NUTS GEO-ONTOLOGY

Otakar Cerba

Assoc. prof. Otakar Cerba, PhD
University of West Bohemia
Technicka 8, 301 00 Plzen, Czech Republic
+420 37763 9206, cerba@kgm.zcu.cz

Abstract
Nomenclature of Territorial Units for Statistics (NUTS) is a European standard for referencing the subdivisions of countries for statistical and data science purposes. There are three NUTS levels for each country. The lowest NUTS level (NUTS 3) is divided into Local Administrative Units (LAU; LAU 1 and LAU 2). The current NUTS classification (2016) contains 104 regions at NUTS 1, 281 regions at NUTS 2, 1 348 regions at NUTS 3 level and 99 787 LAUs. The structure of NUTS and LAU comprises the hierarchical tree structure. Therefore an ontological description of NUTS is a legitimate question for a better implementation of NUTS to any knowledge systems and bases dealing with geographic data and information. There are several pieces of data storing NUTS as RDF (Resource Description Framework) triples, which enable efficient modelling of the regular tree hierarchy. This contribution presents a proposal for a complex ontological system of NUTS. The NUTS Geo-Ontology provides not only the simple structure of NUTS, but it uses the Description Logic for modelling of mutual relations among particular NUTS classes and individuals. Just the implementation of Description Logic as the main logical background of modern ontologies is the primary goal of our research. Also, the implementation of relations is challenging. Except for traditional generalization and specialization, there are topological and mereological relations. Such defined ontology enables a more semantically detailed description of concepts as well as more efficient control of data reliability and correctness for purposes of the geographical domain, including geographical information systems and cartography. The NUTS ontology uses logical axioms also for a derivation of new relations, which are not explicitly coded in the original ontology.

Keywords: *Ontology, geo-ontology, NUTS, topology, mereology.*

INTRODUCTION

Nomenclature of Territorial Units for Statistics (NUTS) is a European standard for referencing the subdivisions of countries for statistical and data science purposes. There are three NUTS levels for each country. The lowest NUTS level (NUTS 3) is divided into Local Administrative Units (LAU; LAU 1 and LAU 2). The current NUTS classification (2018) contains 104 regions at NUTS 1, 281 regions at NUTS 2, 1 348 regions at NUTS 3 level and 99 787 LAUs. Eurostat designed NUTS as well as LAUs (as former NUTS 4 a NUTS 5) as a complex system of territories for providing comparable statistics. The processes of the development of NUTS started at the 1970s. Now users can work with the version 2016, but the NUTS 2021 is in progress.

The structure of NUTS and LAU comprises the hierarchical tree structure. Therefore an ontological description of NUTS is a legitimate question for a better implementation of NUTS to any knowledge systems and bases dealing with geographic data and information. The nature of NUTS emphasizes this fact. NUTS are vehicles for statistical data and information; therefore, they are crucial components of many databases and knowledge bases. Advanced ontological description of NUTS supports sharing and interconnecting of such databases and knowledge bases. It improves communication and limits misinterpretation as well.

The goal of this contribution is to present the draft of a complex ontological structure describing NUTS. The geo-ontology follows similar products – ontologies and linked data containing NUTS. These tools use RDF (Resource Description Framework) triples for NUTS data storing because they enable efficient modelling of the regular tree hierarchy. The presented geo-ontology combines traditional ontological approach based on classes, semantics attributes and linking relations with geographical approach (topology). The NUTS Geo-Ontology provides not only the simple structure of NUTS, but it uses the Description Logic for modelling of relations among particular NUTS classes and individuals. Just the implementation of Description Logic as the main logical background of modern ontologies is the primary goal of our research. Also, the implementation of relations is challenging. Except for traditional generalization and specialization, there are topological and mereological relations. Such defined ontology enables a more semantically detailed description of concepts as well as more efficient control of data reliability and correctness for purposes of the geographical domain, including geographical information systems and cartography. The opportunity of the derivation of many non-explicitly coded properties is the main benefit of the approach based on the elaborate description with logical axioms.

The article is structured as follows. After the introduction characterizing the initial problem, the Research part describes the essential terms of the article (NUTS, ontologies). This section provides a short overview of existing data product, which use ontologies or linked data (RDF triples) for storing information about NUTS. Then short Methodology sections present a summary of methodologies for building ontologies as well. The Results part shows the detail description of proposed geo-ontology. After that, future steps and an overlapping to other knowledge bases are discussed.

