National Technical University of Athens
School of Rural and Surveying Engineering

PROPOSAL FOR THE DEVELOPMENT OF A 3D HYBRID MODEL FOR THE HELLENIC CADASTRE

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OBJECTIVE

The **objective** of this paper is :

- Propose the smooth transition of the existing Hellenic Cadastre 2D-GIS into a 3D hybrid model of cadastral registration, so as to preserve the existing 2D-unit system but also integrate 3D representations of the physical objects.

- Development of a 3D cadastral system approached by 3 different methods, in the Greek island of Kimolos → achieve interoperability among application systems.

OVERVIEW

- Analyze conceptual models and the international implementation experience of 3D Cadastre
- Prove the need to develop 3D Hellenic Cadastre, by giving examples from Greek territory
- Develop a 3D Cadastral Information System using three different approaches, emphasizing the representation of properties

2D CADASTRE

2D Cadastre is defined as a a uniform, systematic and continuously up-to-date information system based on the land parcels, including their geometric description and ownership status, as well as additional information needed for administrative, technical and economic activities.

3D CADASTRE

3D Cadastre is defined as a system which sets out the rights and restrictions on 3D property units that exist above and/or below the land surface.

NEED FOR A 3D CADASTRE

- Overlapping constructions of public use (e.g. intersection of rail and road network)
- Infrastructure above and under the ground (e.g. underground parking, shopping centers, buildings over roads / railways, subways)
- Location and ownership of cables and pipes (water, electricity, sewerage, telephone, gas, coaxial cable TV)
- Many apartments in one building
- Mines (beneath the surface of land parcels)
- Historical monuments (lying underneath privately owned areas)

CONCEPTUAL MODELS OF 3D CADASTRE

Full three-dimensional system
- 3D properties and rights
- remodeling of the legal framework
- 3D representations

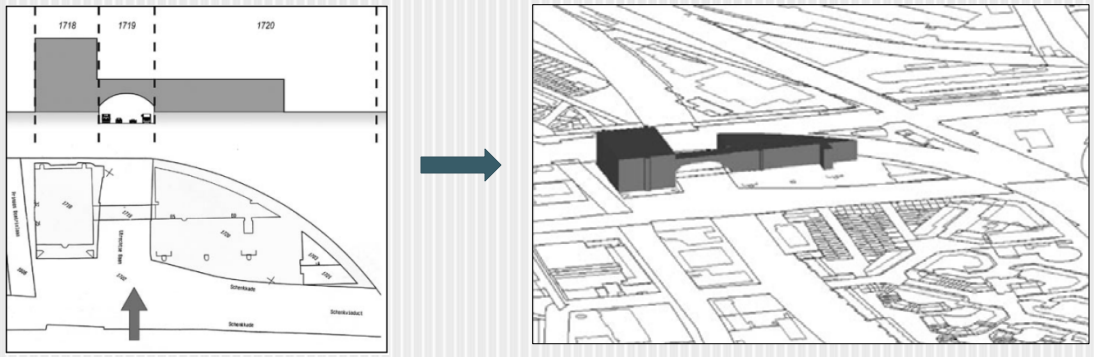
Hybrid form of cadastre
- 2D properties and rights
- preservation of the legal framework
- 3D representations

2D Cadastre with external references
- Existing 2D registration system
- External links with necessary information

INTERNATIONAL EXPERIENCE (1 / 2)

The Netherlands

- Cadastral registration unit : land parcel
- Individual cases of implementing the 3D hybrid cadastre
- Indication of underground constructions in descriptive database (OB code)



Πηγή: Stoter & Oosterom, 2004

Israel

- Cadastral registration unit : land parcel
- Proposal for a 3D multilayer Cadastre (R&D project)
- Indicators that point to the multilayer objects related to the land parcel

INTERNATIONAL EXPERIENCE (2 / 2)

Sweden

- Cadastral reference unit : land parcel
- Establishment of 3D property units
- 2D representations of properties and rights

Australia

- Cadastral registration and reference unit: 3D property
- 2D representations of properties and rights (external files)
- Individual examples of implementing a full 3D cadastral registration system

Greece

- Cadastral reference unit : land parcel
- Cadastral registration in 2D space
- Land parcel owner → owner of the whole upper space / subsoil
- Representation of properties in 2D space

HELLENIC CADASTRE (HC)

The basic real properties registered by the Hellenic Cadastre are :

- Land parcels
- Horizontal ownerships
- Vertical ownerships
- Composite vertical ownerships
- Special real property objects
- Mines

HELLENIC CADASTRE (HC)

Special real property objects are by the common law relationships of separate property, under which the owner on the ground parcel is not necessarily the person who owns the buildings, which constitute separate property objects. In such cases, ownership of a building under this legal status does not mean co-ownership to the land parcel.

The extent of the special real property object is not always within the limits of the parcel delineated in the earth's surface.

- Yposkafa (underground houses carved into the rocks)
- Anogeia (constructions above private properties)
- Kamares (buildings arching over alleys)
- Syrmata (seaside settlements)

NEED FOR A 3D HELLENIC CADASTRE

- Areas of intense relief
- Population growth in urban centers

} overlapping property projections in a 2D-unit system

▼

- Multilayer constructions of services and utility networks (tunnel, subway, cables with constructions above them)
- Overlapping public and private properties (underground parking, building complex, properties over buildings / roads / roadside arcades or arches)
- Overlapping private properties (yposkafa, anogeia, condominium ownership rights, right of implantation to a separate property)

