Formal Semantics in 3D Cadastre

Dubravka Sladić [*], Aleksandra Radulović [*], Miro Govedarica [*]
[*] University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
dudab@uns.ac.rs, sanjica@uns.ac.rs, miro@uns.ac.rs

***Abstract* — The paper presents LADM based Serbian cadastral domain model, as a base application schema for the ontology development. After that, rules for formalizing an application schema in OWL, defined in ISO 19150, have been followed to obtain standard based formal ontology for Serbian cadastral domain model.**

I. Introduction

In the field of geospatial semantic web, a special interest is shown to the formal semantics in the 3D cadastre. This topic is cited as one of the six key research challenges in the 3D cadastre field [1]: "Ontology should be further developed in OWL (or RDF) for 3D land administration based on the foundation of ISO 19152, not only for a 3D cadastre in the narrow sense, but in the sense of the entire chain of activities of 3D (rural or urban) development" and as such presents a wide range of possible solutions (registration of 3D rights, survey and measure spatial units in 3D, data analysis, dissemination, permits in 3D, etc.). Cadastral information system consists of two parts: land register that records legal rights on properties and digital cadastral plan which identifies legal boundaries of cadastral parcels through geodetic survey and produces traditional 2D cadastral maps. With the proliferation of 3D data acquisition technologies, there is an increasing demand also to record the third dimension, hence solve situations of overlapping rights in 3D. Therefore, although 3D cadastre is not officially accepted in Serbia, it is no longer sufficient to view the domain of cadastre through 2D perspective.

More formal semantics is requested within the cadastral domain. Further formalization of the involved information will better support the various steps and enable as much automation as possible based on formal knowledge and reasoning. There are several research questions that need to be answered in this domain including how to implement formal semantics based on a standards for geospatial ontologies (ISO 19150 and GeoSPARQL). Also it might be useful to investigate the use of OWL 2 profiles for modeling ontologies in cadastre, to get formal semantics and support reasoning. Another research question is to assess weather it is useful to use Linked Data principles and publish RDF cadastral data to the LOD cloud [2], that includes spatial data from cadastral maps (cadastral parcels, cadastral municipalities, buildings,…) and legal data about rights, considering the growing number of geospatial data already published.

RDF spatial data is gaining importance and it is proposed that INSPIRE data is encoded in RDF as well [3]. Guidelines for the RDF encoding of spatial data specify an experimental encoding rules for representing spatial data sets in INSPIRE as RDF. In particular, it specifies the rules for converting an INSPIRE application schema to an OWL ontology. The use of RDF is optional and is intended to support the e-government and open data community in Europe, which is increasingly looking at RDF to represent data. Guidelines for the RDF encoding of INSPIRE data also include base ontology of ISO 19150. Examples are given for the Cadastral Parcels data theme, which could be linked to LADM profile.

There are several researches concerning ontologies in 3D cadastre and linked land administration. Ref. [4] describes the ontology for representing roles in land administration systems. A formalized ontology that emphasizes user roles in the land administration may help identify user roles by reasoning on submitted documents / information. Ref. [5] examines the conceptual framework on how to support the semantic representation of LandXML using ontology in the 3D cadastre. In this paper, the 3D ontology for the cadastre is designed to describe the concepts used in the 3D cadastre case study for Singapore. Applying the Linked Data approach, the European Commission established e-Government Core Vocabularies in RDF and the [6] develops a core immovable property vocabulary for European linked land administration. Ref. [7] describes the development of a Knowledge Organization System in terms of a thesaurus for the domain of cadastre and land administration. The main purpose is to contribute towards the development of 'Linked Land Administration' that adopts Linked Data technologies for semantic management of datasets kept in public registries, and scholarly and legislative resources kept in libraries. The thesaurus is mainly derived from terms of the standard ISO 19152. The domain ontology for the cadastre based on upper ontologies was proposed in [8]. The approach based on semantic annotations of cadastral data and services has been proposed in [9]. This forms a two-layered environment, consisting of a data layer and a layer of knowledge. The data layer stores geodetic and legal data, while the layer of knowledge stores ontological knowledge that emphasizes the semantic aspect of the cadastre. A more recent work proposes the use of semantic tools in code lists management [10]. In contrast, this research is based on Serbian cadastral domain model and follows the rules specified in ISO 19150, with the main purpose to publish cadastral data in RDF.

