https://doi.org/10.4233/uuid:05737379-602e-46fd-891a-c9683fffd104

Revising Surveying and Representation Package of LADM Profile for Serbia to Support 3D Spatial Information

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Key words: LADM, LiDAR, 3D spatial information, CityGML, BIM/IFC.

SUMMARY

LADM profile for Serbia was developed by Radulović et al. (2017) reflecting the current state of Serbian cadastral information system which is based on 2D spatial information. It also provides general discussion of the need for establishing 3D cadastre in Serbia without specific details about its possible implementations and developments. Given the increasing usage of 3D datasets acquisitions in Serbia in recent years, particularly by LiDAR technology, in this paper we revise the surveying and representation package of Serbian LADM profile in the context of 3D spatial information and the process of retrieving 3D geometries of spatial units. With the proliferation of 3D datasets special attention should be paid to spatial sources such as LiDAR (airborne and terrestrial) and UAVs for buildings and BIM/IFC for building units, while formats for representation such as CityGML, CityDB, IndoorGML, BIM/IFC, etc. should also be addressed. Similar to 2D digital cadastral map supported by sketches of indoor information, we propose 3D digital cadastral map supported by indoor information represented by 3D formats (BIM/IFC, CityGML, IndoorGML). The link will be established by the means of unique property identification number. This approach will be demonstrated on two case studies. The first case study uses the procedure to obtain 3D city database developed based on airborne LIDAR data for the city of Novi Sad. The second case study uses the procedure to obtain 3D city database developed based on UAV data and terrestrial LiDAR for the city of Novi Pazar. For both case studies, different type of manual and automatic points cloud classification and 2D and 3D vectorization was done.

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1. INTRODUCTION

LADM profile for Serbia was developed by Radulović et al. (2017) reflecting the current state of Serbian cadastral information system which is based on 2D spatial information. It also provides general discussion of the need for establishing 3D cadastre in Serbia without specific details about its possible implementations and developments. Given the increasing usage of 3D datasets acquisitions in Serbia in recent years, particularly by LiDAR technology, in this paper we revise the surveying and representation package of Serbian LADM profile in the context of 3D spatial information and the process of retrieving 3D geometries of spatial units.

Most of the municipalities in Serbia have 2D spatial data in the form of digital cadastral map containing 2D parcel boundaries and building footprints. These boundaries are represented by the class RS_BoundaryFaceString in the surveying and representation package of Serbian LADM profile. The Serbian cadastre recognizes three types of real properties defined by the Law (Official Gazette, 2009): land parcels, buildings and building units. Building units are separate parts of the buildings that make one structural units, such as apartments, business offices, garages. Alphanumeric data about rights, right holders and real properties is in the cadastral database. Building units in Serbian 2D cadastre are represented by the 2D CAD sketches of the floor plans. All this information is linked by unique property identification number (UPIN).

With the proliferation of 3D datasets in recent years in Serbia, special attention should be paid to spatial sources such as LiDAR (airborne and terrestrial) and UAVs for buildings and BIM/IFC for building units, while formats for representation such as CityGML, CityDB, IndoorGML, BIM/IFC, etc. should also be addressed. The possibility of using these spatial sources and representation formats has been widely analysed in the literature. Góźdź et al. (2014) have analyzed the possibilities of using CityGML for 3D representation of buildings in the cadastre. The possibilities of integration of LADM and CityGML for 3D cadastre have been analysed by Rönsdorf et al. (2014) and Sürmeneli et al. (2021). Biljecki et al. (2017) developed 3D city model by inferring heights of buildings solely from 2D footprints and attributes which can be obtained from cadastral map and cadastral data. Using LiDAR data to develop 3D building model has been described by Roschlaub and Batscheider (2016). Koeva and Elbernik (2016) analysed the potential use and challenges for updating 3D cadastral objects using LiDAR and image-based point clouds. Park and Guldmann (2019) developed a 3D city models with building footprints and LIDAR point cloud classification using a machine learning approach. The possibilities of mapping private, common, and exclusive common spaces in buildings from BIM/IFC to LADM have been analysed by Alattas et al.

(2021), while mapping of complex ownership spaces have been analysed by Atazadeh et al. (2017). Working with open BIM standards to source legal spaces for a 3D cadastre has been disscussed by Oldfield et al. (2017), while extending CityGML for IFC-sourced 3D city models has been analysed by Biljecki et al. (2021). In this regard, similar to 2D digital cadastral map supported by sketches of indoor information, we propose the development of 3D digital cadastral map supported by indoor information represented by 3D formats (BIM/IFC, CityGML, IndoorGML) based on available 3D data and common 3D data acquisition practices. The link between these information and datasets will be established by the means of UPIN. This approach will be demonstrated on two case studies that will show the common procedures for the 3D data acquisition and 3D city modeling that could be used to extract buildings for the purpose of 3D cadastre and development of 3D cadastral map.