NEED FOR A 3D HELLENIC CADASTRE

Overlapping public and private properties

DEVELOPMENT OF THE 3D CADASTRAL SYSTEM

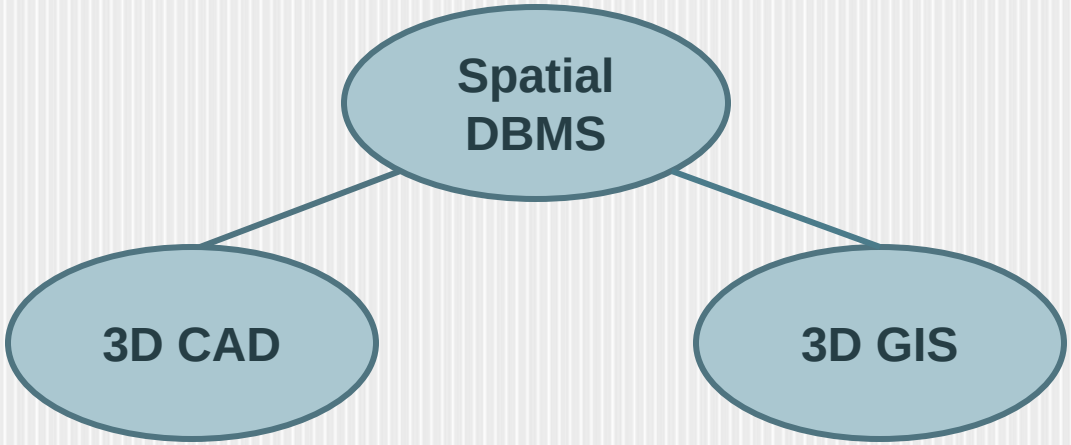
RECORDING

UPDATE

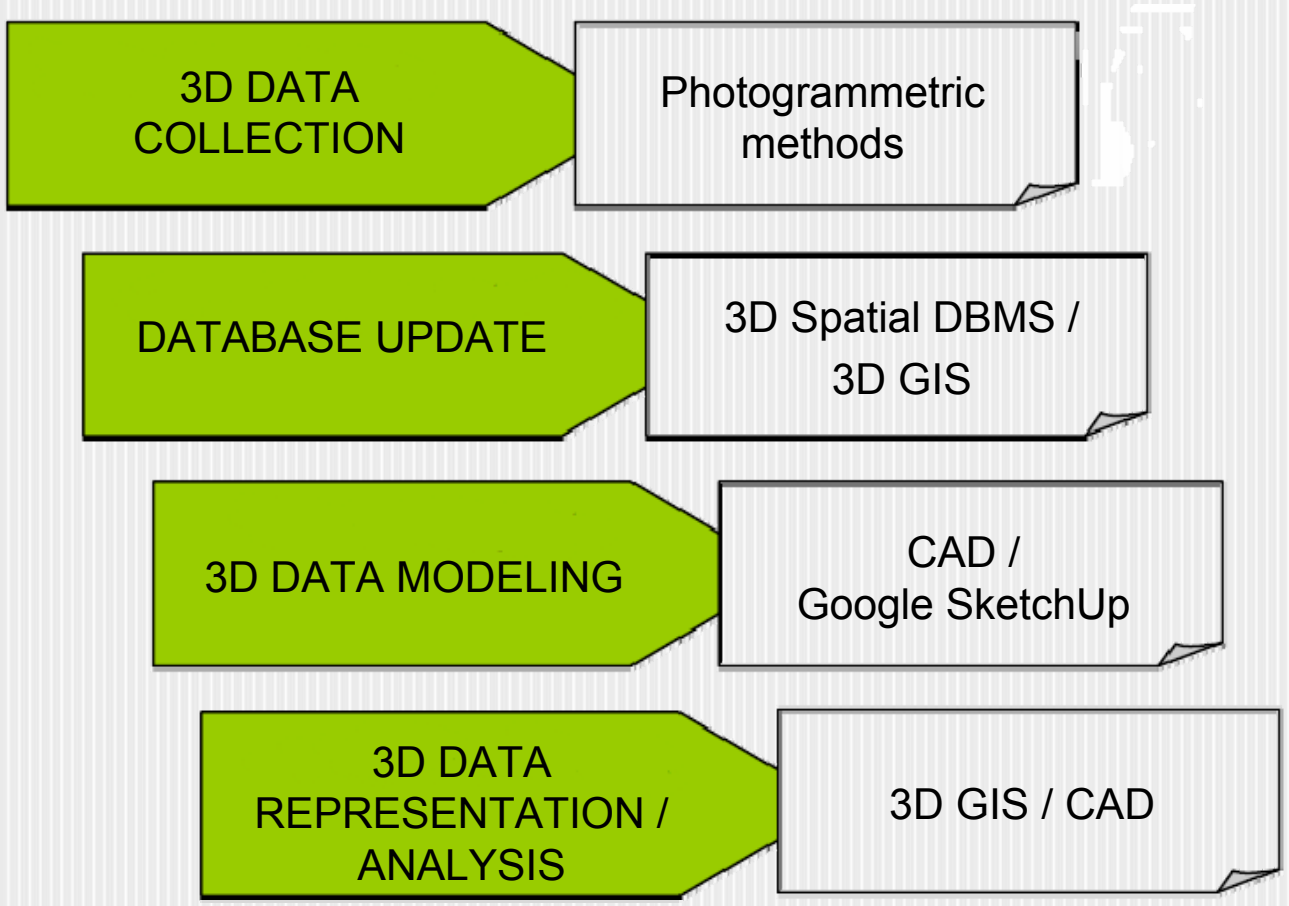
ANALYSIS

VISUALIZATION

} 3D cadastral objects



DEVELOPMENT OF THE 3D CADASTRAL SYSTEM



AREA OF STUDY

"Kimolos island"

- Located in the southeastern Aegean Sea
- Part of the southwest Cyclades island complex
- Product of intense volcanic activity → hot springs, unusual geological formations and a variety of rocks (chalk - "kimolia")

CONCEPTUAL MODEL

- Cadastral objects

ENTITY	*TOPOLOGY*
YPOSKAFA	POLYGONAL
KAMARES	POLYGONAL

- Determination of attribute data

cadastral ID, special real property object code, location, area

APPLICATION DATA

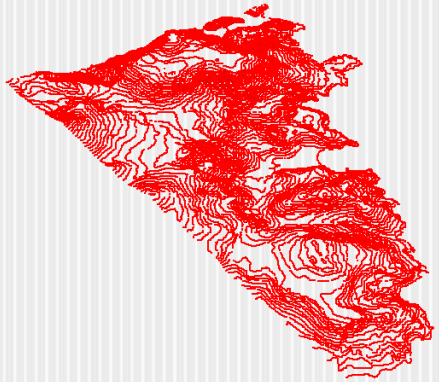
- Cadastral map: Planimetric information