Serbian cadastral domain model as the country profile for the real estate cadastre, based on the Land Administration Domain Model (LADM), defined within ISO 19152 was proposed in [11]. All UML conceptual models based on ISO 19100 series of standards follow the rules for application schemas defined in ISO 19109 [12]. Therefore, the actual use of the LADM also implies that an application schema, such as a country profile, should be developed. Rules for formalizing an application schema in OWL defined in ISO 19150 [13], were used to develop ontology.

The paper is structured as follows. The next Section shortly presents Serbian cadastral domain model (LADM country profile). After that, in Section 3, rules for formalizing an application schema in OWL have been followed to obtain an ontological model. GeoSPARQL was used to ensure required relationships specified in LADM (and LADM country profile) [14]. The Section 4 presents an overview of cadastral Linked Data. Conclusions are given afterwards.

II. Serbian Cadastral Domain Model

Serbian cadastral domain model as the country profile for the real estate cadastre, based on the Land Administration Domain Model (LADM), defined within ISO 19152 [15].

Since the data of cadastral records are of great importance for the economic development of the country, they must be well structured and organized. Cadastral records in Serbia met numerous problems in past several years. In order to avoid existing problems in 2D cadastre as well as to introduce the possibility of including 3D objects, it is necessary to create a domain model according to current standards and national legislation. Profile for cadastral records in Serbia is based on the international standard ISO 19152 – Land Administration Domain Model (LADM). LADM describes basic cadastral concepts including spatial units and their geometric representations, as well as rights, restrictions and responsibilities that certain parties have over them.

Fig. 1 shows spatial unit package. Class RS_SpatialUnit indicates all types of real properties. Specializations of this class are classes RS_Parcel that represent parcel, RS_PartOfParcel that represent part of parcel with same way of use (field, pasture,forest…), RS_Building that represent building located on one part of the parcel and RS_LegalSpaceBuildingUnit with its specialization RS_PartOfBuilding that represent apartments or business offices. Attributes and code lists are added according to rulebook on real estate cadastre in Serbia. Another class is RS_RequiredRelationshipSpatialUnit which serves to indicate some special spatial relation between two spatial units. Topological relationships between spatial units can be verified by implementing operation of ISO 10125-2 standard (i.e. operation ST_Within to provide that building is located within the parcel).

