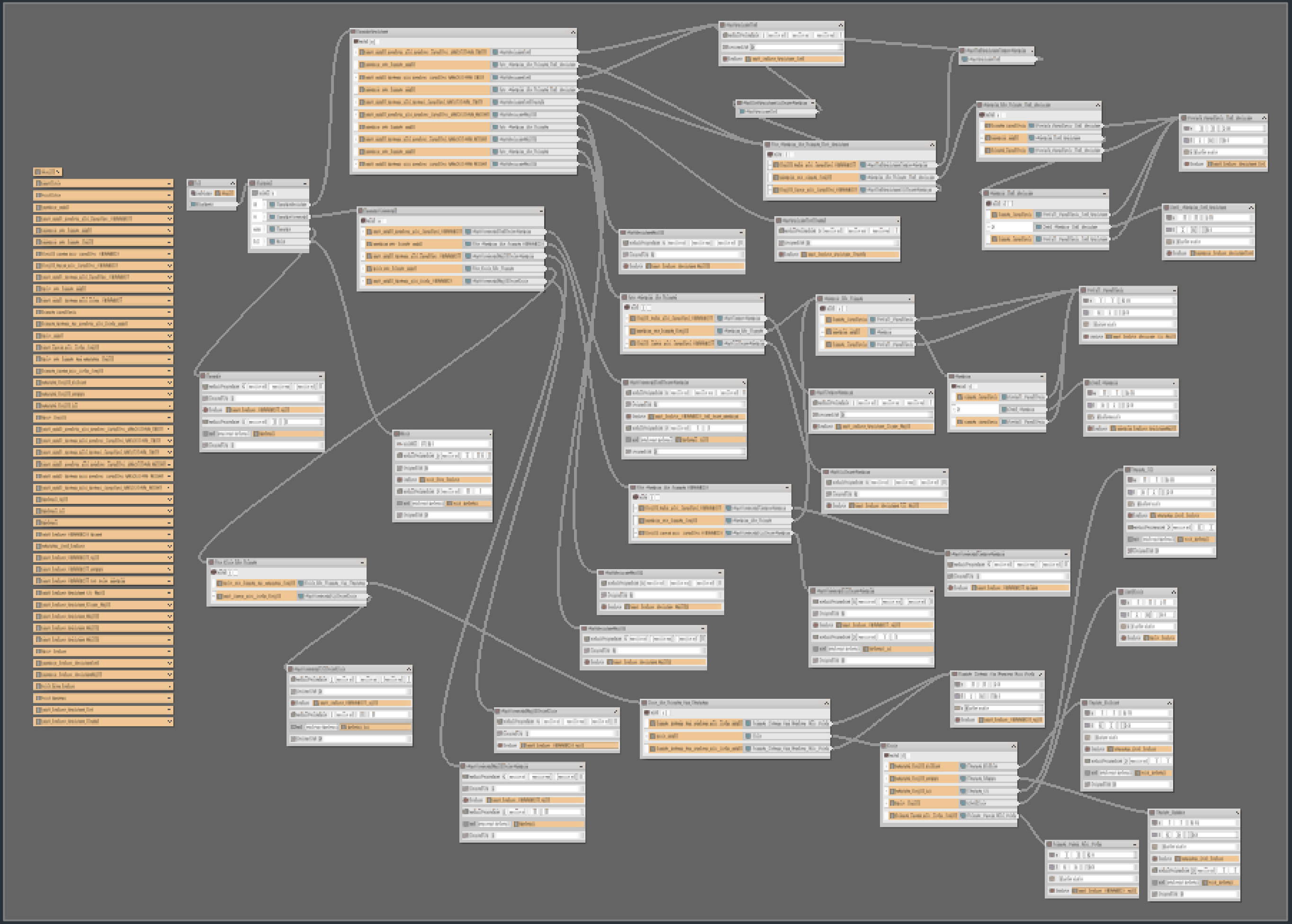
VISUALIZATION AND EXPORT OF THE 3D MODELS

Esri CityEngine software was used for
the visualization of the generated 3D models,
using the CGA rule files and the respective shapefiles, and
export the models in suitable 3D formats (Collada/KML)