The first case study uses the procedure to obtain 3D city database developed based on airborne LIDAR data for the city of Novi Sad. For this purpose, the Riegl LMS-Q680i laser scanner and digital camera DigiCAM H39 was used. The flight altitude, according to the orography of the area and safety standards, has been maintained about 200 m AGL and speed about 45 km. In this case study, it has been operated with the parameters of 40 points per square meter, and aerial images with 5 cm per pixel. In this part of case study, after LiDAR scanning, as a first step orthophoto images and a georeferenced point cloud have been created. After that, initial classification, detail classification, 2D or 3D vectorization, and creation of digital elevation model was done.

The second case study uses the procedure to obtain 3D city database developed based on UAV data and terrestrial LiDAR for the city of Novi Pazar. For this purpose, for aerial images DJI MAVIC PRO with camera CMOS with effective pixels:12.35 M, and for terrestrial scanning Leica ScanStation P20 was used. Flight control and planning was performed from the Pix4Dcapture mobile application, and total of 3 flights are planned at an altitude of 80 meters and one at an altitude of 40 meters. The total number of photos collected from altitude of 80 m is 943 and from altitude 40 m is 676. Data processing was performed through Agisoft Metashape software. The area was scanned with terrestrial laser scanning during 3 days with a total of 33 stations. Also, total of 11 ground control points (GCP) was collected for precise georeferencing of the model. A cloud of dots, mesh, texture, and orthophoto was generated from both subprojects, and then merged into joint one. The generated point cloud at the output consists of a total of 1,184,126 points.

For both case studies, different type of manual and automatic points cloud classification and 2D (Asphalt road, field road, pedestrian road, forest, park, isolated trees, bush, terrace, river, stream, water, canal, fence, railway, bridge, parking, bench, bus stops) and 3D (House, building, residential and commercial building, auxiliary building, lighting, pole, power lines, traffic sign) vectorization was done. Data transformation was done according to the model proposed by Jovanović et al. (2020). For the purposes of visualizing the CityGML model on the web, the 3D city model created and stored in the 3DCityDB Database was then exported in glTF format to be visualized with the help of Cesium JS Web Map Client, and KML for visualization in Google Earth.

2. SURVEYING AND REPRESENTATION PACKAGE OF LADM PROFILE FOR SERBIA

LADM profile for Serbia was developed by Radulović et al. (2017) reflecting the current state of Serbian cadastral information system which is based on 2D spatial information. Classes in the surveying and representation subpackage are RS_Point, RS_SpatialSource, and RS_BoundaryFaceString (Figure 1). In the cadastral survey procedure, geodetic measurement of real property was carried out according to the actual field situation. The subject of geodetic measurement is the boundary points at the border lines of cadastral municipalities, parcels, parts of the parcel, according to the use type, and buildings, as well as other construction facilities. Data on the geometries of spatial objects can be acquired by using the polar, photogrammetric, global navigation satellite system (GNSS) method, the laser scanning method, and their combination. The individual points or complete spatial units are associated to the RS_SpatialSource class which represents a spatial source. A survey was documented with spatial sources. The types of spatial sources were defined within the RS_SpatialSourceType code list. The spatial profile for Serbia is 2D topological, so the RS_BoundaryFaceString class with GM_MultiCurve type was use used for geometries.