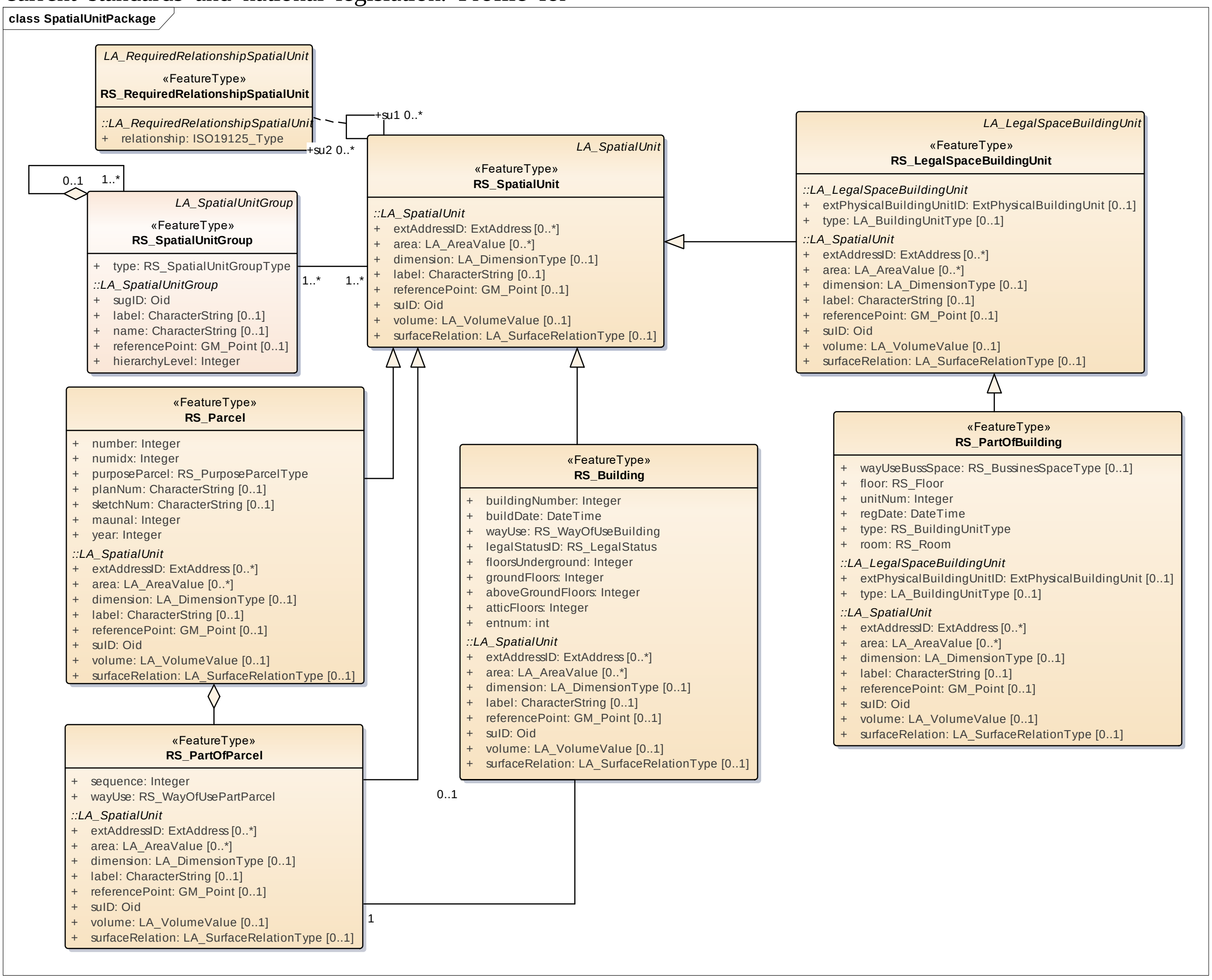

Figure 1. Spatial unit package of the Serbian profile

Fig. 2. shows the surveying and representation subpackage. Classes of this subpackage are RS_Point, RS_SpatialSource and RS_BoundaryFaceString. In the cadastral survey procedure, geodetic measurement of real property is carried out according to the actual situation in the field and points of measured locations are stored (RS_Point). The individual points or complete spatial units are asociated to RS_SpatialSource class which

represent a spatial source. A survey is documented with spatial sources. Spatial profile for Serbia is 2D topological so the class RS_BoundaryFaceString with GM_MultiCurve type is used for geometries. LADM has additional class LA_BoundaryFace for representing legal spaces of 3D spatial units (Fig. 3). In order to expand Serbian cadastre with 3D legal spaces in future, additional class RS_BoundaryFace may be introduced.

