Spatial Data Support for Building Monitoring

Bence TORONYI, Hungary

Key words: Spatial Data Management, Remote Sensing, Digital Image Processing, WEB Services

SUMMARY

Nation-wide Building Monitoring is the responsibility of Hungarian Regional Development and Town Planning Non-profit Ltd. (VATI). FÖMI's task is divided into two levels: Building extraction from orthophoto and digital terrain models and Web Map Service (WMS) of extracted features, together with cadastral map and orthophoto layer to VATI. Building extraction from orthophotos based on digital image processing techniques developed by FÖMI. Building extraction from digital terrain models based on two country-wide datasets, HUNDEM-5 database (5m resolution GRID format elevation model) and a Digital Surface Model (derived from aerial photographs by autocorrelation method) with 1m resolution. Both two methods have very good and reliable results for building extraction. FÖMI has developed a WMS service to VATI, which covers necessary data resulted from the different procedures.

The paper deals with the Building extraction techniques used for the monitoring and the implementation of WMS Service.

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1. INTRODUCTION

Institute of Geodesy, Cartography and Remote Sensing (FÖMI) as a part of the Hungarian Land Administration has a key role in Hungarian Spatial Data Infrastructure (SDI). FÖMI's activities (e.g. GNSS services, Geodynamics research, Operation, Support and Development of Unified Land Registry IT systems, Remote Sensing activities, Data Services, Topographic mapping) cover an important, large part of national SDI.

Active participation in international (mainly EU funded) projects is an important resource to increase the number and quality of services for citizens and national SDI.

In order to detect buildings which has no permission and changes in buildings distribution FÖMI and Hungarian Regional Development and Town Planning Non-profit Ltd. (VATI) have established a joint project called "Building Monitoring", which has used different spatial and remote sensing data analysis methods for the automatic detection of buildings.

FÖMI as the spatial data analyzer and provider, while VÁTI acts as the national-level building authority, which makes decisions on the cases, based on spatial data services provided by FÖMI. The overall goal of the project has been to establish a remote sensing data-based technology for building detection, with the usage of other spatial datasets (e.g. digital elevation and surface models, cadastral data etc.). By the usage of digital image processing algorithms the buildings were detected from digital orthophotos. These algorithms used not only remote sensing (orthophoto) data, but the existing building layer of cadastral databases as well. Then the differences of building layer of cadastral databases and detected buildings from orthophotos were categorized based on the amount of changes. Then all these data (detected buildings, orthophotos, cadastral data, categorized changes etc.) were provided for VÁTI as the basis of decision-making procedures.

The paper deals with the implementation of Building Monitoring project, from FÖMI's point of view, as developer, data provider.

2. BUILDING MONITORING PROJECT

FÖMI and VÁTI agreed in 2011 to establish a project on building monitoring including automatic classification of buildings from remote sensing data in cooperation with other (e.g. height) data and serving the classified data on Internet from FÖMI to VÁTI.

Checking the possibility of classification a pilot project was established for 19 settlements of Hungary, which acts as a representative sample for the utilization of such methods. Pilot project was successfully executed and the results showed, that FÖMI's development in building monitoring is a real valuable success to expand the project to nation-wide level.

3. USED DATABASES IN THE PROJECT

3.1 Digital Orthophoto Database of Hungary

Digital Orthophoto Database of Hungary is a composition of digital orthophotos from different years of aerial photography. Generally 1/4-th of the country is covered by digital orthophotos per year. The present situation is showed on Fig. 1.:

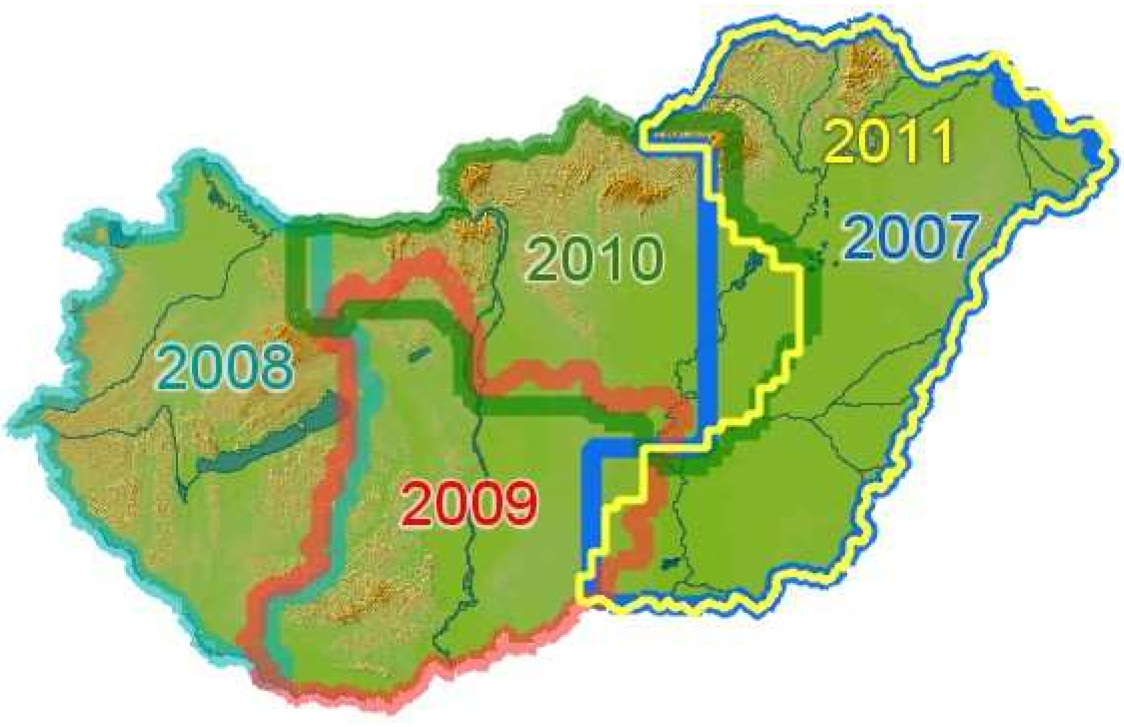

Fig. 1.: Digital Orthophoto Coverage of Hungary

The main purpose of Digital Orthophoto Database of Hungary is the annual updating of Land Parcel Identification System (LPIS), which serves for the management of area-based agricultural subsidies from the European Union. Therefore aerial photography is carried out in vegetation period, which limits the use of the database in surveying and mapping activities, but useful for building detection as the results of the project showed it.

Main technical characteristics of the orthophoto database are the following:

Ground resolution: 0,5m
Colour depth: 2 * 24 bit: RGB + CIR
Average horizontal accuracy: 0,5m.

3.2. Digital Elevation Model of Hungary (HUNDEM-5)

HUNDEM-5 database was derived from the digital contour lines of 1:10 000 scale topographic maps of Hungary, and then modified by stereo photogrammetric measurements. This huge database contains more than 3,7 billion points, within a GRID model. The estimated accuracy of heights (derived from ground and photogrammetric measurements) is 0,7m. Resolution of the GRID is 5m. (Fig. 2.)