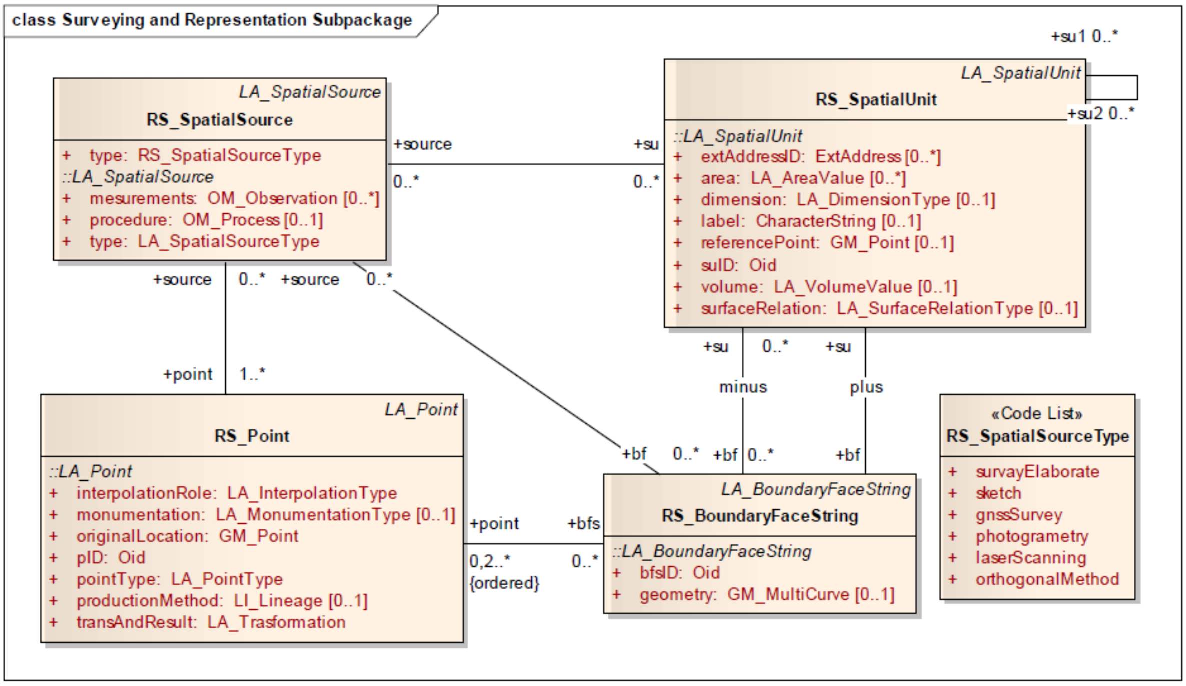

Figure 1. Surveying and Representation sub-package of Serbian LADM profile (Radulović et al., 2017)

Considering the more recent surveying practices the aforementioned package should be revised and extended appropriately. Particularly the code list RS_SpatialSourceType should be extended to include terrestrial and airborne LiDAR scanning. Furthermore, UAV is recognized as a novel technology that is gaining increasing use in the surveying activities. Considering spatial representation of 3D legal boundaries of the properties, two formats to store 3D spatial data are widely used in practice in Serbia, namely CityGML and BIM/IFC. However, they are not used for the cadastral registration purposes and the cadastre remains 2D based. Since Serbian cadastre recognizes three types of properties: land parcels, buildings and building units, the letter two can be represented using mentioned formats. In particular, CityGML Building class may be used to represent buildings in Serbian 3D cadastre. IFC entity ifcBuilding can also be used to represent buildings. However, buildings represented as BIM/IFC models are not as widespread as buildings in CityGML format stored in 3D city databases, so for this purpose CityGML is more appropriate. However, more and more digital twins of buildings are available, particularly for the new buildings, and in recent years, we are witnessing the increasing building construction activities. Therefore, this data can be used instead of CAD sketches that are traditionally attached to the cadastral map and surveying elaborate to represent building units. Furthermore, IFC entities such as ifcSpace or ifcSpatialZone can be used to represent legal boundaries of building units in 3D as shown in Sladić et al. (2020). All this information is linked by unique property identification number (UPIN). According to the The Law on the Procedure for Registration in the Real Estate Cadastre and Utility Network Cadastre (Official Gazette, 2018), for each property the unique identification number is determined individually and recorded. Its purpose is to facilitate data access and management on properties, since the attributes needed to identify a property are administrative municipality code, cadastral municipality code, number and sub-number of the parcel, a number of the part of parcel i.e. sequential number of building on the parcel (1-n) and sequential number of building unit within building (1-n, this number is 0 for the building itself).

Figure 2 represents the extended UML model of surveying and representation package. It contains the extended spatial source code list, which includes new spatial data acquisition methods. Apart from ordinary 2D sketches of indoor space (floor plans and vertical cross sections) that are used to determine geometrical boundaries of legal spaces such as building units, which are usually submitted in CAD format, we propose the use of BIM/IFC format for the indoor space representation in 3D. However, BIM/IFC does not contain explicitly defined boundaries of legal spaces such as building units (2D sketches in CAD divide building units by a bold line). Rather it is a collection of indoor spaces such as rooms and other building premises, divided by wall and other building elements, so further mapping of IFC to legal spaces is needed. One simple solution is to add an UPIN attribute to all the premises that comprise a single building unit (legal space) such as apartment. Cadastral map will contain 2D spatial data of the parcel boundaries and building footprints, with the addition of 3D building model in CityGML format. Further integration may be achieve by integrating LADM based legal and CityGML based physical model by integrating CityGML class _AbstractBuilding and its inherited class Building with the RS_Building class from the LADM profile. Buildings in CityGML are bounded by multi surfaces (gml:MultiSurface) which can be used for the representation of RS_BoundaryFace in LADM profile. For this purpose CityGML version 2.0 (Gröger et al., 2012) has been used since the developed data is stored in this format. RS_BoundaryFaceString is still used for the parcel boundaries and building footprints as shown on Figure 1.