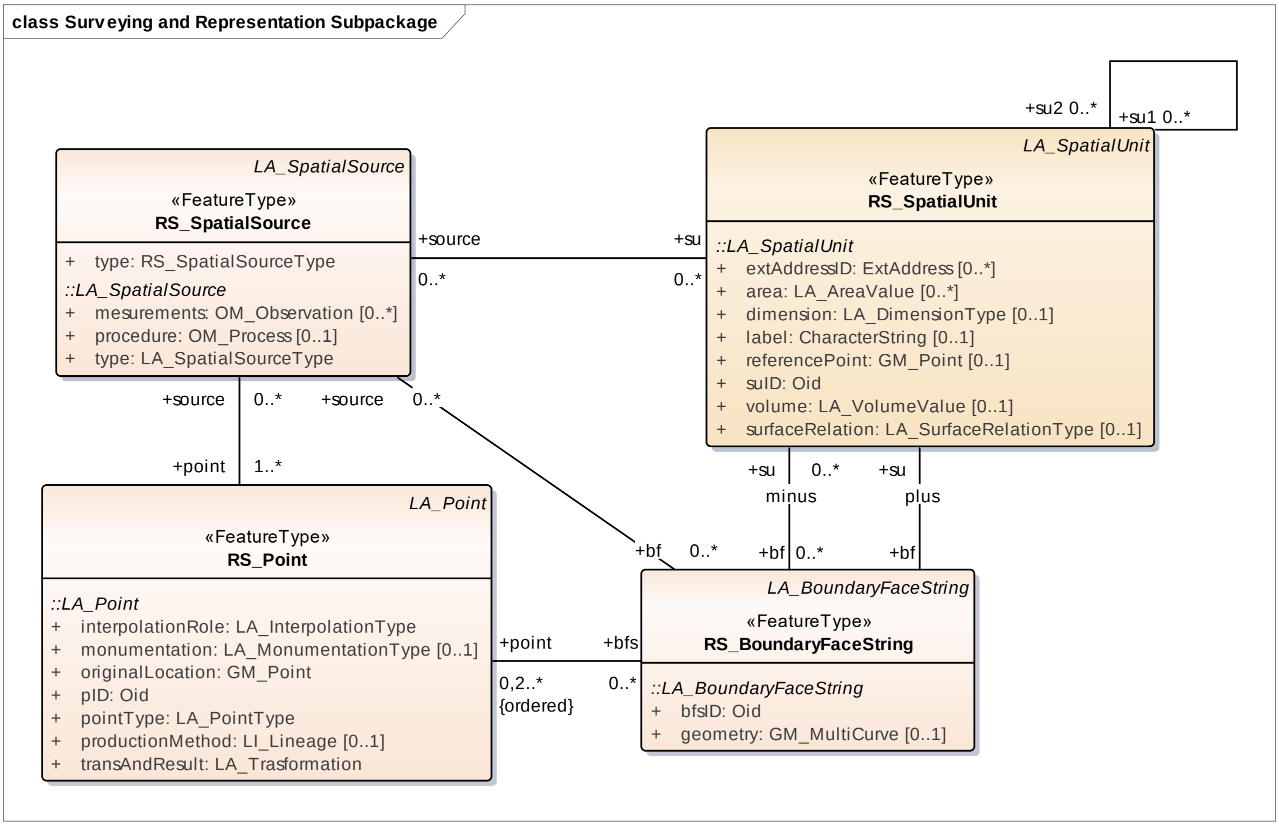

Figure 2. Surveying and Representation Sub-packages of the Serbian profile

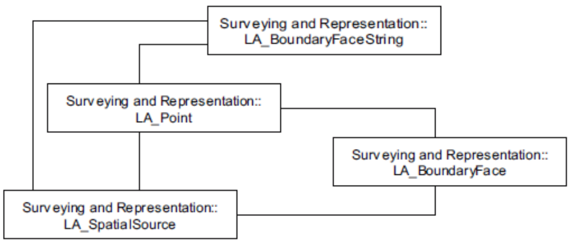

Figure 3. LADM LA_BoundaryFace for 3D spatial units

III. FORMALIZING SERBIAN CADASTRAL DOMAIN MODEL IN OWL ACCORDING TO ISO 19150

ISO 19150-2 defines rules and guidelines for the development of ontology to support better mutual use of geographic information on the semantic web. It defines the conversion of UML static modeling elements used in ISO 19100 standards in OWL. It then defines the conversion rules for describing the application schemes based on the general model of spatial objects defined in ISO 19109 within the OWL framework. UML application schema that has been shown in previous Section is translated into OWL according to the guidelines given in this standard. The application schema has been converted manually using Protege. However, the use of tools such as ShapeChange, that enable automatic conversion of UML application schema in Enterprise Architect to GML application schema, but also to OWL, should be further analyzed. The part of the resulting OWL class hierarchy has been shown on Fig. 4.