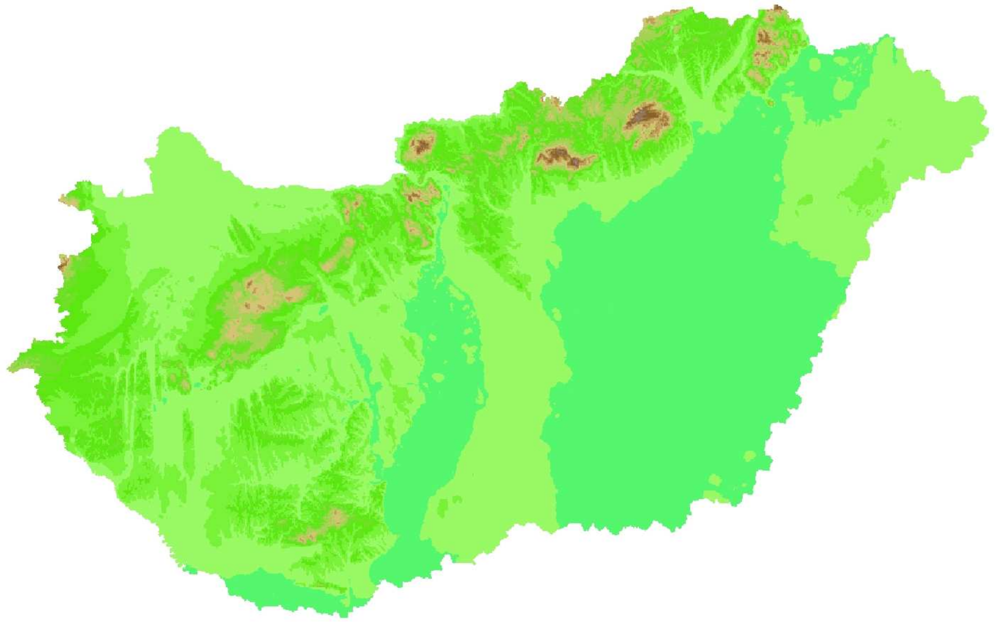

Fig. 2.: HUNDEM-5 database of Hungary

3.3. Digital Surface Model of Hungary (DSM)

In cooperation with the Mapping Non-profit Limited of the Hungarian Home Defense Forces (MNL) FÖMI received the task to establish a Digital Surface Model of Hungary, derived from aerial photographs taken in the mentioned aerial photography projects (see 2.1). Ground resolution of DSM is 1m and its accuracy is about 0,5m.

The whole, nation-wide database has not been established yet, but for 8 sample areas FÖMI and MNL has finished the surface model. The results of these sample areas were used in Building Monitoring project, for refinement of digital image processing output. (see Fig. 3)

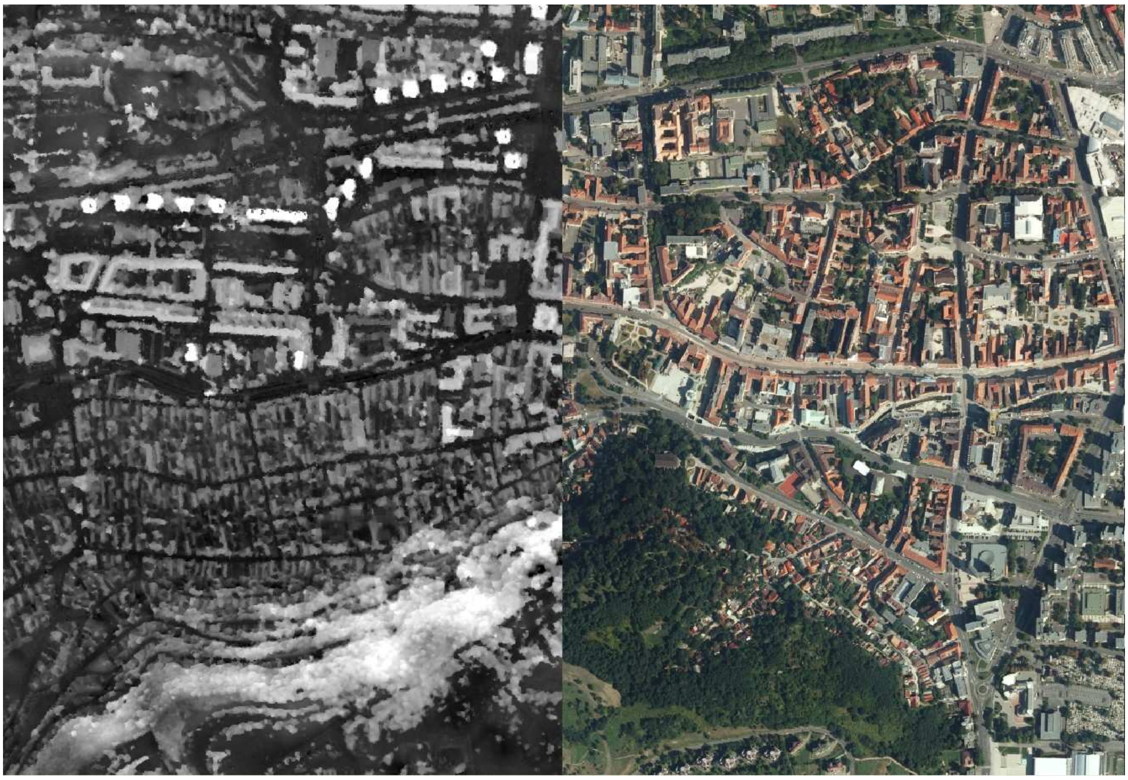

Fig. 3.: DSM and HUNDEM-5 differences (left) and digital orthophoto (right, Miskolc, Hungary)