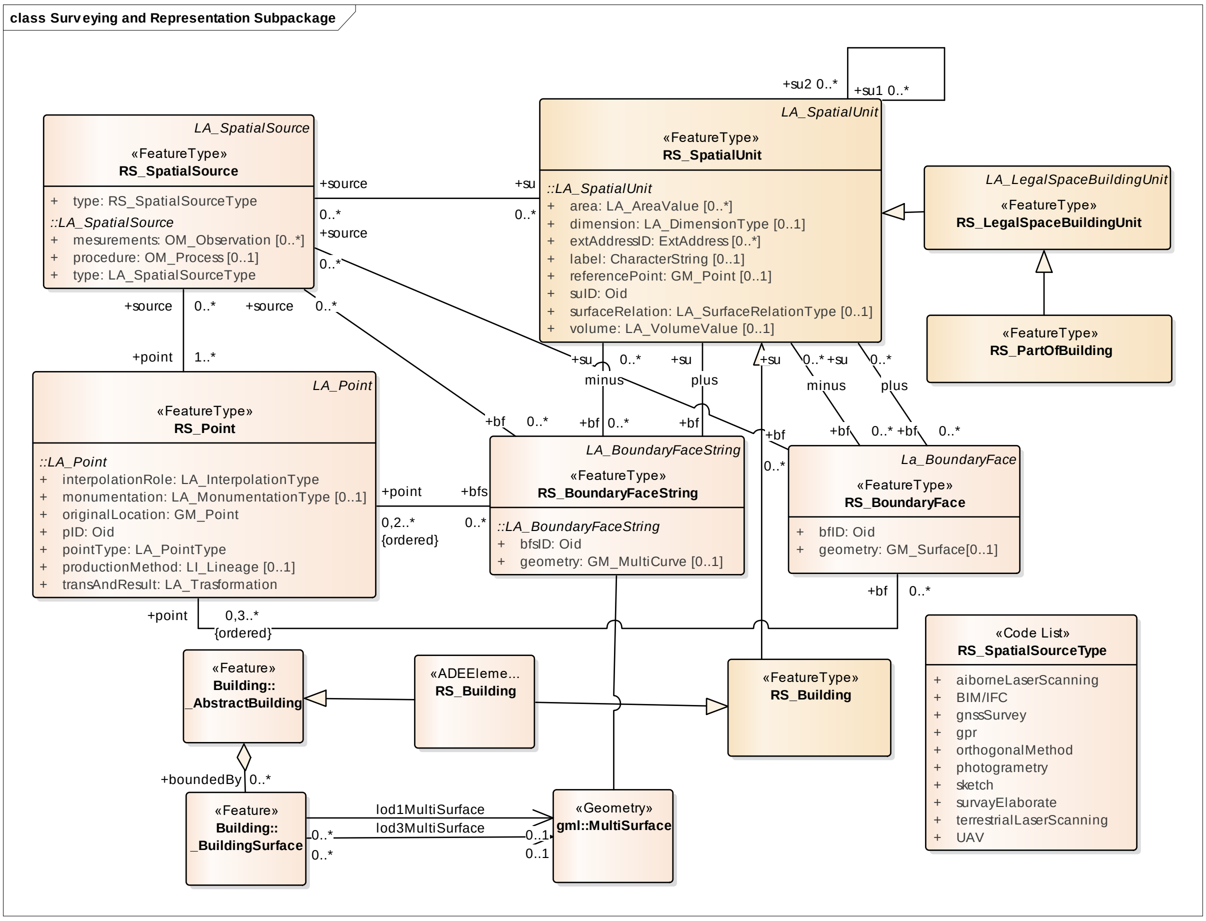

Figure 2. Extended UML model of surveying and representation to support 3D spatial information

3. 3D CITY DATABASE DEVELOPMENT BASED ON AIRBORNE LIDAR, TERRESTRIAL LIDAR AND UAV DATA

This section presents two case studies of the development of 3D city database which can be used as a source of 3D geometries of buildings and serve as a basis for the development of 3D cadastral map. The first case study uses the procedure to obtain 3D city database developed based on airborne LIDAR data for the city of Novi Sad. For this purpose, the Riegl LMS-Q680i laser scanner and digital camera DigiCAM H39 was used. The flight altitude, according to the orography of the area and safety standards, has been maintained about 200 m AGL and speed about 45 km. In this case study, it has been operated with the parameters of 40 points per square meter, and aerial images with 5 cm per pixel.