RESEARCH

The article works with specific terms (NUTS, LAU, ontology and geo-ontology), which are defined at the beginning of the Methodology section. After that remaining parts describing existing ontologies and other semantic products dealing with NUTS and a summary of methodologies for the development of geo-ontologies follow.

Nomenclature of Territorial Units for Statistics or NUTS is a geocode standard used for referencing the subdivisions of countries [1]. Eurostat developed this system primarily for statistical purposes, but the European Union’s Structural Funds and Cohesion Fund uses NUTS as delivery and locating mechanisms. The regions are divided into four levels of NUTS and two levels of LAU (Local Administrative Units; formerly known as NUTS 4 and NUTS 5). The particular countries are represented by NUTS 0. LAU 2 is the most detail feature of the NUTS system. It corresponds to municipalities. The following table (Table 1) show the NUTS levels and number of respective regions (information adopted from NUTS 2016 version effective from 1 January 2018, [2]). Territories were classified based on governing principle, but they are also limited by population (for example NUTS 1 region should have between 3 and 7 millions people). The NUTS structure covers not the area of the European Union, but also countries of EFTA and associated countries such as Turkey or Albania. Publications [3-5] provides more information about NUTS.

Table 1. NUTS units overview.

Level	**Code example**	**Description**	**Number of areas**
NUTS 0	CZ	Country	28
NUTS 1	CZ0	Major socio-economic regions	104
NUTS 2	CZ01	Basic regions for the application of regional policies	281
NUTS 3	CZ011	Small regions for specific diagnoses	1 348
LAU 1	CZ0641	Upper local administrative units	8 695
LAU 2	CZ554499	Municipality	162 386

The ontologies (in the meaning of information technologies, not as the discipline of philosophy) represents the advanced communication tools using principles of description logic and pieces of markup languages and general modelling of resources. Changes of views on ontologies are evident from the development of definitions of ontologies [6-9]. Ontologies represent compelling tools enabling the transformation of standard information to a formal and formalized structure. The understanding of ontologies is significant from the perspective of implementation of participation and involvement of various experts, stakeholders and public.

There are only a few publications focused on geo-ontologies (ontologies in spatial data and information domain, ontologies of geographical objects). Geo-ontologies can be described as an ontology dealing with “the totality of geospatial concepts, categories, relations, and processes and with their interrelations at different resolutions” [10]. Their specifics (e.g. the relation of objects to the Earth surface, a considerable share of A Box structure coming from the traditional GIS /Geographic Information System/ approach, semantics, which is implicit and evident at the instance level, the necessity of maintaining the logical as well as spatial integrity) are mentioned in publications [11-15]. According to [16], this specific type of ontology an essential tool from the perspective of the semantics of seemingly clear and unambiguous geographic data and information. Such description using an explicit semantics improves the understanding of particular structures of the geographic world as well as the world as the whole among different subjects (cultures, languages, nations, social groups, professional groups and others). This attribute is essential from the view of geographic data and manipulation, sharing, changing and interconnecting.

The development of NUTS Geo-Ontology has to follow existing semantic products describing NUTS units. There is a lack of ontologies containing data or information about NUTS. However, NUTS are in many cases published as Linked Data. The form of linked data is very similar to ontologies because both products use RDF triples of a description of any feature. Therefore NUTS as linked data could be used as inspiration for the development of an ontology, as well as linked data, could be a content of the ontology. The following list shows the example of NUTS presented as linked data.

- Linked Open Data by Eurostat are accessible through SPARQL endpoint. It is a standard interface enabling entering the query and retrieving data. However, there is missing detail information about data and its structure. Also, the link to Base-URI for the NUTS classification is broken.

- Linked Open Data by Eurostat are interconnected with the EU Open Data Portal, which provides data about NUTS. It is possible to download data in five formats (SHP, SVG, GDB, GeoJSON and TopoJSON). However, the data is provided as traditional spatial data without any semantic information.

- NUTS RDF is the transformation of NUTS data to RDF format published on geovocab.org. There are links to various NUTS level. These links go to tables with particular objects (for example CZ). Users can download data, including geometry in various formats (GML, KML, HTML and two serializations of RDF). Data contains only codes and names of particular units. There are also topological relations and identical relations (owl:sameAs). The same relations link particular NUTS object with an equivalent object in other datasets (but during the testing the majority of links were broken).