3.4. Cadastral Database of Hungary

A Unified Land Registry system is operating in Hungary, which means cadastral mapping and the management of legal data is the responsibility of the same organization, the Land Office network. FÖMI is a part of Land Office network, its responsibilities are the overall management of unified land registry databases, the continuous development, support and operation of IT systems of Land Office networks. FÖMI is operating Land Registry services via Internet for registered users. Replications of Land Offices' databases can be found at FÖMI for central data management and service, which are updated every second from the

Land Offices. This means every cadastral data of Hungary, including cadastral maps and connected legal data, are available at any time within the Institute.

Buildings, which are registered in Land Registry, are the part of the Hungarian cadastral maps. In the case of non-registered buildings (e.g. not-permitted buildings), the building layer of cadastral databases is a very well-used master database for the detection of them. (Fig. 4.)

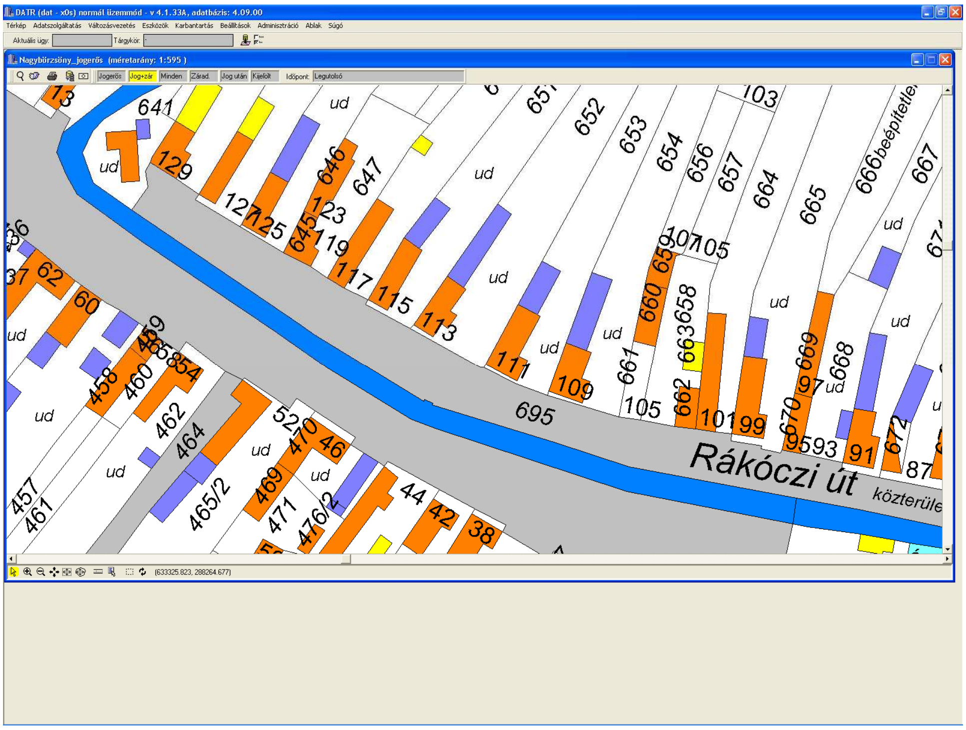

Fig. 4.: Buildings in cadastral databases

4. DIGITAL IMAGE PROCESSING TECHNIQUES USED IN BUILDING MONITORING

One of the main direction of digital image processing developments is the measuring of town/city environment. Generally there are two questions, which should be answered:

- size, environ and condition of built objects,
- change detection (natural-artificial).

