TermIt: Managing Legal Thesauri

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Abstract. Thesauri are simple enough to be understood by domain experts yet formal enough to boost use cases like semantic search. Still, linking the meanings of thesauri concepts to their definitions in source documents, interlinking concepts across thesauri, and keeping the set of concepts semantically consistent and ready for subsequent conceptual modeling require appropriate tools. We present TermIt, a web-based thesauri manager addressing these issues. We show a scenario in the urban planning domain, and compare TermIt to other tools in this scenario. Next, we evaluate TermIt features and usability and discuss its impact beyond the original scenario.

Keywords: Thesaurus, Ontology, SKOS, UFO

1. Introduction

Consider two sentences: "The construction of the Large Hadron Collider took ten years." and "The construction of the Large Hadron Collider is hidden in a 27 km-long underground tunnel." The word *construction* is used in different meanings conveyed by the context – an event/process in the former case and an object (the outcome of the process) – in the latter. Similarly, according to the Czech Act No. 406/2000 Coll. on energy management, a building is "a construction both above and below ground with heating", while according to the Czech Act No. 256/2013 Coll. on the land registry, a building is "a construction above ground with solid foundations".

Both examples denote similarly sounding, yet conceptually different *concepts*, often coming from different legal acts, or other contexts. Especially in case of legal acts, each slight meaning shift or ambiguity of a word or phrase has an impact on a large amount of activities dependent on that legal act – semantics of information system APIs, descriptions of (open) data sets, or meaning of a legal document. These problems affect not only people, but also machines – word-based search engines can neither understand the query context, nor explain the query results.

SKOS [1] has been used for more than a decade for maintaining and organizing domain terminologies and thesauri on web. Yet, existing SKOS management tools provide weak support for creating and maintaining links of concepts to their definitions in documents, interlinking concepts across documents, or validating thesaurus quality.

For more complex tasks, like data integration, thesauri are not enough and *ontologies* [2] are needed. Although ontology creation is out of scope of this paper, we do expect that distinguishing the two types of constructions above not only helps to keep the hierarchy coherent, but also provides a basis for subsequent ontology modeling [3].

We introduce TermIt, a general-purpose SKOS-compliant thesauri management tool, additionally supporting linking the identified concepts to their referential occurrences and definitions in documents (e.g. in the legal acts) and interlinking concepts coming from different contexts.

An overview of TermIt has been given in [4]. This paper focuses on the practical impact of TermIt and presents the following contributions:

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- a practical scenario in the urban planning domain that motivated creation of TermIt,
- concept validation and quality checking using Unified Foundational Ontology [2],
- browser plug-in for web document annotation,
- comparison of TermIt features to state-of-the-art systems and evaluation of its usability by a user study.

Section 2 presents a scenario where TermIt is used. In section 3, we present key technologies relevant for TermIt. Section 4 shows the architecture and features of the system. Section 5 presents existing tools which are in section 6 compared to TermIt w.r.t. the introduced scenario, together with a user study on TermIt usability. The current impact of TermIt is discussed in section 7 and the paper is concluded in section 8.

2. Scenario

In 2014, Institute of Planning and Development of Prague (IPR) published the Prague Building Regulations (PBR), a norm codifying Prague-wide rules for construction and development works. Furthermore, a long-term vision of Prague urban development has been drafted by IPR in 2018 in the Metropolitan plan of Prague (MPP), a key urban planning document heavily linking to the Prague Building Regulations. Both documents refer to the Building Act No.183/2006 Coll., Decree No. 268/2009 Coll., on technical requirements for buildings and several other Czech laws and regulations.

In addition to the normative text itself and various graphical materials and maps, MPP also contains details on urban development in particular localities in Prague. To help citizens explore MPP, a web application[1] is provided by IPR where individual localities in Prague can be explored and filtered according to the various characteristics of the locality, or selected using a map. Both the MPP document and the web application use normative as well as common-sense terminology. However, a closer look at some of the key concepts reveals that they are used inconsistently across both MPP and PBR, as well as across different legal acts and decrees. For example, building has one definition in MPP and another definition in PBR, although both definitions ground the meaning in the same notion of construction, as shown in Figure 1. While in PBR, the definition is taken from the Decree No.268/2009 Coll., in MPP it was modified not to cover subterranean parts. In the Building Act No. 183/2006 Coll. and in the Decree No. 501/2006 Coll. the concept building is used without an explicit definition or any other reference to another concept.