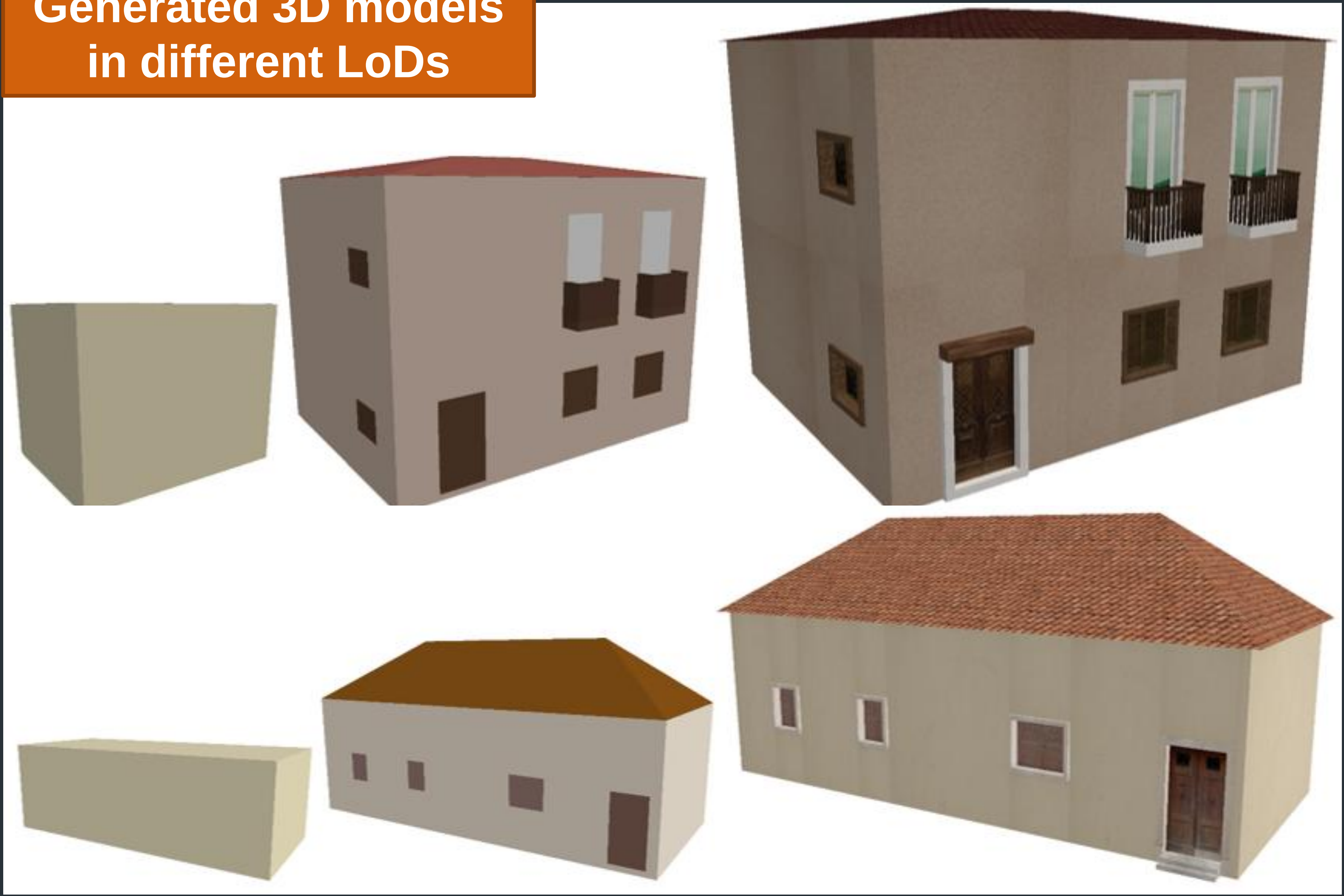
VISUALIZATION AND EXPORT OF THE 3D MODELS

```
Building -->
comp(f) {3: FacadeVrioulwn | 4: FacadeKennedy | side: Facade |top: Roof }

Facade -->
color(wallColor)

FacadeKennedy -->
color(wallColor)
split(x) {~wall_width_aristera_apo_parathiro_KENNEDY: WallKennedyLeftFromWindow |
window_me_toixaki_width: Tile_Window_Me_Toixaki |
~wall_width_deksia_apo_parathiro_KENNEDY : WallKennedyRightFromWindow |
~door_me_toixaki_width: Tile_Door_Me_Toixaki ||
~wall_width_deksia_apo_porta_KENNEDY : WallKennedyRightFromDoor }

WallKennedyLeftFromWindow -->
color(wallColor)

WallKennedyRightFromWindow -->
color(wallColor)

WallKennedyRightFromDoor -->
color(wallColor)

//////////// Tile Window Me Toixaki ////////////////////////////////

Tile_Window_Me_Toixaki -->
split(y) {~height_katw_apo_parathiro_KENNEDY : WallKennedyUnderWindow |
window_me_toixaki_height: Window_Me_Toixaki |
~height_panw_apo_parathiro_KENNEDY : WallKennedyUpFromWindow}

Window_Me_Toixaki -->
split(x) {toixaki_parathirou: Pervazi_Parathirou |
~window_width: Window |
toixaki_parathirou: Pervazi_Parathirou }

Pervazi_Parathirou-->
   s('1,'1,0.3) // paxos
   t(0,0,-0.3)
   i('builtin:cube')
   #texture(facade_texture_down)

Window -->
split(y) {
toixaki_parathirou: Pervazi_Parathirou
| ~2: Only_Window |
toixaki_parathirou: Pervazi_Parathirou}

Only_Window -->
   s('1,'1,0.3)
   t(0,0,-0.3)
   i('builtin:cube')
   color('#955F3E')
   #texture(window_wood)

WallKennedyUnderWindow -->
color(wallColor)

WallKennedyUpFromWindow -->
color(wallColor)
```