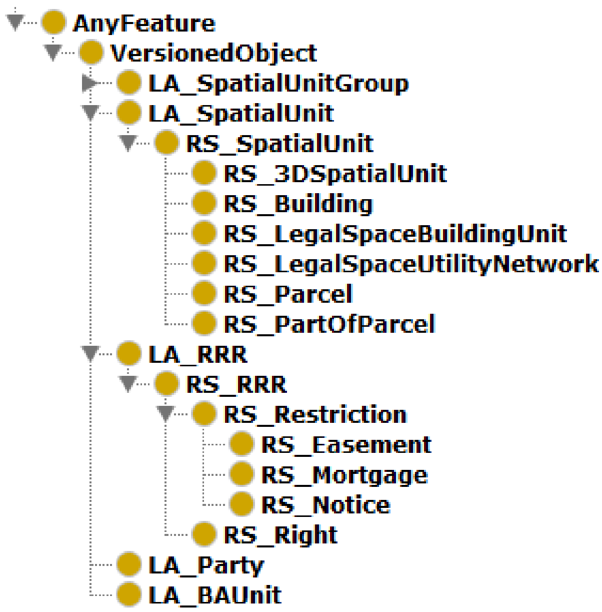

Figure 4. OWL class hierarchy

According to ISO 19109, a FeatureType is defined as an abstraction of real world phenomena. A feature type is represented by a UML class having the stereotype <<FeatureType>>. ISO 19150 specifies the rules for FeatureType as following: “To support the implementation of feature type in OWL, the ontology corresponding to ISO 19109 introduces a Class <OWL> AnyFeature, which is the most generic feature type. In OWL, a feature type corresponds to a Class<OWL> using an owl:Class declaration”. The corresponding application schema ontology is shown in Listing 1 and Listing 2. Listing 2 shows OWL class RS_Parcel.

```
<rdf:RDF
xmlns="http://geoinformatika.uns.ac.rs/Par
cels#"
xml:base="http://geoinformatika.uns.ac.rs
/parcele"
xmlns:rs="http://geoinformatika.uns.ac.rs
/parcel#"
xmlns:owl="http://www.w3.org/2002/07/owl#"
xmlns:rdf="http://www.w3.org/1999/02/22-
rdf-syntax-ns#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-
schema#"
xmlns:xsd="http://www.w3.org/2001/01/XMLSc
hema#"
xmlns:skos="http://www.w3.org/2004/02/skos
/core#"
xmlns:dc="http://purl.org/dc/elements/1.1/
#"
xmlns:iso19150-
2="http://def.isotc211.org/iso19150-
2/2012/base#"
xmlns:GM_Primitive="http://def.isotc211.or
g/iso19107/2003/GeometricPrimitive#"
xmlns:gfm="http://def.isotc211.org/iso1910
9/2013/GeneralFeatureModel#">

<owl:Ontology
rdf:about="http://geoinformatika.uns.ac.rs
/Parcele">
 <rdfs:label>Example</rdfs:label>
 <owl:versionInfo>v1.1</owl:versionInfo>

<owl:versionURI>http://geoinformatika.uns.
ac.rs/2017/Parcels</owl:versionURI>
 <owl:imports
rdf:resource="http://def.isotc211.org/iso1
9150-2/2012/base"/>
 <owl:imports
rdf:resource="http://def.isotc211.org/iso1
9107/2003/GeometricPrimitive"/>
 <owl:imports
rdf:resource="http://def.isotc211.org/iso1
9109/2013/GeneralFeatureModel"/>
</owl:Ontology>
…
```

Listing 1. Application schema ontology

Querying through SPARQL endpoints that support GeoSPARQL may be used to determine required relationships specified in the class RS_RequiredRelationshipSpatialUnit specified in the country profile. The three basic classes in GeoSPARQL ontology include (Fig. 5):

```
<owl:Class rdf:about="&rs;RS_Parcel">
  <rdfs:label>Parcel</rdfs:label>
  <rdfs:subClassOf rdf:resource="&rs;
RS_SpatialUnit"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty
rdf:resource="&rs;number"/>
        <owl:allValuesFrom
rdf:resource="&xsd;integer"/>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty
rdf:resource="&rs;numidx"/>
        <owl:allValuesFrom
rdf:resource="&xsd;integer"/>
    </owl:Restriction>
  </rdfs:subClassOf>
   <rdfs:subClassOf>
     <owl:Restriction>
       <owl:onProperty
rdf:resource="&rs;manual"/>
         <owl:allValuesFrom
rdf:resource="&xsd;integer"/>
     </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty
rdf:resource="&rs;purposeParcel"/>
        <owl:allValuesFrom
rdf:resource="&RS_PurposeParcelType"/>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty
rdf:resource="&rs;partOfParcels"/>
        <owl:allValuesFrom rdf:resource="&
rs;RS_PartOfParcel"/>
    </owl:Restriction>
  </rdfs:subClassOf>
<rdfs:isDefinedBy>http://standards.iso.org
/iso/19109/ed-2/en</rdfs:isDefinedBy>
</owl:Class>
```

Listing 2. OWL class RS_Parcel

- geo:Feature – This class represents a feature that can have a spatial location, for example, a park, a monument, etc.
- geo:Geometry – This class represents a representation of a spatial location, or its coordinates.
- geo:SpatialObject – This class is super class of geo: Feature and Geo: Geometry.

