3D Cadastre Developments in Hungary

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Key words: Cadastre, Land Administration, 3D data modeling, Land Management, GIS

SUMMARY

Geometric part of the Unified Hungarian Land Registry (Cadastral maps) has been operating in standardized environment since 1996. MSZ 7772-1 Standard on Digital Base Map, Conceptual Model (developed by Institute of Geodesy Cartography and Remote Sensing, FÖMI) — based on the pre ISO and CEN standards on Geographic Information — defines a 3D relational database model for cadastral maps and linked attributes. Till now 3D capacity of Cadastral Map Databases has not been utilized.

In Unified Hungarian Land Registry the seeds of 3D Cadastre have been planted since the establishment of the Unified System in 1972. This base was the registering of condominiums, and other special 3D objects.

Main Acts, which strongly influence Land Registry, (Act on Surveying and Mapping Activities from 1996, and Act on Land Registry from 1997), have been elaborated for the Land Registry situations in the mid of 90's. Technical and infrastructure developments during the last 15 years force the change on not only the technical, but on the legal environment, as well. The paper deals with the present situation, the proposed, new legislation and technical solutions in Unified Land Registry, which all of them points to a real 3D Cadastre in Hungary.

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1. INTRODUCTION

Hungarian Land Administration has old tradition in Land Management based on the establishment of Cadastre-Land Registry in the ages of Austro-Hungary, at the end of the XIX. Century. Management of Cadastre-Land Registry of Hungary has been continuous during the Communist era as well, counter to other Socialist Countries.

In 1972 a new restriction on Land Registry was introduced, which established the Unified Hungarian Land Registry. In Unified Land Registry both Cadastral Mapping and Land Registry are the responsibilities of the same institutional system, the Land Office Network. Institute of Geodesy, Cartography and Remote Sensing (FÖMI) is a part of this system, like the overall responsible institution of research and development, maintenance and data service.

In the mid of the 90's two, new acts has taken into force, which determine Land Administration activities, Act on Surveying and Mapping activities, and Act on Land Registry. These two acts contain some 3D Cadastre solution (e.g. registering of condominiums, cellars etc.), but real 3D cadastre issues has not been regulated.

Technical development of Land Administration sector has been started at this time as well. At first step the legal part of the Unified Land Registry has been developed (TAKAROS system), then the Network of Land Administration Sector (TAKARNET) and its services were introduced and at the end of 2009, a new integrated IT system, DATR (both the legal and cadastral part) were introduced. In 2010 a new data service system, TAKARNET24 were established and has been operating since June, 2011. All these IT systems are the result of FÖMI's development work.

This paper deals with the renewed legal framework of Hungarian Unified Land Registry and technical solutions related to 3D Cadastre.

2. LEGAL FRAMEWORK OF HUNGARIAN UNIFIED LAND REGISTRY

Mainly two Acts determine the activities of Hungarian Land Administration, but naturally there are other legislations, which influence them (e.g. Act on Arable Land, Act on Forestry etc.). These two Acts are:
- o Act on Surveying and Mapping Activities (Act LXXVI. 1996) and
- o Act on Land Registry (Act CXLI. 1997).

These two Acts has come into force 16 and 15 years ago, and elaborated into an analogue (paper based) physical environment. During the last one and a half decade many important and successful technical developments has been completed in Hungarian Land

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Administration, but the changes in legal environment did not follow the results of them.

In 2011 Ministry of Rural Development (responsible for Land Administration) decided the modification of these two Acts for to make a new legal environment, which satisfied the technical requirements, including 3D Cadastre issues as well.

2.1. New concept on Surveying and Mapping Activities and Land Registry

The goal of this Act is to determine the tasks of the State in Surveying and Mapping and to establish a condition system, which provides maps in a cost-effective way for the whole economy.