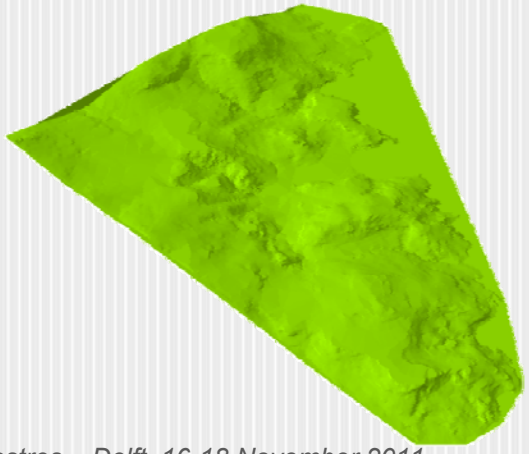
- Orthophoto of Kimolos, scale 1:2000
- Aerial images: Vertical information (stereo-photogrammetric processing)
- Contour map, scale 1:5000 : Digital Elevation Model
- Terrestrial images of buildings facades of Kimolos

3D BACKGROUND

Digital Elevation Model

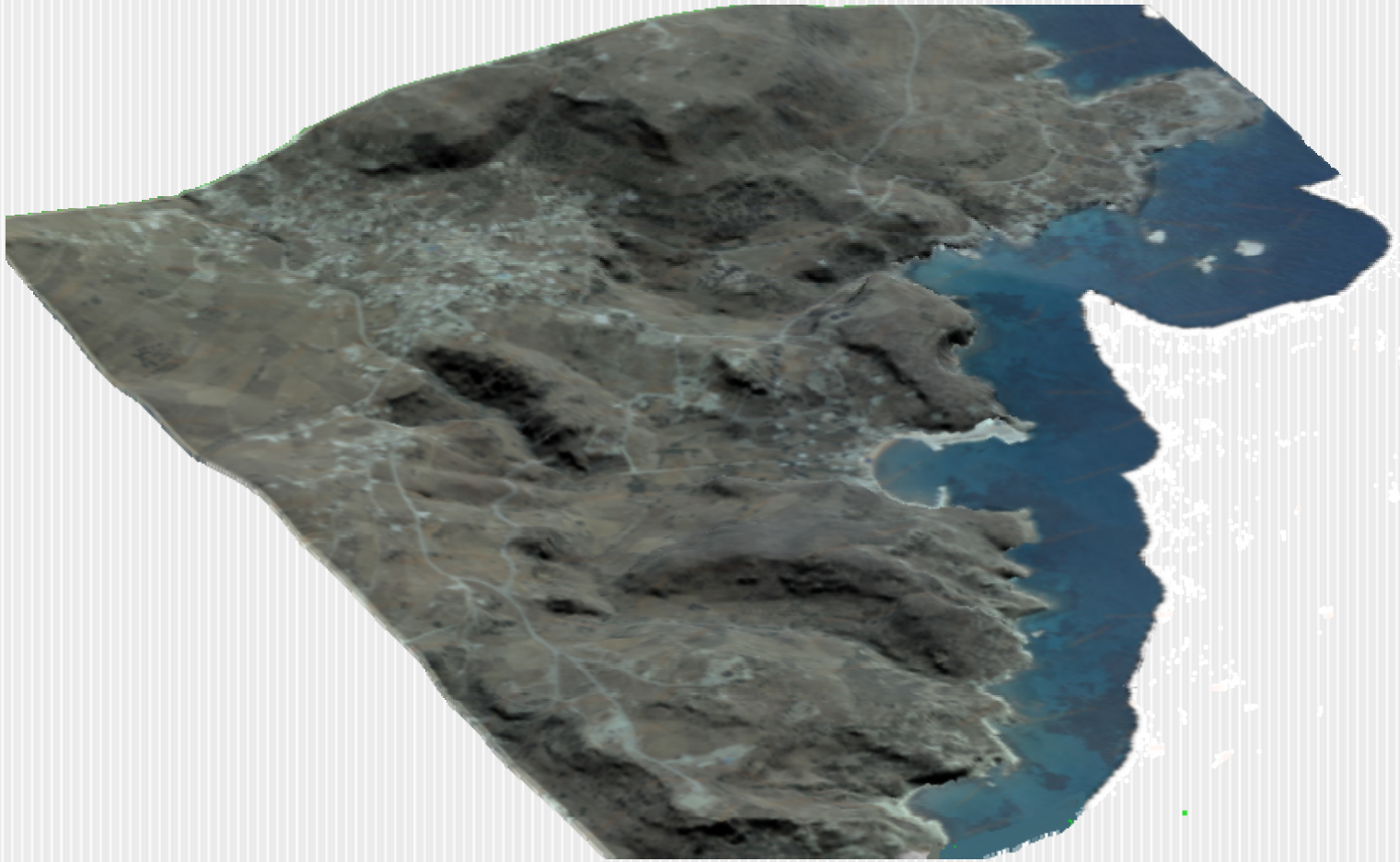
- contour map, scale 1:5000



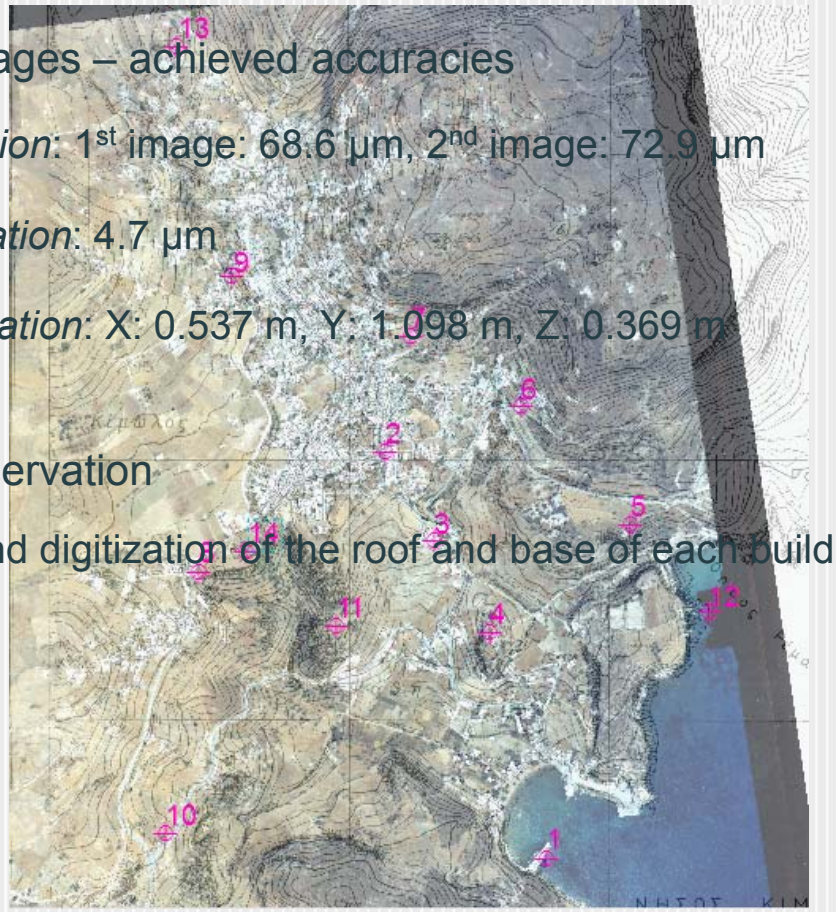


Orthophoto

3D BACKGROUND



- Data collection for extraction of vertical information
  - Pair of aerial images, scale 1:10000 (1997)
  - Measurement of control points: orthophoto and contour map (7 points)
- Orientation of images – achieved accuracies
  - *Interior Orientation*: 1st image: 68.6 μm, 2nd image: 72.9 μm
  - *Relative Orientation*: 4.7 μm
  - *Absolute Orientation*: X: 0.537 m, Y: 1.098 m, Z: 0.369 m
- Stereoscopic observation
  - Measurement and digitization of the roof and base of each building



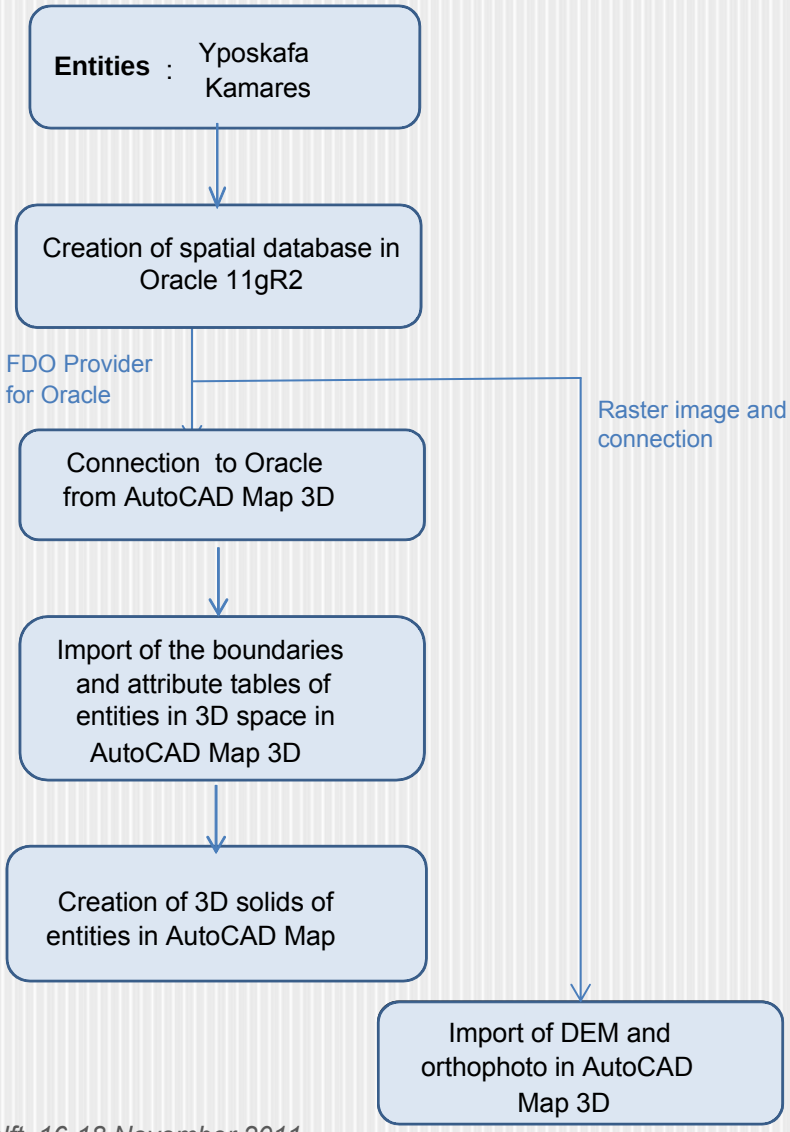
IMPLEMENTATION OF THE 3D CADASTRAL SYSTEM

- Combination of spatial DBMS with CAD system
- Combination of 3D GIS with 3D modeling software
- Combination of spatial DBMS with 3D GIS

COMBINATION OF SPATIAL DBMS WITH CAD SYSTEM

- Spatial DBMS: **Oracle Spatial 11gR2**
  - Design of spatial database → registration of cadastral objects in 3D space
  - Integration of spatial and descriptive information on the database
  - Spatial Analysis: spatial operators and data types (according to OGC)
  - Support of 3D geometric data types (multipolygon, solid, surface)
  - Object - relational database model
- CAD system: **AutoCAD Map 3D 2011**
  - 3D modeling and representation of cadastral objects
  - Spatial analysis among cadastral records (spatial and topological queries)

COMBINATION OF SPATIAL DBMS WITH CAD SYSTEM



DESIGN OF SPATIAL DATABASE

- Creation of tables of entities : descriptive information, geometry
- Creation of spatial index : R-tree
- Creation of metadata table : spatial extend of data, coordinate reference system, tolerance