In this part of the case study, after LiDAR scanning, as a first step orthophoto images and a georeferenced point cloud have been created. After that, initial classification, detail classification, 2D and 3D vectorization was done using classified LiDAR data and according to the relevant rules in the Republic of Serbia (Republic Geodetic Authority of Serbia, Digital Topographic Key, 2005). List of all layers can be seen in Table 1. Finally, results of these basic processing steps were a fully classified point cloud, and a file containing 3D building models in a CAD structure.

Table 1. 2D and 3D vector layers

2D CAD/Vector Layers	3D CAD/Vector Layers
Asphalt road, field road, pedestrian road, forest, park, isolated trees, bush, terrace, river, stream, water, canal, fence, railway, bridge, parking, bench, bus stops	House, building, residential and commercial building, auxiliary building, lighting, pole, power lines, traffic sign

The second case study uses the procedure to obtain 3D city database developed based on UAV data and terrestrial LiDAR for the city of Novi Pazar. For this purpose, for arial images DJI MAVIC PRO with camera CMOS with effective pixels:12.35 M, and for terrestrial scanning Leica ScanStation P20 was used. Flight control and planning was performed from the Pix4Dcapture mobile application, and total of 3 flights are planned at an altitude of 80 meters and one at an altitude of 40 meters. The total number of photos collected from altitude of 80 m is 943 and from altitude 40 m is 676. Data processing was performed through Agisoft Metashape software. The area was scanned with terrestrial laser scanning during 3 days with a total of 33 stations. Also, total of 11 ground control points (GCP) was collected for precise georeferencing of the model (Figure 3). A cloud of dots, mesh, texture, and orthophoto was generated from both subprojects, and then merged into joint one. The generated point cloud at the output consists of a total of 1,184,126 points.