- The Open Data Portal Germany (OPAL) project provides data in OWL format. The current version (0.3.0) contains classes for particular NUTS and LAUs levels. There are two object relations – has broader, has related match. They correspond with similar properties used in the SKOS standard. The ontology does not contain any individuals yet.

- The Ministry of Housing, Communities and Local Government of United Kingdom publishes data about NUTS without geometry and any additional attributes for the territory of the United Kingdom of Great Britain and Northern Ireland. Data is available as RDF triples (N-triples). The similar data is offered by the British Office for National Statistics (this dataset is more vibrant from the perspective of attributes). Those are examples of NUTS presentation on the national level.

- Other datasets providing NUTS as RDF triples are mentioned in [4].

METHODOLOGY

During the last thirty years, many various methodologies for the development of ontologies were created. The article [16] mentioned eight methodologies which can be re-used for building geo-ontologies – TOVE, Enterprise Model Approach, METHONTOLOGY, Methodology published by Bernaras et al., On-To-Knowledge Methodology, DOLCE, Ontology Development 101 and UPON. The selection of this methodologies follows many research studies [17-21]. All methodologies have a one common characteristics – they deal with a participatory phase. It enables the participation of a larger group of co-creators. Co-creation process is crucial for geo-ontologies because this type of ontologies is usually cross-domain and requires the engagement of many experts from various domains. The same methodologies could be used for development geo-ontologies as well because there are not specific and intricate methodologies for the construction of geo-ontologies. The development process of NUTS Geo-Ontology uses components of methodologies mentioned-above.

The methodology used for the construction of NUTS Geo-Ontology includes the following steps. Above all, the first three items are fundamental from the perspective of design and further development of the ontology. Existing outputs of these three steps are presented in the Results section of the article.

1. Specification

2. Initial ontology development

3. Ontology refinement and structuring
4. Ontology maintenance
5. Ontology implementation
6. Ontology evaluation
7. Documentation

Ad 1. The NUTS Geo-ontology provides spatial information about NUTS regions (as the fundamental statistical unit) in Europe. The content of the ontology includes necessary identification information about NUTS (official NUTS codes) and a set of object relation interconnecting particular NUTS. These object properties describe topology and mereology (whole-part relation) semantically. The ontology will re-use existing vocabularies and other ontologies (such as GeoSPARQL) as much as possible. The purpose of the developed ontology is to serve as fundamental knowledge bases for thematic statistical application and services as well as for all tools and products dealing with NUTS. The primary value added to similar existing products (mentioned in the Research part) consists of the implementation of Description Logic for the description of NUTS. It enables automatic control of ontology consistency and correctness of information during ontology update and maintenance as well as the automatic derivation of new pieces of information which are not coded in the original ontology.

Ad 2. The initial ontology is composed of two main classes (*Country* and *StatisticalUnit*) and object relations. The *StatisticalUnit* class contains four sub-classes: *NUTS0*, *NUTS1*, *NUTS2* and *NUTS3*. The *StatisticalUnit* class is limited by the covering axiom (Stevens 2011) – *StatisticalUnit is SubClass Of NUTS0 or NUTS1 or NUTS2 or NUTS3*. All sub-classes of *StatisticalUnit* class are disjointed. The object relations are divided into three groups: *mereologicalProperty* (relations following RCC8 /Regional Connection Calculus/ approach; [22, 23], *mereologicalProperty* (*hasPart* and *isPartOf*) and *semanticProperty* (*neighbourhood*). All object properties have the same domain and range – *owl:Thing* (the root element of the ontology). The mutual relations among particular types of relations are explained in the following section of this paper. The logical rules and axioms have been tested of the sample of individuals (countries Austria, Czech Republic, Slovakia, Slovenia and Luxembourg and NUTS 1 units in these states).

Ad 3. The ontology can derive new information based on existing information and logical rules. The class *Country* and the majority of topological relations between particular individuals (NUTS units) are the explicit input of the ontology. Reasoner derives other information (for example classification of individuals or mereological relation or defined classes). The NUTS Geo-Ontology is developed in the Protégé software [24, 25], version 5.5.0. Therefore the in-built reasoners (above all FaCT++ 1.6.5) are used. The examples of logical rules and inferred information are described in the next section of this contribution.