The main issues, which handled in this Act are the following:
- o State works and State Data
    - o State Databases
    - o Data Services,
    - o Control Networks
- o State Databases
    - o Database of State Boundary
    - o Database of Control Points,
    - o State Cadastral Map Databases,
    - o State Topographic Databases,
    - o State Remote Sensing Databases,
    - o Databases for State Defence,
    - o Gazetteer
    - o Archive Databases.
- o Surveying and Mapping Activities
    - o Mounting and measuring surveying marks
    - o Ownership of surveying marks,
    - o Protection of Surveying Marks
- o Ownership of Surveyed Data
- o Institutional Issues in Surveying

New concept on Surveying and Mapping activities changed from the old, map-based regulation to database fundament. State Cadastral Map Database is the geometric part of the Unified Land Registry Database, which has been defined in the Act on Land Registry.

Topographic mapping activities are shared between the public (FÖMI) and military mapping agencies. Large scale (1:10 000) topographic mapping is the responsibility of public, while smaller scale topographic mapping belongs to the military mapping agency.

State Remote Sensing Databases are Orthophotos, Satellite Images, LIDAR (including Terrestrial LIDAR technics), Photogrammetric products, which elaboration financed by the State.

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New concept also includes 3D Cadastral issues, which determine that 3D objects, related to Land Registry, should be stored in State Cadastral Map Databases. Because of the importance of 3D Cadastre solution, new Act on Surveying and Mapping Activities modifies the Act on Land Registry as well.

Act on Land Registry defines a Unified Land Registry, which means the legal and geometric (cadastral map) part of the Land Registry compose one system. All geometric characteristics of Land Registry components (parcel boundary, area etc.) are derived from the State Cadastral Map Database. The Database of Land Records and State Cadastral Map Database compose one Database, Unified Land Registry Database.

Principles of Hungarian Unified Land Registry have not been changed, which are the follows:
- o Title and its effect
- o Publicity
- o Authenticity
- o Application
- o Rank and
- o Deed.

Title and its effect defines, that all rights and facts are derived from registering them.
Publicity means that the data, registered in Hungarian Unified Land Registry are public (except some special data, e.g. Personal Identifier).
Authenticity means that all data, registered in Land Registry are authentic.
If anyone wants to change or register anything in Land Registry, he must make an Application for it.
The principle of rank defines, that all actions in Land Registry should be carried out based on the time of registration of Application.
If any rights or facts should be registered, it must be based on a Deed, defines the principle of Deed.

This Act defines cadastral parcel, which is a continuous part of the Earth's surface, on which the ownership and/or handler relationships are homogenous. There are other types of real properties beside cadastral parcels, which are the components of Land Registry (e.g. buildings, condominiums, flats, shops etc.).

Former Act defined some 3D Cadastre issues. These are the registering of condominiums, flats, shops, other areas within the condominium, cellars of which entry on public parcels etc. Registering of these 3D situations, based on the 2D cadastral map. For example flats, shops are not the part of Cadastral Map Database, these are described by the floor-plans of them, which act as Cadastral Map of flats. Therefore change management of them is a very hard work. Cellars are described only by the entry line of them in Cadastral Map Database.

Because of the above situation, and introducing a real 3D Cadastre in legislation, the renewed Act on Land Registry defines a new type of property, which opens the doors to 3D Cadastre.

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This new type of property is defined by the follows:

"Under-ground and above-ground passes objects, structures, which has homogenous ownership and/or handler relationships should be taken into account as an independent property, which must be registered in Land Registry."

By this action utilities, overcrossings and other objects should be registered as an individual property and 3D legal relationships should be modeled in Hungarian Unified Land Registry.

Versus with some 3D Cadastre solution, the Hungarian concept registers 3D object in space. Connecting legal space of 3D object should be derived from the geometry of object itself.

Legal space required for 3D Cadastre object is defined in different Laws, Regulations related to Land Use and Land Development in Hungary. This means if 3D objects and their legal space should be registered in Land Registry, the required legal space must be modeled based on regulations.