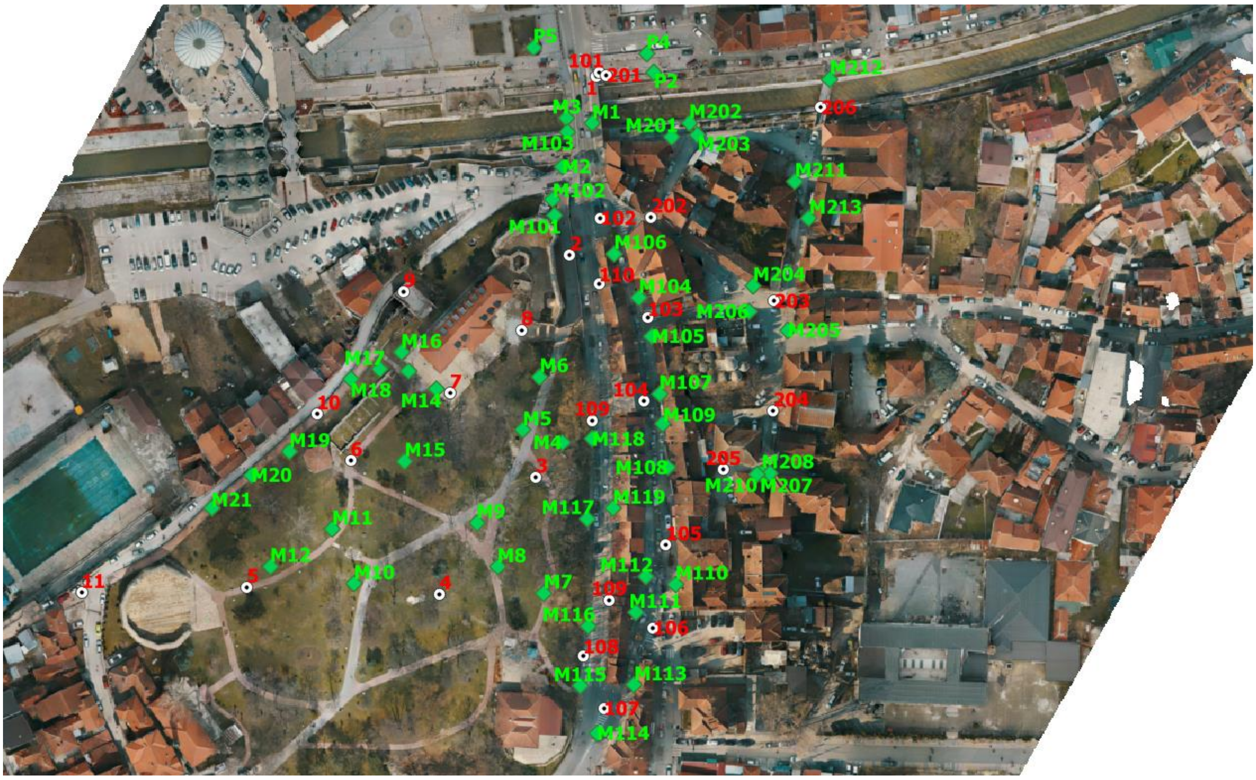

Figure 3. Scanning area. Stations are highlighted in red, marker positions are highlighted in green

For both case studies, different type of manual and automatic points cloud classification and 2D (Asphalt road, field road, pedestrian road, forest, park, isolated trees, bush, terrace, river, stream, water, canal, fence, railway, bridge, parking, bench, bus stops) and 3D (House, building, residential and commercial building, auxiliary building, lighting, pole, power lines, traffic sign) vectorization was done. Data transformation was done according to the model proposed in Jovanović et al. (2020).

As a result of the transformation, the CityGML model of 1204 of the city buildings (Case study 1 – Novi Sad city center, campus and Petrovaradin Fortress) of LoD2 with photorealistic elements of the roofs and in an appropriate coordinate system were created. One of the main advantages of mass LiDAR surveying and processing and automatic classification of point cloud data is results of classification and possibility to connect results with features defined by the CityGML standard. Table 2 gives an overview of all CAD layers, which have been transformed into GML format by ETL transformation, that is, into features defined by the CityGML standard.

For the purposes of visualizing the CityGML model on the web, the 3D city model created and stored in the 3DCityDB Database was then exported in glTF format to be visualized with the help of Cesium JS Web Map Client for Novi Pazar (Figure 4), and KML for visualization in Google Earth (Figure 5).

Table 2. CAD layers which have been transformed into 3D model defined by the CityGML standard.

CAD Layers	CityGML Features
House, building, auxiliary object, residential and commercial object	Building, RoofSurface, WallSurface
Breaklines, grid	TINRelief
Forest, thicket	PlantCover
Road, field road, pedestrian road	Road
Parking, other	LandUse
Water	WaterBody

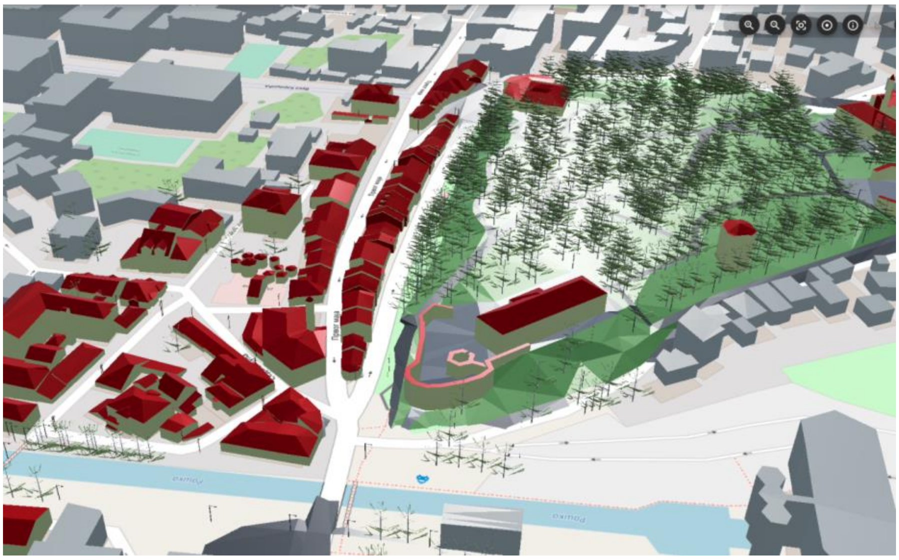

Figure 4. View of the 3D model with the corresponding features in Table 2 in accordance with the CitiGML standard displayed in the Cesium JS Web Map Client – case study 2 – Novi Pazar