Separatiing artificial objects from its natural environ is trivial at first sight, using Normalized Difference Vegetation Index (NDVI). But classification (categorization) of built objects is more difficult, more complex image analyzing methods are needed.

Raised image analysis problems are the following (Fig. 5).:

- Definition of building categories based on typical characteristics: Spectral characteristics of buildings are various (e.g. geometric properties, illumination, roofing materials, roof's state etc.), therefore description unambiguous categories is impossible,
- Separating buidings from built-objects (e.g. roads, railway, parking places) is not possible just by spectral properties,
- Aerial photography of used orthophotos was not taken at the same time, therefore important factors (e.g. sun-angle, illumination) are not uniform and calibration is not executable. Declination of high-object is a well-known problem in the case of orthophotos, which occurs difficulties as well,
- shaded and covered areas are not classifiable

Fig. 5.: Various spectral and geometric properties on orthophoto (Eger)

In order to eliminate the above mentioned problems object-based image analysis methods were used.

4.1. Object-based image analysis (OBIA) in building monitoring

The main goal of object-based image analysis is to obtain such information from images, which are not available by the usage of pixel-based analysis. Visual interpretation is accurate enough, even in worse-quality images, because the human vision recognizes geometric and textural contexts and categorizes objects well.

Substance of OBIA is the modeling of human vision by mathematical analysis of geometry and texture.

Texture measures the homogeneity, order of pixels composed the object, using Grey Level Co-occurence Matirx (GLCM) based statistics. Geometry describes the size, spatial density and fit to regular form of objects. In the case of building monitoring density is important, which describes the fit and difference from the densest object (square). Elongated objects has a lesser density than compact objects.
Density properties of objects spectrally is useful to separation of roads, railway objects and bridges, which spectrally seem like buildings. Vegetation, shadows and vehicles can bend these objects and some buildings could be linear, which could cause classification errors. On Fig. 6. a street, which composes one segment, can be separated based on density, but on Fig. 7. the density based classification of the long building results an error (the is building classified into road).

Fig. 6.: Classification of street based on segmentation(good result)

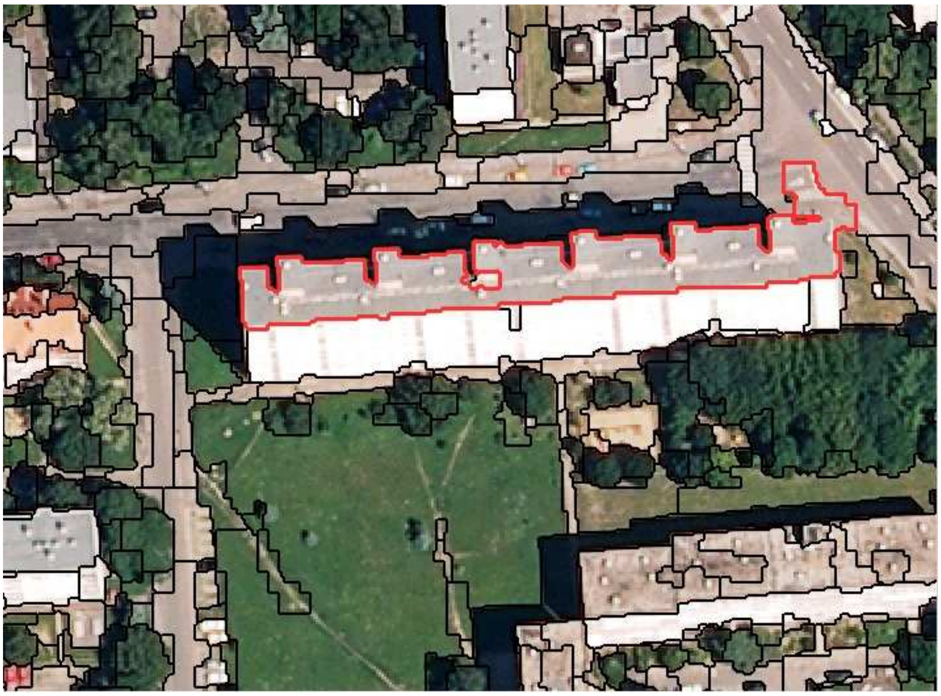

Fig. 7.: False classification of building based on density

Segmentation creates objects. For good results segmentation should be executed in iteration. OBIAs were carried out by Definiens eCognition software.