Storage of geometry

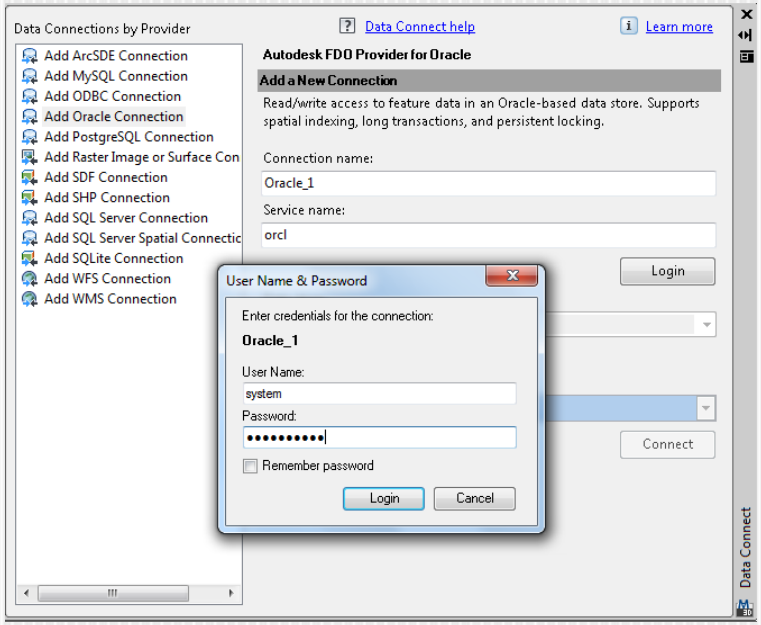
CREATE TYPE sdo_geometry AS OBJECT (
SDO_GTYPE NUMBER,
SDO_SRID NUMBER,
SDO_POINT SDO_POINT_TYPE,
SDO_ELEM_INFO MDSYS.SDO_ELEM_INFO_ARRAY,
SDO_ORDINATES MDSYS.SDO_ORDINATE_ARRAY);

Insertion of values into entity “kamares”

```
INSERT INTO KAMARES_KIMOLOS_CAD (FID, CODE, KAEK, PROP_TYPE, LOCATION, AREA, SHAPE)
VALUES (1, 838, '290610104114', 23, 'KIMOLOS',13.89,SDO_GEOMETRY
(3003,   3D polygon
2100,
NULL,
SDO_Elem_Info_Array (1,1003,1),
SDO_ORDINATE_ARRAY(550966.2553,4071536.5102,79.000,550968.9440,407153.3880,79.000,55096
6.0250,4071542.0100,79.000,550963.9402,4071538.2958,79.000,550966.2553,4071536.5102,79.
000)));
```

3D REPRESENTATION OF CADASTRAL OBJECTS

- Database connection with AutoCAD Map 3D : FDO Connection
- Import of the spatial and descriptive information (tables) of entities
- Import of DEM and orthophoto

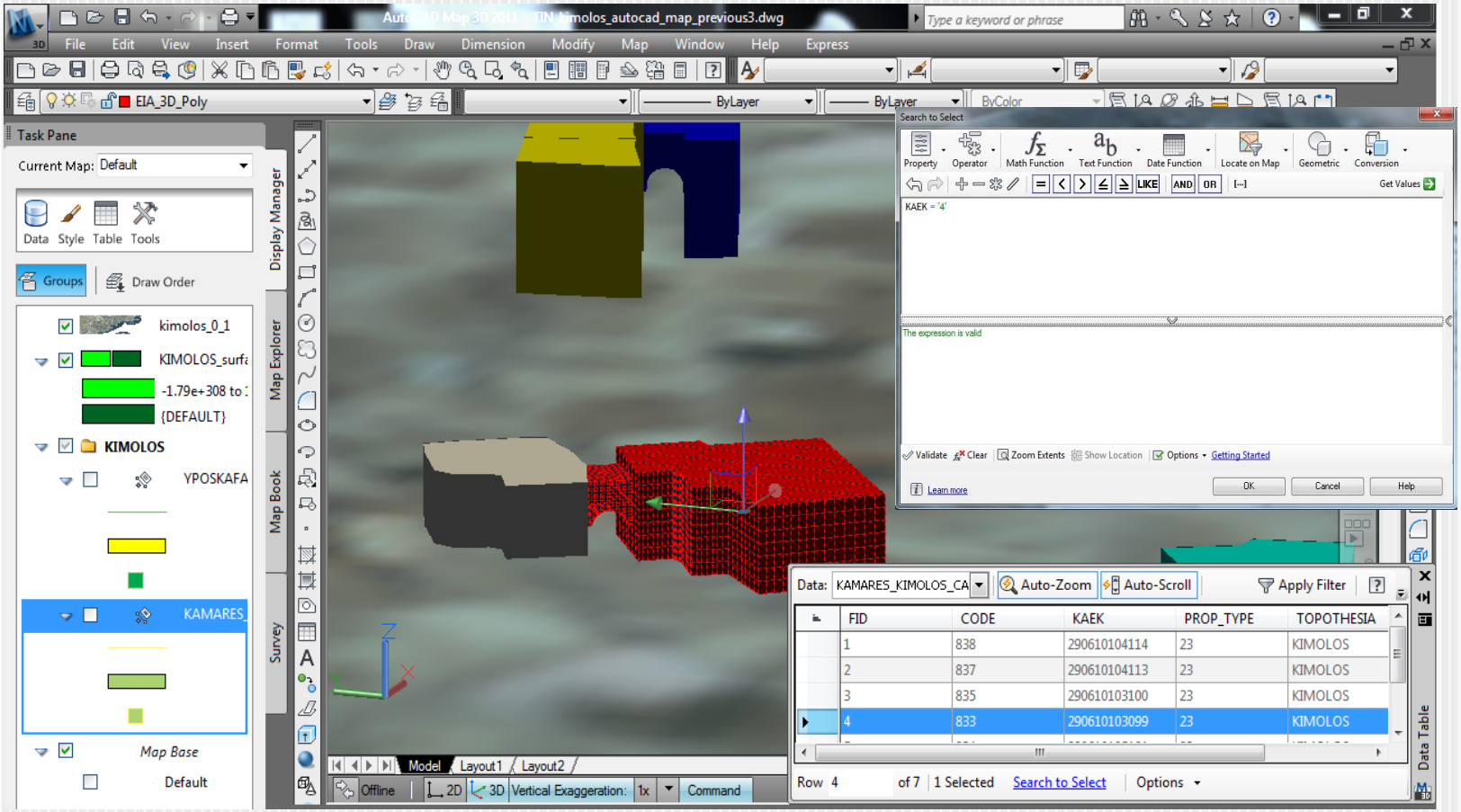


- Support only of basic geometric types in 3D space (point, line, polygon)
- Import of the outlines of properties in 3D space
- 3D modeling of cadastral objects