RESULTS

This section contains a set of logical statements, which play a crucial role in the development of NUTS Geo-Ontology. These statements have been transformed into the logical rules in the ontology. They guaranteed the consistency of the ontology as well as they enable derivation processes mentioned above in this article. The rules follow the nature of NUTS and implemented types of relations.

The logical statements are described by following symbols:

- X – class (because of compression of long labels of classes, the acronyms are used: *C – Country*, *SU – StatisticalUnit*, *N0-N3 – NUTS0-NUTS3*)
- $X(a)$ – instance of the class, for example $C(AT)$
- $R(a, b)$ – relation between two instances
- $\equiv$ – equivalence
- $\sqsubseteq$ – inclusion
- $\sqcap$ – intersection (and)
- $\sqcup$ – union (or)

- $\bot$ – empty concept (without instances)

The first four axioms concern classes of the NUTS Geo-Ontology and their hierarchy.

1. $N0 \sqsubseteq SU$ (the same relation is true for *N1*, *N2* and *N3*) – classes representing of particular NUTS level are sub-classes of the general statistical unit.

2. $SU \sqsubseteq N0 \sqcup N1 \sqcup N2 \sqcup N3$ (closure axiom) – the general statistical unit (in the perspective of NUTS Geo-Ontology) is composed only from classes of particular NUTS levels.

3. $N0 \sqcap N1 \sqcap N2 \sqcap N3 \sqsubseteq \bot$ (disjoint classes) – classes representing of particular NUTS level do not have any collective element (intersection). **Each NUTS unit has to be a part of exactly one NUTS level.**

4. $N0 \equiv C$ – NUTS 0 corresponds to countries, therefore **classes *Country* and *N0* have to be identical**. After reasoning, the instances of *Country* class belong to the *N0* class.

The ontology contains object properties limited by the following characteristics. These restriction are partially based on GeoSPARQL standard [26] and mereotopology rules [27, 28].

5. The ontology contains all RCC8 relations except PO (partially overlapping). **The nature of NUTS (tree structure of disjointed areas) does not allow any overlappings between particular regions.**

6. Inverse relations – $R(a,b) \Rightarrow Ri(b,a)$ – following couples of object relation are inverse: *hasPart* – *isPartOf*, *NTPP* (non-tangential proper part) – *NTPPi*, *TPP* (tangential proper part) – *TPPi*.

7. Symmetric relations – $R(a,b) \Rightarrow R(b,a)$ – the ontology contains these symmetric relations: *neighbourhood*, *EC* (externally connected).

8. Functional relations – $R(a,b) \wedge R(a,c) \Rightarrow b = c$ – the mereological relation *isPartOf* is functional. This statement ensures the basic tree structure of NUTS, because **each NUTS unit (except NUTS 0) is part of one NUTS region of the closest higher level**.

The next logical statements enable to derive object relations from existing and explicitly entered topological properties.

9. $EC(a,b) \vee NTPP(a,b) \Rightarrow neighbourhood(a,b)$ – **External connection or non-tangential proper part mean neighbourhood**. If two NUTS entities are interconnected via *EC* or *NTPP* object properties, it is possible to name such relation as neighbourhood and classify it as semantic property. Such name is more comprehensible for users without any experience with topology. In the ontology, this statement is realized through *SuperProperty Of (Chain)* operation.

10. $TPP(a,b) \vee NTPP(a,b) \vee EQ(a,b) \Rightarrow isPartOf(a,b)$ – Similarly to previous point it is possible to infer the mereological property *isPartOf* from topological relations. To be able to generate the essential mereological relation *isPartOf* from topological properties (in case of NUTS) it is necessary to implement a small trick. The *EQ* (equivalence) is originally the symmetric property. However, because of *isPartOf* is not symmetric relation, the equivalence has to be described by two "one-way" additional inverse relations *EQ* and *EQi*. It holds that $EQ(a,b) \Rightarrow EQi(b,a)$. Now it is possible to define that **if one NUTS unit is a proper-part of other NUTS unit or both units are topologically identical, they are also interconnected by mereological relations** (there are restrictions for the installation of topological relations, which limits using *TPP*, *NTPP* and *EQ* properties for NUTS classes).

11. $EC(a,b) \wedge EQi(b,c) \Rightarrow EC(a,c)$ – **If two NUTS units are identical (from the topological view) and one of them is interconnected with any other NUTS element via *EC* relation, then this element is connected by *EC* relation with second equivalent entity**. There is the important condition (explained in following rules): *a* and *b* are instances of the next higher NUTS level than *c*, for example, $N0(a), N0(b), N1(c)$.