The Act authorizes FÖMI to elaborate the required legal and technical regulations for the implementation of 3D Cadastre in Hungarian Unified Land Registry. Therefore 3D elements of the Act will not come into force immediately, if the Act voted by the Parliament, only after these regulations and technical conditions are ready.

The Act has been published to the Parliament in March 2012. If Parliament voted the Act it will be come into force at the half of 2012.

3. TECHNICAL ISSUES

Hungarian Unified Land Registry is operating in a self-developed IT environment DATR, which is a FÖMI developed system en-bloc. This IT system is based on Hungarian Standard MSZ 7772-1 Digital Base Map, Conceptual Model. The Standard defines a 3D space as default, but 3D geometric and topological primitives and structures are not included.

For the establishment of the technical background of the above-mentioned new legal environment, a lot of development and modeling work must to do. Since all source codes of IT systems are available at FÖMI, coding of models would not be a real problem. FÖMI do not plan using other (e.g. OGC, ISO) Standards in the implementation of 3D Cadastre, interfaces to and from such standards will be developed.

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3.1. Data modeling in 3D Cadastre

Data modeling in 3D Cadastre is an important issue, since legal spaces should be modeled, which have special characteristics (e.g. legal spaces are not physical objects,, infinite legal spaces etc. (Thompson-van Oosterom, 2011)).

Thompson recommended a model, which is using regular polytopes for 3D Cadastre geometric representations. Regular polytopes can be unbounded, only the part of the boundaries belongs to the object (Thompson, 2007). He also mentioned the usage of TEN (Tetrahedronized Irregular Network) as the possible 3D topological encoding of objects.

Stoter used TIN (Triangulated Irregular Network) models for integrating 2D parcels and 3D objects in one environment. He used constrained TINs for more precise 3D representation of parcels (Stoter, 2004).

Thompson and van Oosterom invented an axiomatic definition of valid 3D parcels in a space partition with different geometric primitives (Thompson-van Oosterom, 2011.)

Since the analysis of the above mentioned 3D Cadastre modeling theories exceeds the range of this paper, a short description of FÖMI's ideas on modeling of legal spaces is invented in next sections. The illustrations in the next chapters are 2D for ease of drawing.

3.2. Handling of infinity by homogenous coordinates

In 3D Cadastres legal spaces have special characteristics, against the 2D situations. Legal space defined in 3D Cadastres can be infinite (unbounded) as it is shown on Fig. 1:
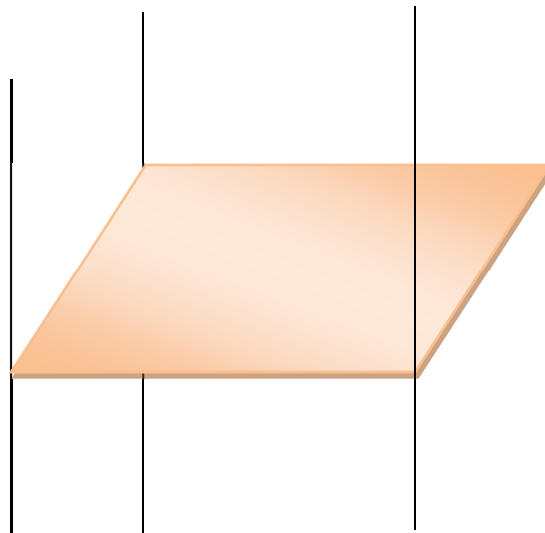

Fig. 1.: Cadastral parcel with infinite legal space

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On Fig. 1. a cadastral parcel is shown, on which the legal space (e.g. ownership right) is infinite to the top and bottom. There can be different solutions for this situation, one of them described below.