4.2. Developed image analysis methods for building extraction

FÖMI has developed two methods for building detection. First method based on paralell pixel- and object-based image analysis without any height information, while the second method is an object-based image analysis aided by height information. Post-processing techniques of the results of the two methods were the same.

4.2.1. Paralell pixel- and object based image analysis

In the case of pixel-based analysis clusterization were carried out for 60 clusters and then linked them to different classes. Most of the clusters can be linked to classes uniquely, but in the case of some clusters (5-10) objects are mixed. This number were not decreased by the increasing of number of clusters.

In object-based image analysis multi-step segmentation were used and resulted objects were classified based on thier spectral and geometric properties.

Both method provides sometimes false results, but most part of false classification is disjunct, therefore the interception of the results could be good. But some parts of false classification (e.g. parking places, concrete covered places) can not be eliminated, because these errors can not be corrected by spectral analysis. With the usage of height information of objects the results can be improved significantly.

4.2.2. Object-based image analysis with height data

Objects’ heights are derived from HUNDEM-5 and DSM database, from the difference of the two height data. Segmentation is the same as the first method (see. 4.2.1.), but the classification is executed using objects’ NDVI average value and height. But in the case of some artificial objects (e.g. bridges) the analysis of geometric characteristic of objects is necessary as well.

The result of this method is better, but the lower resolution of HUNDEM-5 and DSM could cause local errors, because of the interpolation of heights. Advantage of this method is the full automatization of the procedure (the 4.2.1. method cannot be automatized because of the clusterization). But this method is really reliable, if the height information from DEM and DSM are accurate enough. Fig. 8.: shows the results of 4.2.2. method, while Fig. 9. shows false results of the 4.2.1. method.

Fig. 8.: Building classification using height data

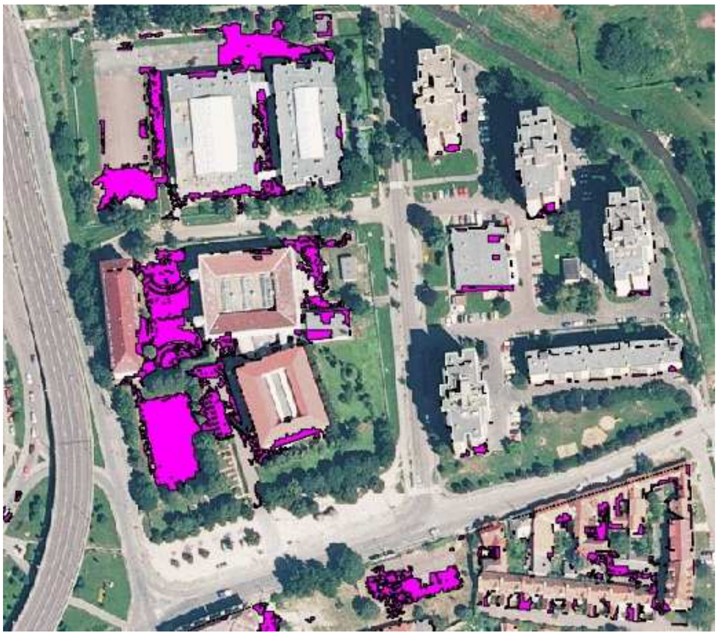

Fig. 9.: Building classification without height data

4.3. Results of image analyses

For the accuracy analysis of building extraction from orthophotos some test-areas were classified by both methods and for the independent analysis visual interpretations were used for the same areas. Accuracy was measured based on contingency.matrix derived κ, which is showed in Table 1.:

Method	κ
Without height	68%
With height	88,3%

Table 1.: Result of classification

It is clear, that height aided classification method is better and more efficient, as the 20% incrementation by pixel is showing it..

5. ESTABLISHMENT OF MAP SERVICES FOR VÁTI

Results of building classification were postprocessed into Open GeoSpatial Consortium (OGC) standard Web Map Service (WMS) service (Fig. 10).