3D REPRESENTATION OF CADASTRAL OBJECTS

YPOSKAFES

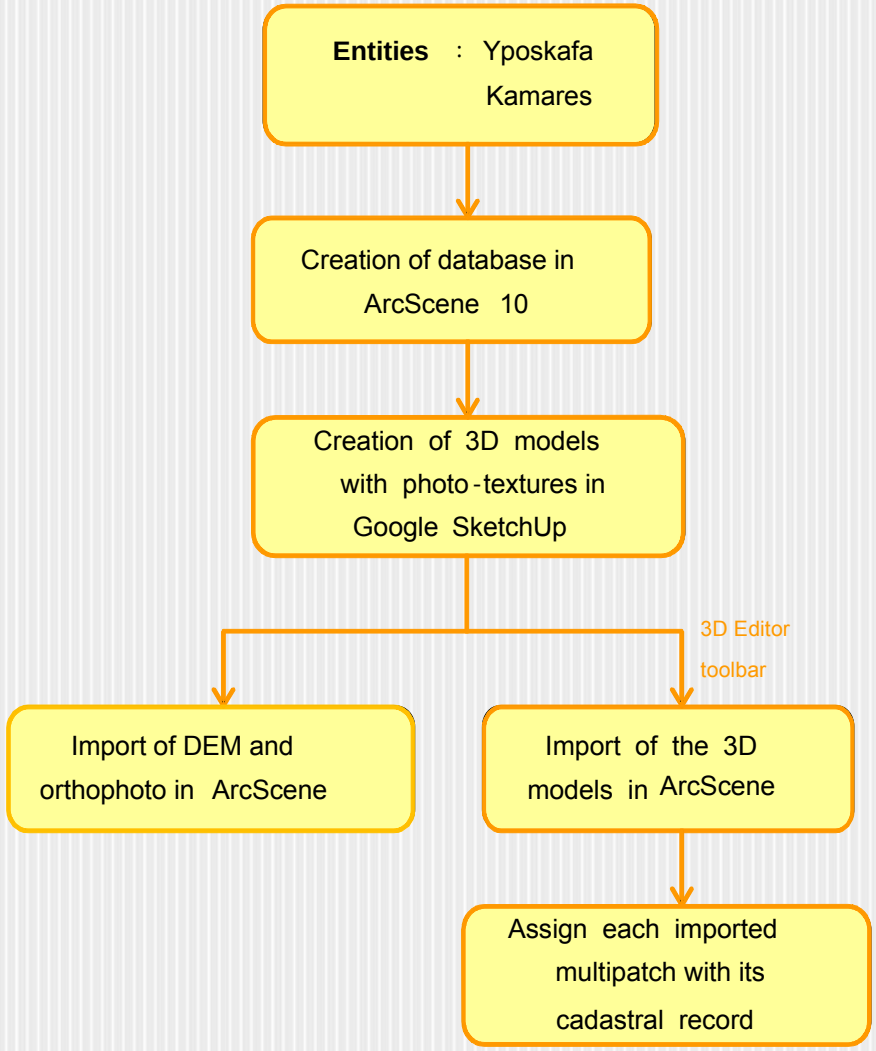
- Cadastral Objects from the property graded plan



COMBINATION OF 3D GIS WITH 3D MODELING SOFTWARE

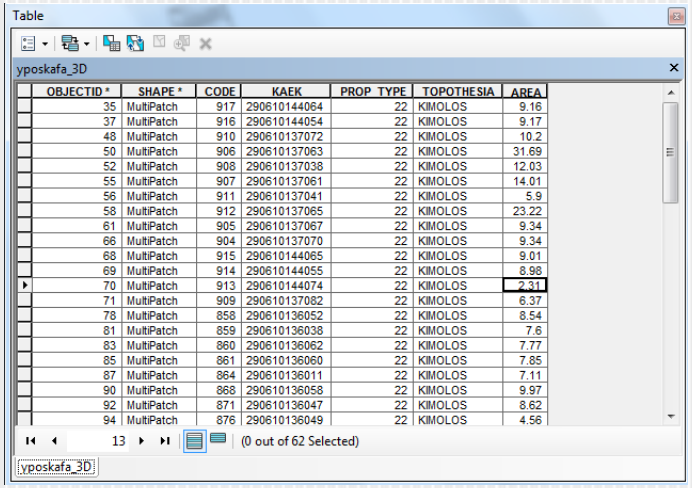
- 3D GIS: **ArcScene 10 (ArcInfo ESRI)**
  - Database design → registration of cadastral records
  - Integration of spatial and descriptive information on the same system
  - Relational database model (attribute data)
  - Spatial analysis: spatial operators and functions (3D Editor, ArcToolBox)
  - 3D representation and navigation
- 3D Modeling: **Google SketchUp 8**
  - 3D modeling of objects at a higher level of detail
  - Detailed design using special toolkits, measuring tools and library materials

COMBINATION OF 3D GIS WITH 3D MODELING SOFTWARE

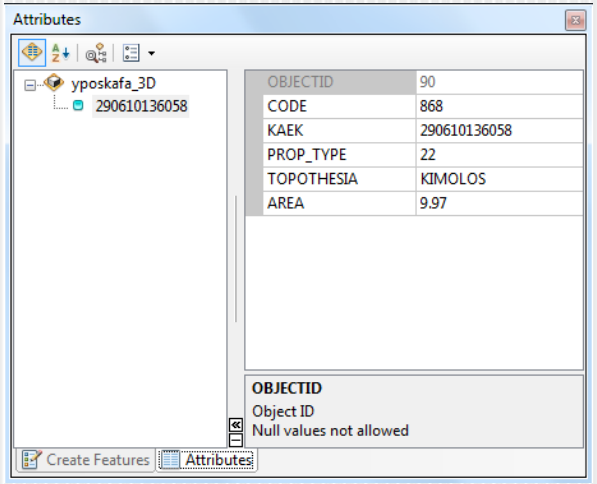


LOGICAL MODEL OF DATABASE DESIGN

- Internal database of ArcScene
- Import of spatial data in DBMS (DEM, orthophoto, cadastral map)
- Creation of personal geodatabase (entities storage – multipatch format)
- Recording of attribute data in database
- Selection of spatial entities for information extraction