12. $EC(a,b) \wedge TPPi(b,c) \Rightarrow EC(a,c)$ – this is the paraphrase of previous statement applied to *TPP* property.

The following restrictions define the behaviour of particular classes (NUTS levels) and their instances.

13. **Each element of NUTS 1, NUTS 2 and NUTS 3 has to be linked to just one region of the next higher NUTS level** (for example $isPartOf(N1(a), N0(b))$). This fact is guaranteed by the functional character of *isPartOf* property and closure axiom [29].

14. From the previous rule there is derived other restriction – **Each element of NUTS 0, NUTS 1 and NUTS 3 has to be connected to at least one region of the next lower NUTS level**.

15. **Two elements on the same NUTS level have to be interconnected by a following mutual topological relation: *EC*, *NTPP*, *DC*** (disconnected; this relation holds for all other cases; therefore it is not modelled in the ontology).

16. Two elements on the same NUTS level must not be interconnected by a mereological property as well as by topological equivalence.

The previous logical rules are implemented in the code of the NUTS Geo-Ontology. The ontology uses the OWL 2 (Web Ontology Language; [30]). The main benefit of proposed ontology is the ration between explicitly entered information and derived information. For example, the asserted (original) ontology provides only one information about the individual *AT* (represented Austria): *AT* belongs to *Country* class. All other 37 pieces of information are derived during the reasoning process.

DISCUSSION

The current version of the NUTS Geo-Ontology represents a prototype for further testing, optimization and improvements. For next months there are planned following steps:

- Implementation of defined classes or relations such as *BorderRegion* class.
- Completing of logical rules and restrictions for NUTS 2 and NUTS 3 regions. It is connected with the implementation of transitive relations to enable inheritance of object properties.
- Populating of the ontology – sequential adding of new instances.
- Interconnection of the ontology with other semantic tools and Linked Data resources through identity relations. This step concerns not only classes or instances but also relation. Authors of the NUTS Geo-Ontology have in mind a re-using of topological relations as they are defined in the GeoSPARQL standard [26].

The NUTS Geo-Ontology will be implemented for other solutions. There are suggestions to use the ontology as the fundamental framework for the assessment of regional attractivity. The NUTS Geo-Ontology can be used on a national level as well (for example, in the Czech Republic it can be interconnected with National Set of Spatial Objects – NaSaPO).

CONCLUSIONS

The main goal of this contribution was to presents a proposal of NUTS Geo-Ontology. This knowledgebase store essential data about NUTS units, including topological, mereological and semantic relation. Just the amount of relations (defined as object properties) represents one of the main benefits pro introduced solution. The second advantage consists in the implementation of logical rules and restrictions. They enable to derive much new information from the original ontology. For example, the semantic property *neighbourhood* is inferred from topological relation externally connected (*EC*) and non-tangential proper-part (*NTPP*). The using of Description Logic is beneficial also from the perspective of checking the correctness and integrity of the ontology.

The introduced ontology is just a fragment of a future complex solution. The Discussion section offers several ideas and plans on how to continue in this work and extend the ontology. They consist above all in adding new types of properties (transitive relations) and populating of the ontology (addition of new instances representing particular NUTS regions).

The NUTS Geo-Ontology can be interconnected with other knowledge bases, ontologies and Linked Data resources. This extension can provide more semantics (links to semantic vocabularies), standardization (connections to standardized vocabularies) or information (relations to Linked Data providing statistical data for NUTS). The extensibility shows the main scope of the NUTS Geo-Ontology. It should be used as essential reference tools providing information about NUTS for various purposes. The main benefit of the proposed solution is the ability of automated checking integrity and consistency as well as the derivation of new information from implemented logical construction during the phase of reasoning.

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BIOGRAPHY

Assoc. prof. Otakar Čerba, Ph.D. works at the Department of Geomatics (Faculty of Applied Sciences, University of West Bohemia, Plzeň, Czech Republic). He is focused on web cartography, thematic cartography, Linked Data on the geographic domain and semantic issues of geographic data. He has been involved in many international projects such as Humboldt, SDI4Apps, SmartOpenData, Plan4all or ROSIE. Otakar Čerba is the members of the board of Czech Association of GeoInformation and the chair of the Commission on Maps and the Internet of International Cartographic Association.