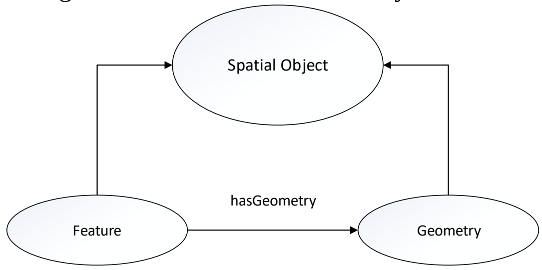

Figure 5. Basic GeoSPARQL classes

The relation: hasGeometry connects a feature with its geometries (locations). By separating features from their locations, GeoSPARQL allows more geometric representations to be linked to a single feature for different purposes (for example, a settlement can be represented by a point or a polygon, a river can be represented by a line or polygon). Then, each geometry has its own RDF literal representation, which is associated to the corresponding type of representation.

Feature-to-feature relations allow the examination of topological relationships between geo-objects as in the following example. The query "which buildings are inside of a Parcel1" can be written as follows:

```
PREFIX rs:
<http://geoinformatika.uns.ac.rs
/ApplicationSchema#>
PREFIX geo:
<http://www.opengis.net/ont/geosparql#>
PREFIX geof:
<http://www.opengis.net/def/function/geosp
arql/>

SELECT ?f
WHERE {
rs:Parcel1 geof:sfWithin ?g1.
?f a rec:Building.
}
```

Listing 3. GeoSPARQL query

According to INSPIRE, a spatial object is an rdfs:subClassOf the GeoSPARQL class "Feature". A spatial object in ISNPIRE is synonymous with geographic feature in the ISO 19100 series. This alignment supports querying of INSPIRE spatial objects encoded in RDF at SPARQL endpoints that support GeoSPARQL. Similarly, the OWL class “AnyFeature” that subsumes all feature types should also be a subclass of the GeoSPARQL class "Feature" and a relation between INSPIRE spatial objects such as cp:CadastralParcel and gfm:AnyFeature can be established.

IV. CADASTRAL LINKED DATA

The Semantic Web is usually called a Web of Data and contains various kind of data. The Semantic Web technologies such as RDF, OWL, SKOS, SPARQL, etc. provides an environment where application can query that data, make inferences using vocabularies, etc. However, to make it a reality, it is important to have the huge amount of data on the Web available in a standard format, reachable and manageable by Semantic Web tools. Not only the Semantic Web needs access to data, but relationships among data should be established, as opposed to unrelated collections of datasets that is the usual case. This collection of interrelated datasets on the Web is often referred to as Linked Data. To achieve and create Linked Data, technologies should be available for a common format, RDF, to make either conversion or on-the-fly access to existing databases (relational, XML, HTML, etc.). Query endpoints have to be set up to access that data more conveniently. A set of Semantic Web technologies are provided to get access to the data [16].

RDF can be used to publish and interlink data on the Web. For example, retrieving http://www.geoinformatika.uns.ac.rs/parcel#parcel132 could provide data about a particular parcel, including the fact that it is related to the building, as identified by its URI. Retrieving building’s URI could then provide more data about it, including links to other datasets such as the architect that designed it, its cultural value, tourist attraction, urban zone it belongs to, its 3D models, etc. A person or an automated process can then follow those links and aggregate data about these various things. Such uses of RDF are considered as Linked Data. The e-government applications and tools started to use the Linked Data paradigm based on Semantic Web languages and technologies. If data was available as Linked Data, these e-government applications and tools could then easily link to it.

Since traditional cadastral information systems contain large amount of data stored mainly in relational databases, and given the changing nature of the data, it is not convenient to export all the data in RDF, so it is necessary to investigate possibilities of querying and retrieving only required data or to create mappings from the relational databases to RDF. Cadastral information systems also utilize Web services to integrate with the information systems of other organizations (banks, Ministry of internal affairs, Ministry of finances - tax administration, business registry agencies, etc.) that use cadastral data, as well as for the work of the eGoverment portal through which online services to clients are executed. Geoportal is established and maintained by the mapping agencies as part of the Spatial Data Infrastructure and provides view of layers of spatial data, including cadastral parcels and buildings. Therefore, geospatial web services must also be considered.