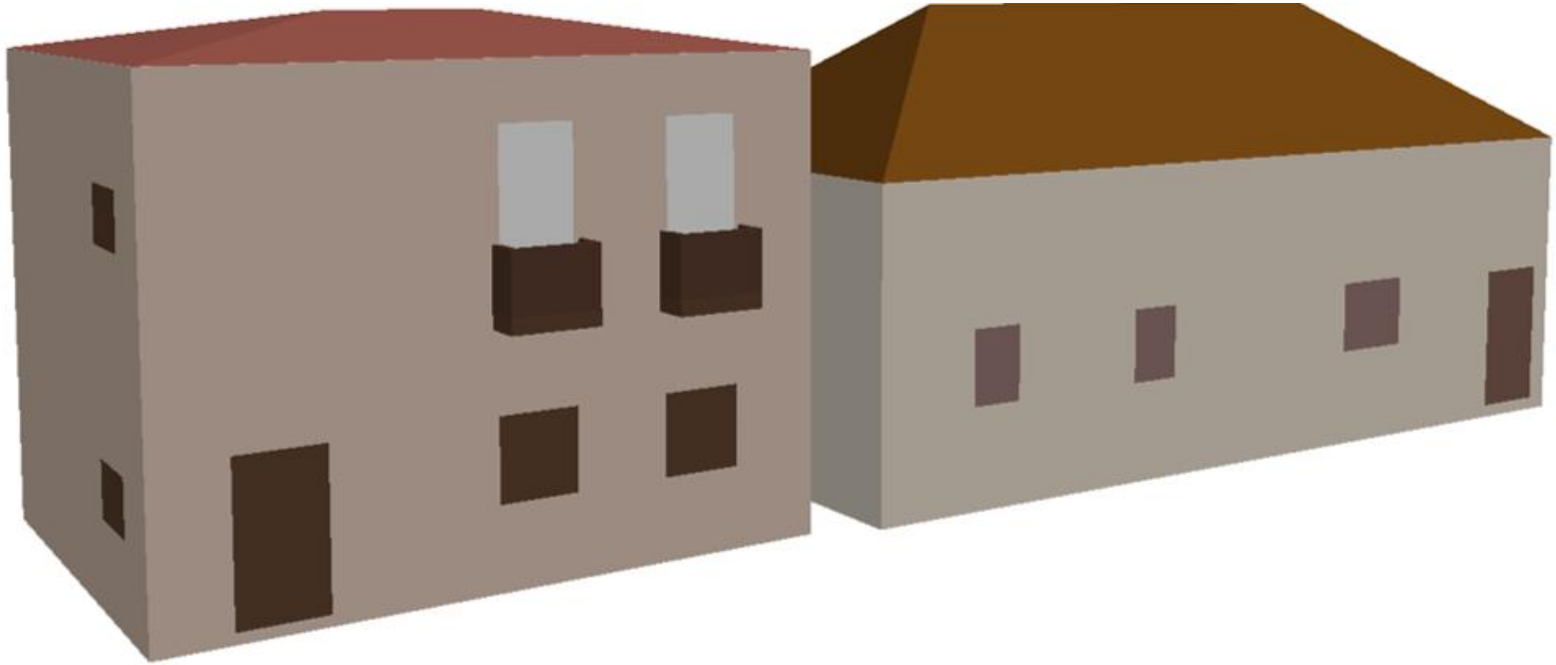
Textual and visual representation of the CGA rule of an apartment