One of the resolution of this problem can be the exchange of our traditional Euclidean space to Projective space. Projective space is an affine space (the space of our measurements) plus the plain at infinity. The plain at infinity has no any special role in Projective space as in Euclidean or Affine geometry (Coxeter, 1969). All parallel lines meet on the plain at infinity or all parallel plains meet on the same line on plain at infinity. Therefore if our Euclidean space is exchanged to Projective space there will not be unbounded polytopes anymore, because the plain at infinity closes the unbounded polytopes.

One of the most elegant property of Projective space is the principle of duality, which asserts that every definition remains significant, and every theorem remains true, when we consistently change the words point and plain (Coxeter, 1969) (On projective plain duality refers to point and line).

At FÖMI, based on our long experiences in Projective Geometry, a new conceptual model has been developed for 3D Cadastre geometric and topological issues, based on the usage of projective coordinates, which are handling situations at infinity.

Projective geometry is using homogenous coordinates for the analytic description of projective space. Homogenous coordinates describes a position (point) in 3D space by four coordinates (X,Y,Z,W). As a convention if W coordinate of a point is zero, the point is at infinity. Because of the construction of homogenous coordinates if we multiply by a non-zero number of the coordinates, we get the same point:

$$(X,Y,Z,W) \equiv (\lambda X, \lambda Y, \lambda Z, \lambda W) \text{ if } \lambda \neq 0.$$

Based on this equation, if $W \neq 0$, division by W is permitted, so (X/W, Y/W, Z/W, 1) results the same point. This means every point at finite can be described by (X,Y,Z,1), where X,Y,Z are the Affine (Euclidean) coordinates of the point (Iván, 1994).

In Projective space the plains have coordinates, from the co-planarity equation:

$$Det \begin{bmatrix} r_1 & r_2 & r_3 & r_4 \\ s_1 & s_2 & s_3 & s_4 \\ t_1 & t_2 & t_3 & t_4 \\ u_1 & u_2 & u_3 & u_4 \end{bmatrix} = 0$$

where

        r,s,t – are three distinct points, which determine the plain
        u – is any point on that plain (Iván, 1994).

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This simple formula for the determination of coordinates of lines or plains follows interesting results (Fig. 2.):
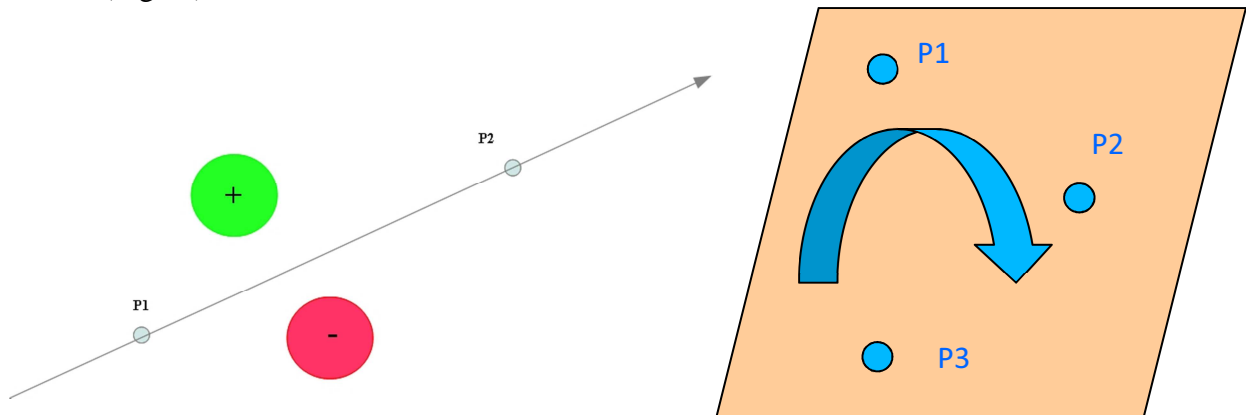