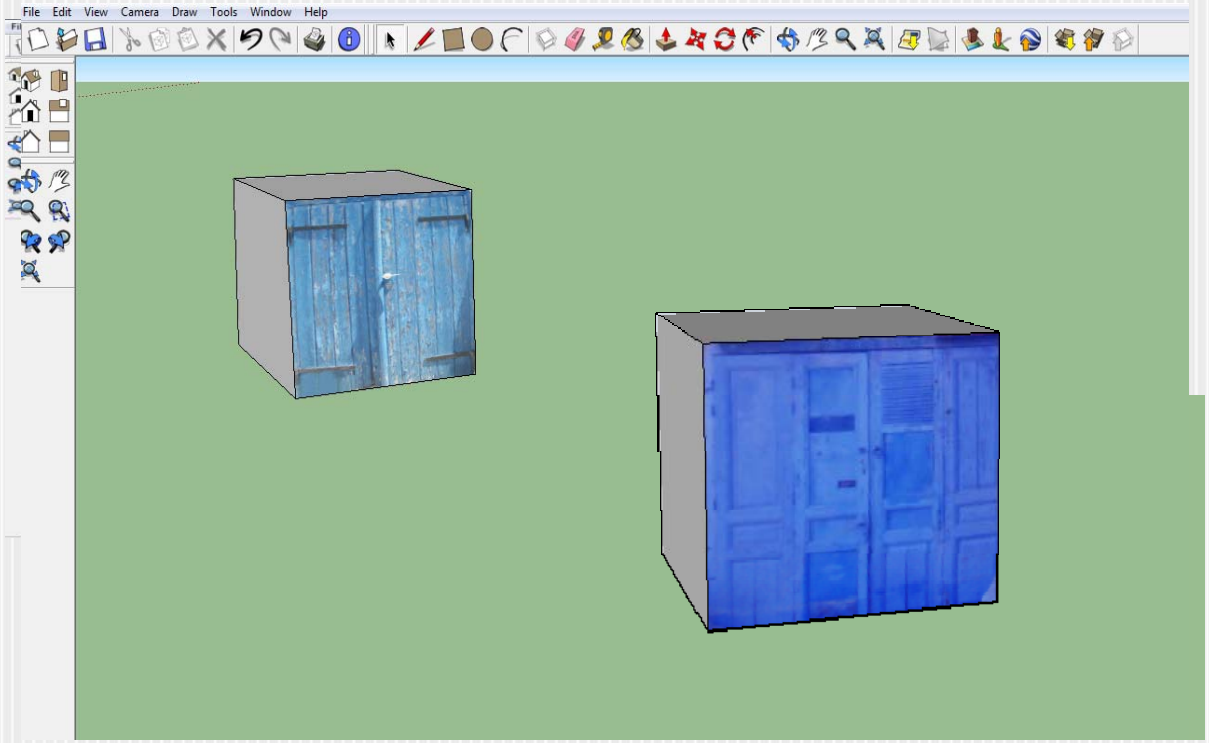


OBJECTID *	SHAPE *	CODE	KAEK	PROP_TYPE	TOPOTHESIA	AREA
35	MultiPatch	917	290610144064	22	KIMOLOS	9.16
37	MultiPatch	916	290610144054	22	KIMOLOS	9.17
48	MultiPatch	910	290610137072	22	KIMOLOS	10.2
50	MultiPatch	906	290610137063	22	KIMOLOS	31.69
52	MultiPatch	908	290610137038	22	KIMOLOS	12.03
55	MultiPatch	907	290610137061	22	KIMOLOS	14.01
56	MultiPatch	911	290610137041	22	KIMOLOS	5.9
58	MultiPatch	912	290610137065	22	KIMOLOS	23.22
61	MultiPatch	905	290610137067	22	KIMOLOS	9.34
66	MultiPatch	904	290610137070	22	KIMOLOS	9.34
68	MultiPatch	915	290610144065	22	KIMOLOS	9.01
69	MultiPatch	914	290610144055	22	KIMOLOS	8.98
70	MultiPatch	913	290610144074	22	KIMOLOS	2.31
71	MultiPatch	909	290610137082	22	KIMOLOS	6.37
78	MultiPatch	858	290610136052	22	KIMOLOS	8.54
81	MultiPatch	859	290610136038	22	KIMOLOS	7.6
83	MultiPatch	860	290610136062	22	KIMOLOS	7.77
85	MultiPatch	861	290610136060	22	KIMOLOS	7.85
87	MultiPatch	864	290610136011	22	KIMOLOS	7.11
90	MultiPatch	868	290610136058	22	KIMOLOS	9.97
92	MultiPatch	871	290610136047	22	KIMOLOS	8.62
94	MultiPatch	876	290610136049	22	KIMOLOS	4.56