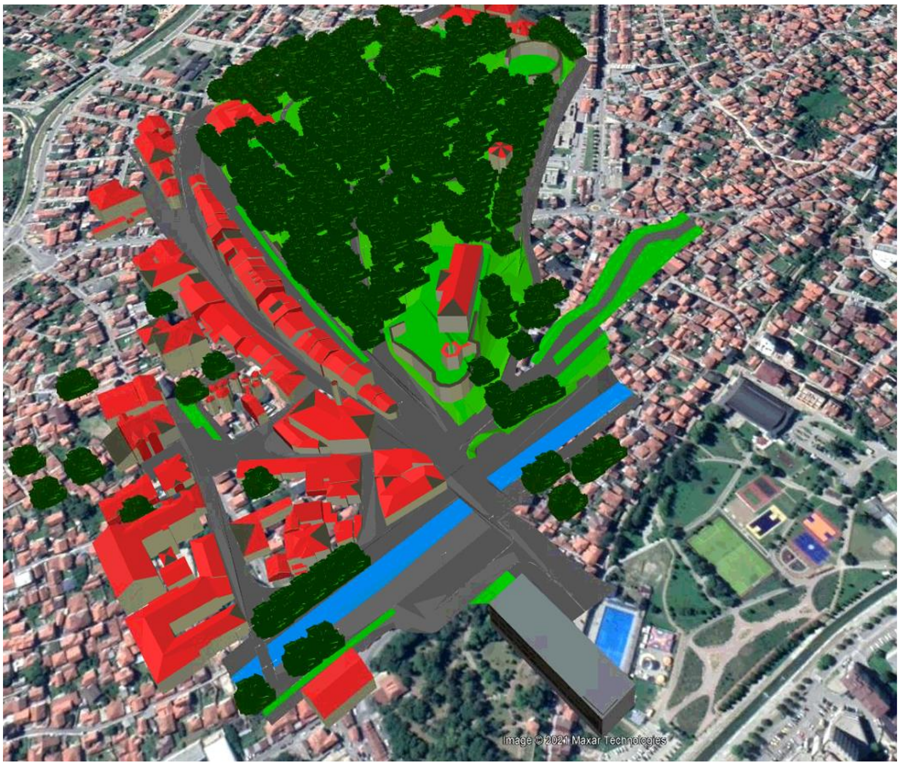

Figure 5. Novi Pazar - Case study 2 – KML

Both tables show that the 3D models necessary for the 3D cadastral purposes are present. CityGML standard has anticipated a mechanism to link an object from a 3D model to a corresponding object in another information system, such as cadastral information system. This is called an external reference and it is represented by ExternalReference class. The generic concept of external references allows for any CityGML object an arbitrary number of links to corresponding objects in external information systems such as cadastre. An external reference of the building contains URI to cadastral information system and the name of the external object which in this case is represented by the unique property identification number. This way the link is established and can be further queried using SQL. What is the limitation of this approach is that all these external references must be added manually, and a method for automation of this process should be developed. For this purpose, 2D cadastral maps can be used since they contain unique property identification numbers, so a method to overlay these building models with building footprints on cadastral map and extract UPIN should be developed.

4. CONCLUSION

In this paper we revised current practices for the spatial data acquisition and recognized the possibilities for improvements in terms of data registration in the cadastre to support collected 3D information. Most of the municipalities in Serbia have 2D spatial data in the form of digital cadastral map containing 2D parcel boundaries and building footprints. These boundaries are represented by the class RS_BoundaryFaceString. The Serbian cadastre recognizes three types of real properties defined by the law: land parcels, buildings and building units. It stores alphanumeric data about rights, right holders and real properties is in the cadastral database and geospatial data in 2D cadastral map for parcels and buildings, while building units are represented by the 2D CAD sketches of the floor plans. All this information is linked by unique property identification number (UPIN). With the proliferation of 3D datasets special attention is paid to spatial sources such as LiDAR (airborne and terrestrial) and UAVs for buildings and BIM/IFC for building units, and formats for representation such as CityGML, CityDB, IndoorGML, BIM/IFC. Similar to 2D digital cadastral map supported by sketches of indoor information, we proposed 3D digital cadastral map derived from a 3D city model supported by attached indoor information represented by 3D formats (BIM/IFC, CityGML, IndoorGML) based on available data, also linked by UPIN. This approach is demonstrated on two case studies in terms of data collection procedures that can be used for 3D cadastre purposes and development of 3D cadastral database. Both case studies use the procedure to obtain 3D city database, which can serve as a basis to populate cadastral database, where properties should be tagged by the UPIN.