Fig. 2.: Line and plain, which is partitioning space

Both the line between P1 and P2 (on the left), and the plain (determined by P1, P2, P3) is partitioning the projective plain (space) into two half plains (spaces). The coordinates of lines (plains) can be determined from co-linearity (co-planarity) formulas. Direction of line (plain) is very important, since it determines the topological construction of the plain (space). If any point on the plain is on the left-hand side of the line (determined by P1 and P2), its scalar product with the line is positive. Dual of this definition in space, if any point above the plain, the its scalar product with the plain is positive. If we change the direction of the line (not from P1 to P2, but from P2 to P1) the definition should be the opposite. In the case of the plain, if the three points, which determine the plain, are in clockwise order or in counter-clockwise order the result is the same as in 2D case. This means directing of lines (plains) is possible by homogenous coordinates as well.

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3.3. Polygons and tetrahedrons

In traditional GIS systems polygons and their topological relations can be described as on FIG 3.:
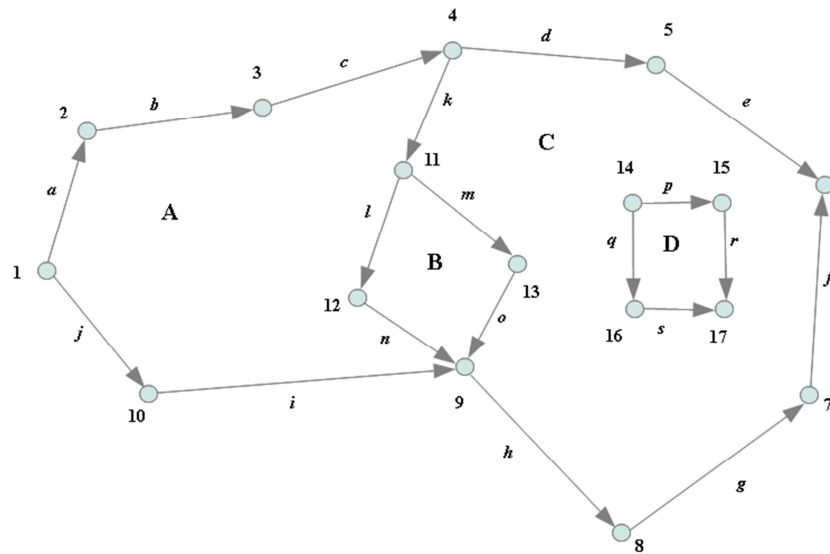

Fig. 3.: Faces and Edges

If the edges are exchanged to infinite lines the following result is   raised as on Fig. 4.:
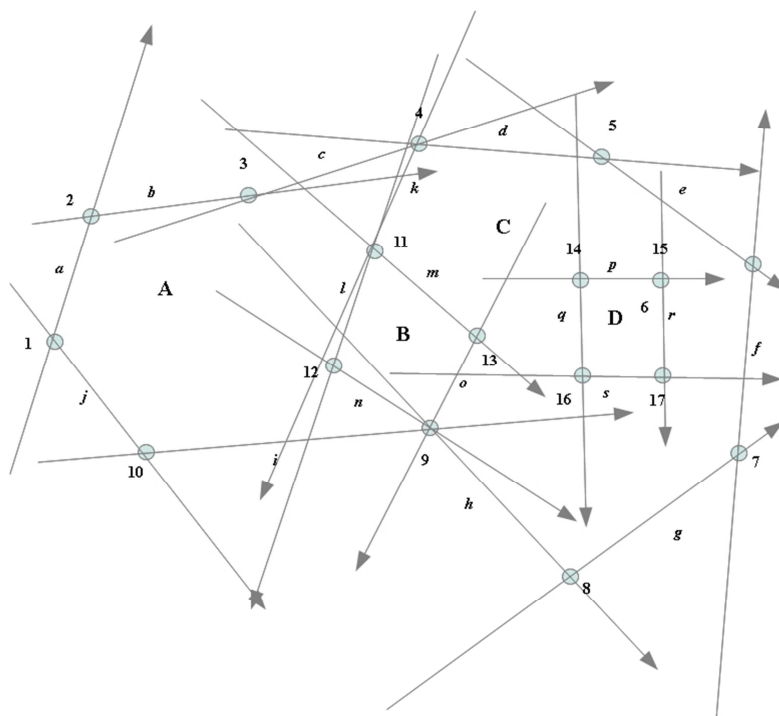

