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

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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 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
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 4\textsuperscript{th} 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 5\textsuperscript{th} dimension (scale):
• Automatic display of the 3D model of the appropriate level of detail (LoD), while the user zooms in and out
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

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

Editing of the building polygons
Creation of 3D faces for each building

Extraction of the geometry of every building façade via structure for motion and dense image matching using terrestrial photographs

Creation of shapefiles for every part of real property enriched with geometric and cadastral attributes

Creation of an external database with cadastral information

Creation of CGA rules for each façade of every building

Creation of a single rule for every part of real property (i.e., apartment, common area)

Visualization and export of the 3D model of every part of real property using the corresponding rule and shapefile

Input to the Viewer

Intergraph ImageStation
Intergraph MicroStation
Agisoft Photoscan
GeoMedia 3D
MS Access
CGA-5DMuPLIS
Programmatically
ESRI CityEngine
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 DTM 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)
The eATE (enhanced Automatic Terrain Extraction) dense image matching module of Erdas Imagine 2015 was used to generate a georeferenced dense point cloud of the study area.
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 an urban block of 1983
Mesh of an urban block of 2010
Final point cloud of an 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
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.
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
<table>
<thead>
<tr>
<th>Field Name</th>
<th>Field Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>The real elevation of the footprint that was produced from the DSM</td>
</tr>
<tr>
<td>Height</td>
<td>The height from floor to ceiling of the volume</td>
</tr>
<tr>
<td>PROP_VER</td>
<td>The name of the relative Cadastral vertical property where applicable, zero otherwise.</td>
</tr>
<tr>
<td>PROP_HOR</td>
<td>The name of the relative Cadastral horizontal property where applicable, zero otherwise.</td>
</tr>
<tr>
<td>BLD_SN</td>
<td>The name of the relative Cadastral building structure where applicable, one otherwise.</td>
</tr>
<tr>
<td>Property_t</td>
<td>Description of the type of Cadastral property</td>
</tr>
<tr>
<td>Floor</td>
<td>Name of floor for the structure (e.x. -1, 1,2...)</td>
</tr>
<tr>
<td>Percentage</td>
<td>The percentage, in terms of ownership, regarding the parcel as was described in Greek Cadastre.</td>
</tr>
</tbody>
</table>
| 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. |

Fields of the attribute table of each inner area
Creation of an external database and connection to the shapefiles

- Creation of shapefiles for every part of real property enriched with geometric and cadastral attributes
- Creation of an external database with cadastral information
- 3 common fields: PARCELID, PROP_VER, PROP_HOR

Geospatial software tools:
- GeoMedia 3D
- MS Access
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
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)
Textual and visual representation of the CGA rule of an apartment
Generated 3D models in different LoDs
Details of a 3D model in LoD3
3D models of buildings in two time periods

Buildings existing in 1983
Block of flats which replaced the old buildings
CONNECTION OF THE 3D MODELS WITH THE APPROPRIATE METADATA

Assignment of the appropriate name to every 3D model

ID_LODi_TIME (e.g., 050580147007000101003_LOD3_1983)

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