Generated 3D models in different LoDs



LoD1 LoD2 LoD3


LoD1
LoD2
LoD3
LoD3 detail
LoD3

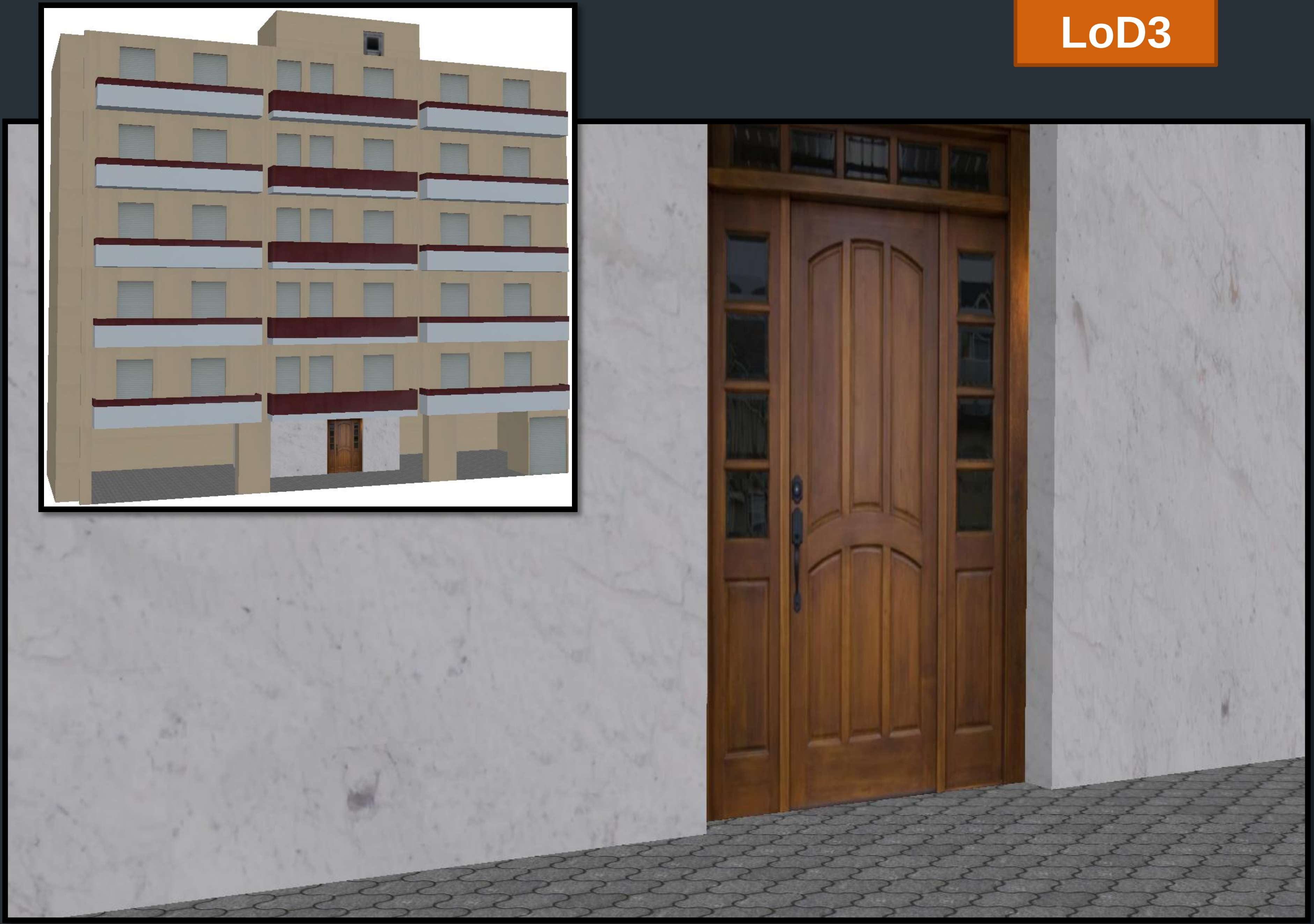


LoD2

LoD3

Details of a 3D model in LoD3

LoD3



Buildings existing in 1983

Block of flats which replaced the old buildings

3D models of buildings in two time periods

CONNECTION OF THE 3D MODELS WITH THE APPROPRIATE METADATA

Assignment of the appropriate name to every 3D model

ID_LODi_TIME
(e.g., **050580147007**000101003_LOD3_1983)

unique identifier of the 3D model

Via the field **ID**, the model is connected with the appropriate entry of the attribute table of a shapefile.

The 3D model accesses all the elevation and cadastral metadata of the attribute table of the shapefile as well as the information contained in the external geodatabase, which is linked with the shapefile.

The other two fields (**LODi** and **TIME**) differentiate the level of detail for which the model is created and the period of time in which the building is observed for the first time.

Name of the shapefile of a building

PARCELID_TIME
(e.g., **050580147007**_1983)

the search for the attributes of a 3D model are limited to only one shapefile

CONCLUDING REMARKS

- The presented research project is currently on-going

  We have reached the stage to implement the new urban plan and start the redistribution of property rights

- The developed tool proved that is useful for applications like 3D cadastral projects and all kinds of urban land readjustment