Fig. 4: Faces and Infinite Lines

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If the faces are convex, they can be determined by the following equation:

$$\begin{bmatrix} X_1 & Y_1 & W_1 \\ X_2 & Y_2 & W_2 \\ ... & ... & ... \\ X_n & Y_n & W_n \end{bmatrix} \begin{bmatrix} x_P \\ y_P \\ w_P \end{bmatrix} \geq 0$$

where

- X_i Y_i W_i - are the coordinates of i-th line bounding the faces
- x_P y_P w_P - are the coordinates of any point within the face
- n – is the number of lines bounding the face.

In 3D space the above formula is the same as in the case of convex polytopes, only the number of coordinates are exchanged from 3 to 4, and lines are replaced by plains.

For managing concave polytopes and holes in the case of legal spaces FÖMI has decided the use of 3D tesselation algorithms to eliminate these problems. One of the most known tessellation algorithm is Delanuay-triangulation, which is generally used for digital elevation model (DEM) creation. If there are edges and faces which must be included in the model (e.g. in the case of DEM the breaklines) constrained Delanuay-triangulation is needed as Storer used it in integration of 2D parcels and 3D objects in one environment (Stoter, 2004).

The algorithm of Delanuay-triangulation can be used in n-th dimensional space as well. The 3D constrained Delanuay-triangulation generates tetrahedral meshes for arbitrarily complex 3D domains, which could be very useful in the case of modeling 3D legal spaces in 3D Cadastre. Evolving of 3D constrained Delanuay-triangulation exceeds the content of this paper, but there are many papers, which deeply study this theorem (Shewchuk 2007, Cavalcanti-Mello). For example the result of a constrained 3D Delanuay-triangulation is seen on Fig. 5.:
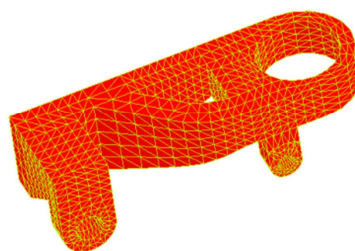

Fig. 5.: Tetrahedron mesh from constrained Delanuay-triangulation (Cavalcanti-Mello)

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3D constrained Delanuay-triangulation is generally used by mechanical engineering and industry, but the flexibility of its results should be taken into account in our 3D Cadastre modeling as well, therefore FÖMI is researching on this way.

Practically 3D constrained Delanuay-triangulation means the fulfillment of a 3D domain by a tetrahedron mesh, with some constrains, which are defined by edges and faces (measurements). Using of homogenous coordinates directs into interesting results as shown on Fig. 6.:
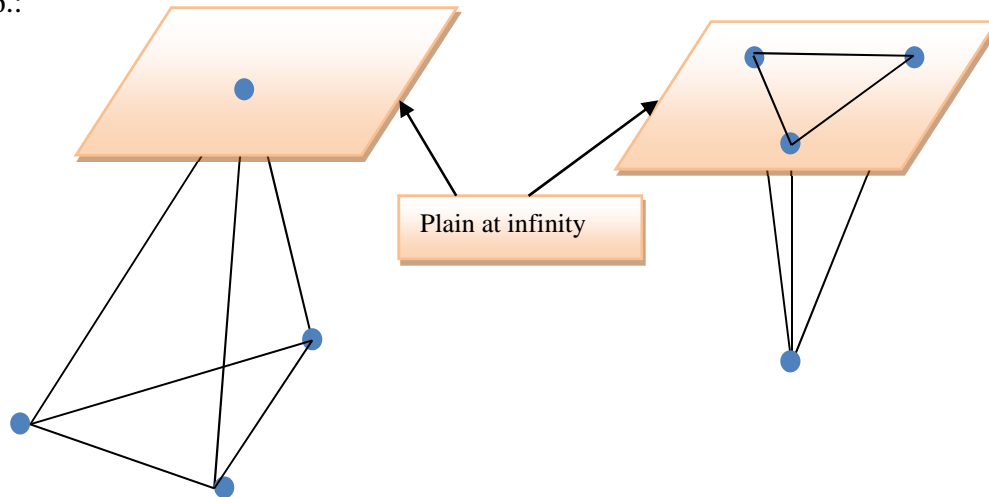
Plain at infinity