In the end, it may be proved useful to link cadastral data sets with data sets of other LOD cloud data as well as their publication to the LOD cloud, considering the fact that there are growing number of geographic datasets already published. Considering that cadastral data sets are very large and often changing, the use of web services is justified for accessing data and setting up a SPARQL Protocol service that would send HTTP responses to an HTTP request in the RDF format (the so-called SPARQL endpoint).

V. CONCLUSION

The paper presents LADM based Serbian cadastral domain model (LADM country profile), as a base application schema for the ontology development and how the rules for formalizing an application schema in OWL were followed to obtain standard based formal ontology for Serbian cadastral domain model. It also assesses the broader use of RDF to achieve web based integration through Linked Data. A future work might consider linking cadastral datasets with other LOD cloud datasets, considering the growing number of geospatial datasets already published. Also, the mapping and alignment with INSPIRE RDF encoding of spatial data should be considered.

ACKNOWLEDGMENT

Results presented in this paper are part of the research conducted within the Grant No. 37017, Ministry of Science and Technological Development of the Republic of Serbia.

REFERENCES

[1] P. van Oosterom, Research and development in 3D cadastres. Computers, Environment and Urban Systems, vol. 40, 2013, pp. 1-6.

[2] The Linking Open Data cloud diagram, available at: http://lod-cloud.net/, (accessed on 18 April 2018).

[3] Guidelines for the RDF encoding of spatial data, http://inspire-eu-rdf.github.io/inspire-rdf-guidelines/(accessed on 18 April 2018).

[4] K. H. Soon, Representing Roles in Formalizing Domain Ontology for Land Administration, 5th Land Administration Domain Model Workshop, Kuala Lumpur, Malaysia, 2013, pp. 203-222.

[5] K. H. Soon, A Conceptual Framework of Representing Semantics for 3D Cadastre in Singapore. 3rd International Workshop on 3D Cadastres, Shenzhen, China, 2012, pp. 361-380.

[6] V. Çağdaş, E. Stubkjær, Core immovable property vocabulary for European linked land administration, Survey Review, 2014, pp. 49-60.

[7] V. Çağdaş, E. Stubkjær, A SKOS vocabulary for Linked Land Administration: Cadastre and Land Administration Thesaurus¸, Land Use Policy, vol. 49, 2015, pp. 668-679.

[8] D. Sladić, M. Govedarica, Đ. Pržulj, A. Radulović, D. Jovanović, Ontology for Real Estate Cadastre. Survey Review, vol. 45, no. 332, 2013, pp. 357-371.

[9] D. Sladić, A. Radulović, M. Govedarica, D. Jovanović, Đ. Pržulj, The Use of Ontologies in Cadastral Systems. Computer Science and Information Sistems (ComSIS), vol. 12, no. 3, 2015, pp. 1033-1053.

[10] E. Stubkjær, J. M. Paasch, V. Çağdaş, P. van Oosterom, S. Simmons, J. Paulsson, C. Lemmen, International Code List Management – The Case of Land Administration, 7th International FIG Workshop on the Land Administration Domain Model, 2018, pp. 223-244.

[11] A. Radulović, D. Sladić, M. Govedarica., Towards 3D Cadastre in Serbia: Development of Serbian Cadastral Domain Model. ISPRS International Journal of Geo-Information, vol. 6 (10), 312, 2017, pp. 1-21.

[12] ISO 19109:2015 Geographic information -- Rules for application schema, https://www.iso.org/standard/59193.html, (accessed on 18 April 2018).

[13] SRPS ISO 19150-2:2017, Geographic information -- Ontology Rules for developing ontologies in the Web Ontology Language (OWL), http://www.iss.rs/rs/standard/?natstandard_document_id=56136, (accessed on 18 April 2018).

[14] GeoSPARQL - A Geographic Query Language for RDF Data, http://www.opengeospatial.org/standards/geosparql, (accessed on 18 April 2018).

[15] ISO 19152:2012, Geographic information -- Land Administration Domain Model (LADM), https://www.iso.org/standard/51206.html, (accessed on 18 April 2018).

[16] Linked Data, https://www.w3.org/standards/semanticweb/data, (accessed on 18 April 2018).