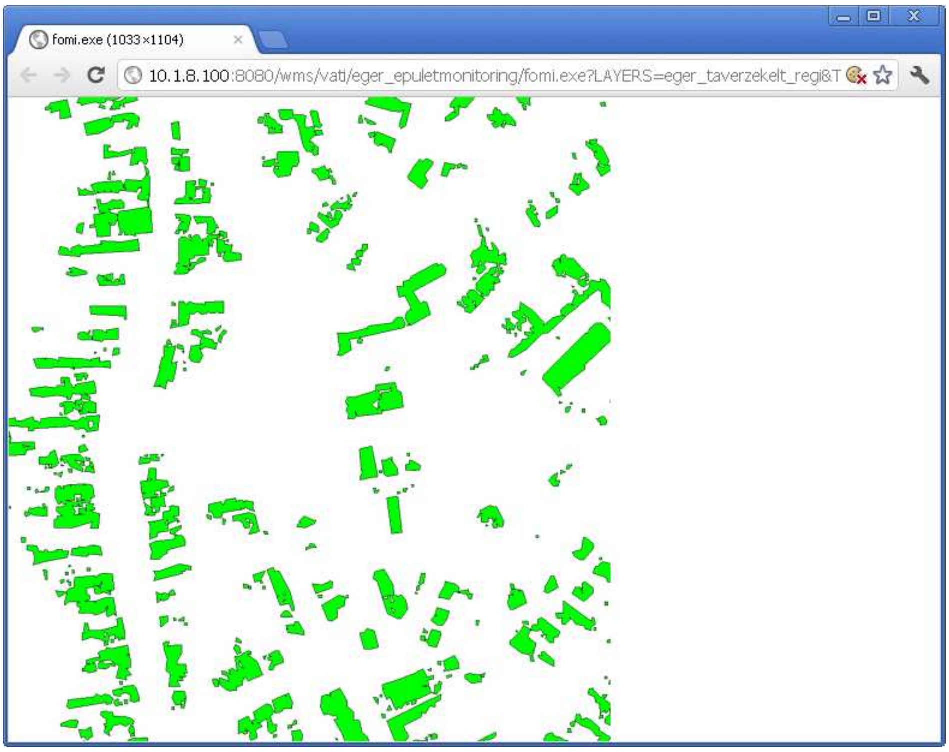

Fig. 10.: WMS service of detected buildings for VÁTI

For the establishment of WMS service an open-source software environment OGC Map Server (ver. 3.0.1) was used, but for the management of the served datasets Quantum GIS (an open source sofware as well) was used (Fig. 11.).