Fig. 6.: Tetrahedrons and infinity

On Figura 6. there are the two, practically possible situation of tetrahedrons with the plain of infinity. On left one vertex of the tetrahedron is on the plain at infinity, while on the right one face of the tetrahedron is the plain at infinity. But in projective space there is no any difference between the tetrahedrons! They can be described on the same way by homogenous coordinates. The situation in "normal", Euclidean space, is the following (Fig. 7.):
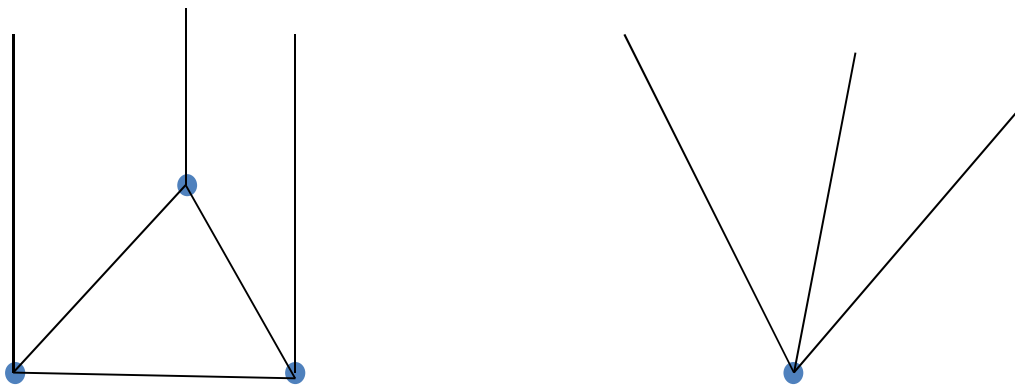

Fig. 7.: Configuration of Fig. 6. at finite space

The tetrahedron, which has a vertex at the plain of infinity, in Euclidean space products a triangle, which has parallel lines from each vertices, while the other one products a point, from which there are three divergent lines.

Another important issue of this approximation of 3D legal spaces is providing the connection between 3D and 2D Cadastre. On Fig. 8. a simple tetrahedral mesh is presented, which describes some legal construction in 3D space:
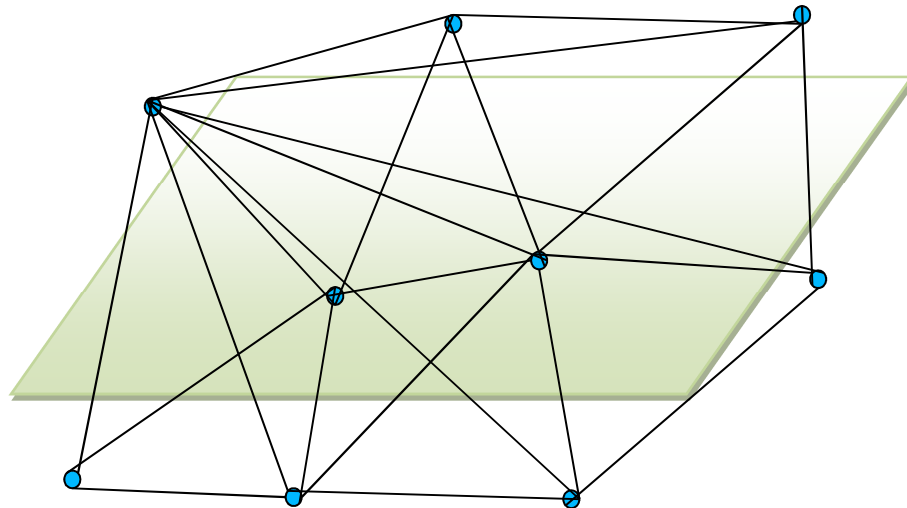