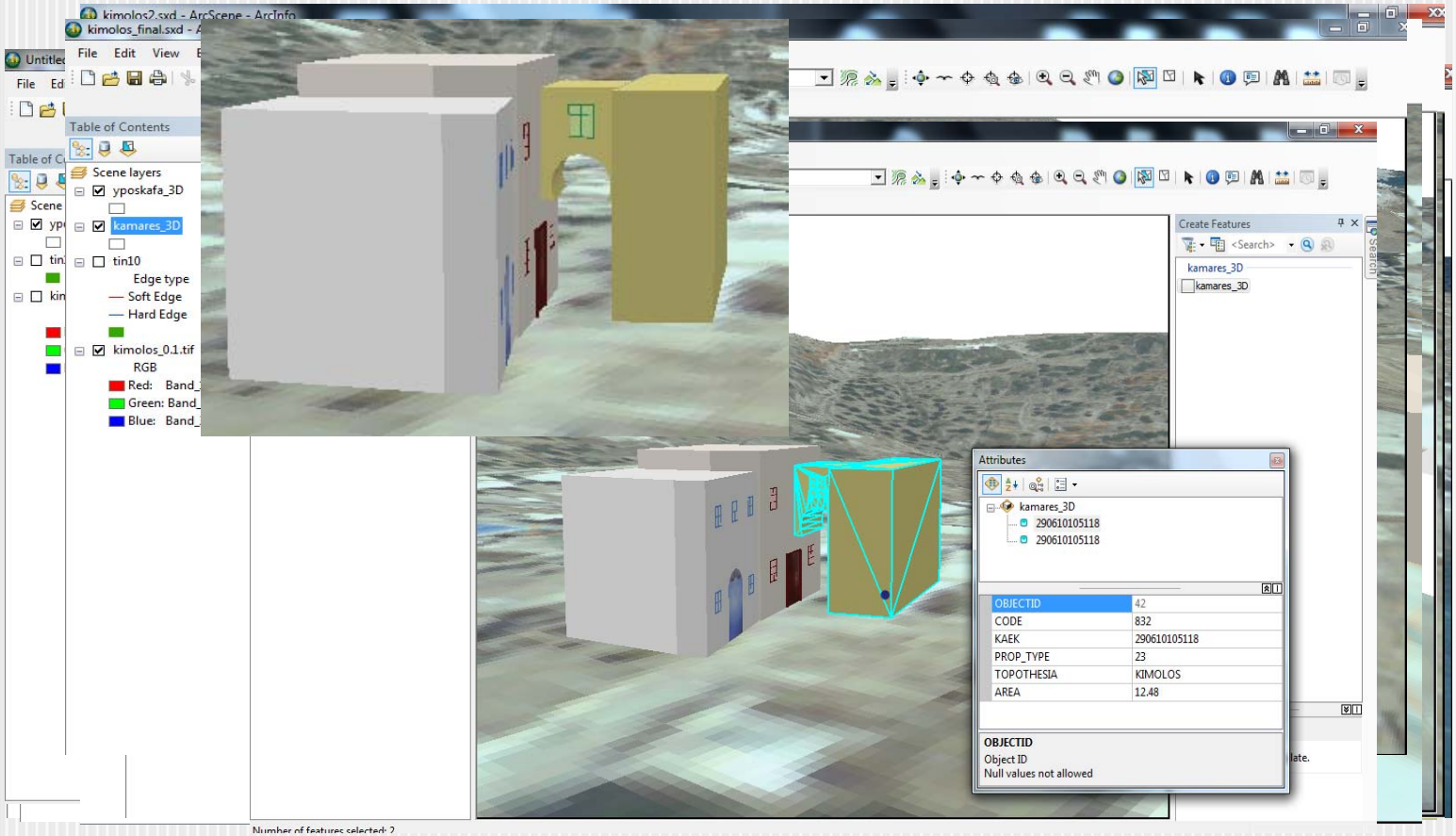
3D MODELING OF CADASTRAL OBJECTS

- Creation of 3D models of buildings in Google SketchUp
  - Import of outlines of buildings
  - Modeling of buildings volumes
  - Add photo-textures / Design buildings facades



3D REPRESENTATION OF CADASTRAL OBJECTS

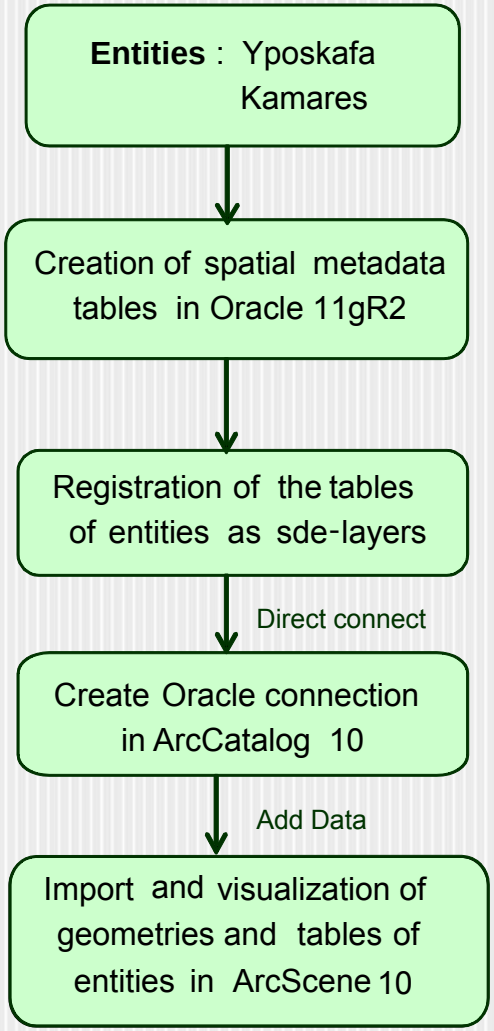
- Import 3D models from Google SketchUp into ArcScene
- Import files through 3D Editor toolbar (.dae format)
- Assign each model to the suitable record of the database



COMBINATION OF SPATIAL DBMS WITH 3D GIS

- Spatial DBMS: **Oracle Spatial 11gR2**
  - Design of spatial database → registration of cadastral objects in 3D space
  - Integration of spatial and descriptive information on the database
- 3D GIS: **ArcScene 10 (ArcInfo ESRI)**
  - ArcSDE component (ArcGIS Server) for accessing and managing geospatial data within relational databases
  - Connection to spatial database through ArcCatalog
  - Spatial analysis: spatial operators and functions (3D Editor, ArcToolBox)
  - 3D representation and navigation

COMBINATION OF SPATIAL DBMS WITH 3D GIS



COMPARISON OF INVESTIGATED METHODS

- **Combination of spatial DBMS with CAD system**
  - Integration of spatial and descriptive information on spatial database
  - Difficulty in design and update of the database for 3D geometric data types
  - No support of complex geometric data types
  - Spatial analysis for the outlines of properties
- **Combination of spatial DBMS with 3D GIS**
  - Support more complex geometric data types
  - Connection to spatial database for expert users
  - Spatial analysis for 3D property models
- **Combination of 3D GIS with 3D modeling software**
  - Representation in a higher level of detail
  - Different programs for the registration and modeling of cadastral objects
  - Time-consuming process of updating or importing cadastral records

CONCLUSIONS

- ✓ Development of a 3D hybrid cadastral system
  - existing database
  - 3D representation of cadastral objects
- ✓ Interoperability among different application systems
  → exchange, support και mutual use of spatial data types
- ✓ Expert users for software management
- ✓ Support of 3D topology in spatial DBMS
- ✓ Support of topology among points, lines, polygons – not volumes (CAD systems)
- ✓ Facilitate users to understand the position, height and volume of properties in combination with the ownership status

Thank you for your attention !