Future work will include further integration of cadastral datasets (CityGML and LADM based), since geometries for buildings are stored in CityGML format. The current analysis is based on CityGML 2.0 format since available datasets are developed in this version of the standard. However, analysis of CityGML 3.0 should also be addressed. Further research directions are pointed toward methods for automation of building extraction from point clouds based on the machine learning algorithms combined with extraction of 3D geometries from the point clouds based on 2D building footprints in cadastral map. This is necessary to avoid manual labeling with UPIN, which is a long and tedious task. For the indoor space and modeling building units boundaries future research directions may be the generation of 3D indoor space based on available 2D floor plans in the cadastre or building units legal spaces mapping in IFC. Future work may also consider mapping of indoor space in available IFC format to CityGML to develop complete a CityDB database (both indoor and outdoor space).

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BIOGRAPHICAL NOTES

Dubravka Sladić (Ph.D) is an Associate Professor at Faculty of Technicial Sciences, University of Novi Sad, Serbia. She has published several papers in ISI journals and more than 20 papers in international and national journals and conferences. She has also participated in several research projects and projects including design and implementation of cadastral information systems in Republic of Srpska in Bosnia and Hertzegovina, Montenegro and Serbia and Information system for valuation in Bar, Montenegro. Her domains of interest are Geographic Information Systems, Spatial Data Infrastructures, Service Oriented Architecture, Cadastral Systems, etc.

Aleksandra Radulović (Ph.D) is an Associate Professor at Faculty of Technicial Sciences, University of Novi Sad, Serbia. She has published several papers in ISI journals and conferences. She has also participated in several research projects including GIS (geoportal) for the Ministry of Environmental Protection and Ecology of Serbia, Information system of the real estate cadastre for Republic Geodetic Authority of Republika Srpska, Information system of the real estate cadastre in Montenegro, Information system for user requests submission in the cadastral system in Republic of Serbia, Information system for valuation in Bar, Montenegro and GIS for the city of Novi Pazar. Her domains of interest are Geographic Information Systems, Spatial Data Infrastructures, Service Oriented Architecture, Cadastral Systems, etc.

Ph.D Dušan Jovanović is an Associate Professor at Faculty of Technicial Sciences, University of Novi Sad, Serbia. He received his PhD thesis in Geoinformatics in 2015 at the University of Novi Sad, Faculty of Technical Sciences. He has published several papers in ISI journals and more than 40 papers in international and national journals and conferences. He has also participated in several national and international research projects and projects including processing aerial, satellite and UAV images and LiDAR data, producing digital ortophoto and DTM an implementation of GIS systems in Republic of Srpska in Bosnia and Hertzegovina, Montenegro. His domain of interest are Geographic Information Systems, Photogrammetry, Laser Scanning, Remote Sensing, and implementation of new geoinformatics trends in education. He is a member in OGC and FIG.

Igor Ruskovski (MSc) is a PhD student and a teaching assistant at Faculty of Technical Sciences, University of Novi Sad, Serbia. His main area of interest is laser scanning, where he's participated in several projects that included field work and laser data processing and modeling. He's also teaching following subjects at the FTS: geoinformatics, geography information systems, spatial databases, laser scanning.

Milan Gavrilović, M.Sc. is a Junior Researcher and doctoral student at Faculty of Technical Sciences, University of Novi Sad. He enrolled in 2014 at the Faculty of Technical Sciences in Novi Sad, majoring in geodesy and geomatics and graduated in 2018, and the same year he enrolled master studies. He also defended his master thesis in 2019 at the Faculty of Technical Sciences in Novi Sad. His research interests include remote sensing, geographic information systems and mapping.

Milka Šarkanović Bugarinović (MSc) is a junior researcher at Faculty of Technical Sciences, University of Novi Sad, Serbia and a PhD student in the field of geodesy and geoinformatics. She is actively participating in the teaching process at multiple subjects related to geography information systems. She has also participated in several projects working with big data processing, laser data processing, and utilities cadastre of Republika Srpska.

Miro Govedarica (Ph.D) is a Full Professor at Faculty of Technicial Sciences, University of Novi Sad, Serbia. His practical and theoretical results belong to area of geoinformatics. He was a project leader in several research projects including GIS (geoportal) for the Ministry of Environmental Protection and Ecology of Serbia, Information system of the real estate cadastre for Republic Geodetic Authority of Republika Srpska, Information system of the real estate cadastre in Montenegro and Information system for user requests submission in the cadastral system in Republic of Serbia, Information system for valuation in Bar, Montenegro, GIS for the city of Novi Pazar and GPS permanent stations network in Serbia. He published a number of papers in journals and scientific conferences proceedings related to geoinformatics. Domain of interest include object-oriented software engineering, databases, geospatial databases, development of service-oriented geoinformation systems, photogrammetry, laser scanning, remote sensing, global navigation satellite systems, geoservices, geospatial data infrastructure and geobig data.

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