Fig. 8.: Simple tetrahedral mesh, representing legal spaces

If within this tetrahedron mesh the height coordinates are stored in relative coordinates (e.g. Z=0 means the height of the ground), and a plain (Z=0) splits this tetrahedron mesh, the result should be a Cadastral Map, which using the geometric and topologic description as on Fig 9.:
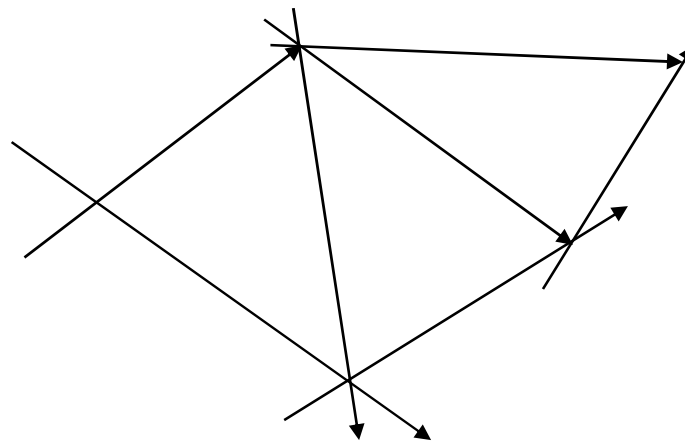

Fig. 9.: Result of splitting tetrahedral mesh by any plain

All the lines on the plain inherit its direction from the direction of faces of tetrahedron mesh, so the result is a topological correct configuration.

At this time utilization of projective, homogenous coordinates in 3D constrained Delenuay-triangulation is under investigation at FÖMI. This general solution, by the utilization of tessellation algorithms, could result a new model for the solution of modeling legal spaces in 3D Cadastre.

3.4. Implementation of research

FÖMI is at the beginning of the elaboration of the mentioned 3D Cadastre geometric model. During the last decade FÖMI invested a lot of work for the development of a real, integrated Land Registry IT system called DATR, which solved most of the procedures by IT from Land Administration point of view. This development is a FÖMI product en-bloc, all source code and application programming interface are available at the Institute. Since FÖMI has not found any GIS software, which can handle homogenous coordinates, infinity and other important properties of the model, our Institute plans to develop an environment for the implementation of our model.

4. CONCLUSIONS

Hungary has a long tradition and experience in the operation of Unified Land Registry. Because of the technical and informatics development of the last decade a new legislation should be introduced, which maps the development in Land Registry and Cadastre. Renewing of Acts, which influence the activity of Land Administration sector should reach our goals, introducing legal regulation of 3D Cadastre, National Spatial Data Infrastrucure and other issues.

In order to reach our goals FÖMI has started a development on the implementation 3D Cadastre in Hungary. FÖMI's model is based on the primary investigation, solutions and its own experiments. FÖMI's own development on an integrated IT system (DATR), builds an environment, which is independent from any commercial solutions and makes possibilities for free thinking. Preparation of the 3D Cadastre model, highlighted in last chapters, is at the beginning, but we hope our research leads to acceptable results.

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BIOGRAPHICAL NOTES

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