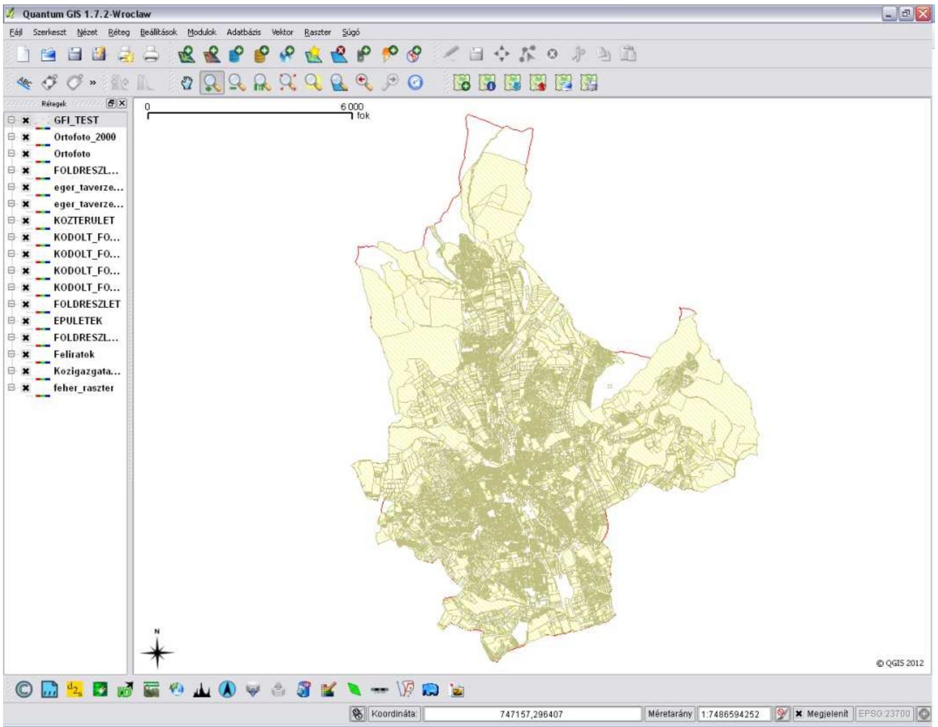

Fig. 11.: Management of WMS services by Quantum GIS

In WMS services the following layers are available:

- Administrative Boundary of Settlements
- Digital Orthophotos
- Cadastral Parcels,
- Buildings from Cadastral Databases,
- Thematic cadastral parcels:
  - Area of buildings increased within the cadastral parcel
  - Area of buildings decrased within the cadastral parcel,
  - Area of building has not been changed within the cadastral parcel,
- Classified buldings from object- and pixel based classification,
- Classified buldings from object-based classification with height data.

Since the services are not fully opeartional for the whole territory of the country, the planned architecture of WMS services is showed on Figure 12.

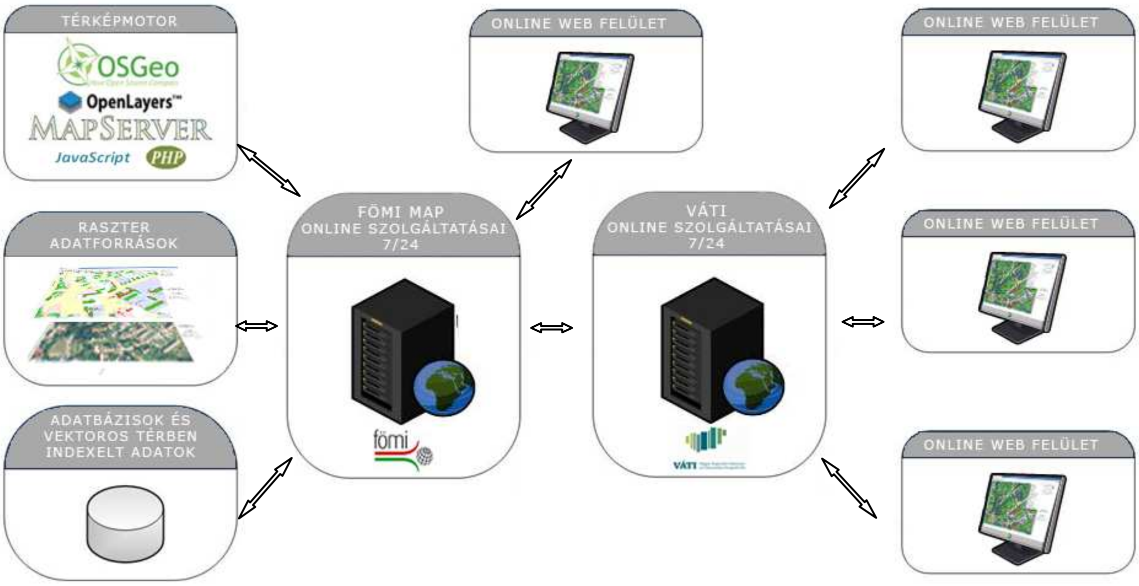

Fig. 12.: Planned architecture of services

The project was successful for 19 settlements of the pilot project. These settlements were choosed as a resresentative sample for all the possible situation. The nation-wide expansion of the project is going on.

6. CONCLUSIONS

Building monitoring project of Hungary is a real challange for image analysis, digital image processing and GIS point of view as well. The successful execution of the pilot project for the 19 settlements showed that there were many opportunities for the increasing of spatial data services of FÖMI, and the Hungarian Land Administration Sector. Nation-wide expansion of Bulding Monitoring project requires more human and financial sources, but the importance of the project could solve this problem.

FÖMI is looking for other possible, value-added services and technical developments to increase the effectiveness and recognition of Hungarian Land Administration.

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BIOGRAPHICAL NOTES

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