The situation is even more confusing when other legal documents are considered. Another meaning for the concept building is provided e.g. in the Energy Act No. 406/2000 Coll. The concept construction is given a different meaning e.g. in the Government Order No. 17/1950 Coll., where it describes not the object itself, but rather the construction works.

These problems deteriorate the search experience in the Metropolitan plan document (users are not able to formulate their query precisely), as well as explainability of the particular search results (users don't know which meaning of a concept is used at some particular place of the text). In summary, the following problems can be identified:

- P1 the textual documents (law/norm texts), as well as the derived artifacts (web application/open data sets) don't provide the user with the explicit context of the concepts, their definition and relation to other concepts,
- P2 a concept denotes different meanings. While sometimes a concept definition is just a more restricted variant of another (building with/without subterranean parts), sometimes a concept denotes two fundamentally different meanings (construction as an object vs. construction as an event). The two different meanings often come from different contexts (documents/thesauri),
- P3 the connection between a concept and the place where it occurs or is defined is not maintained.

3. Background

This section introduces the key standards related to this paper.

[1] https://plan.praha.eu, cit. August 31, 2022

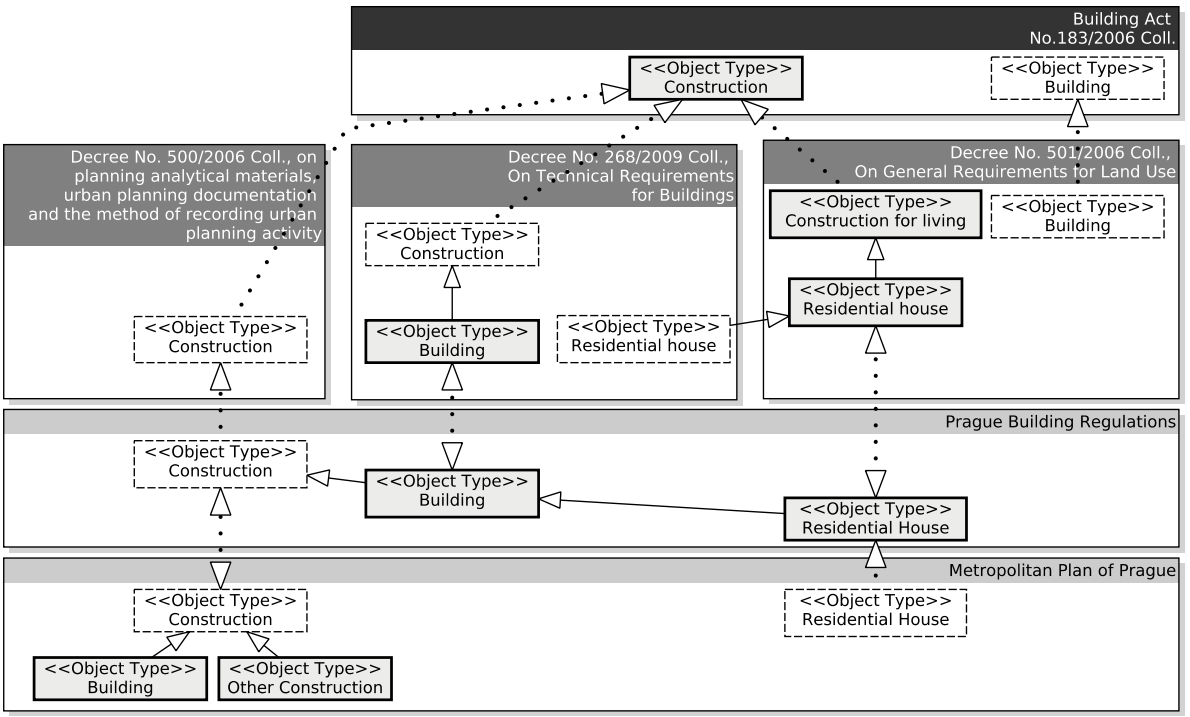

Fig. 1. Terminology ambiguities in the domain of urban planning. For solid-bordered concepts an explicit textual definition is provided in the respective document, while those with bordered dash are only mentioned without an explicit definition. A solid triangle-ended line represents a specialization relationship explicitly mentioned in the definition, while the dotted triangle-ended line represents a specialization based on the explicit document references. Last, dotted line triangle-ended on both sides means the same as two dotted triangle-ended line in opposite directions. Black, dark gray and light gray header denotes laws, ministerial decrees, and Prague-specific regulations, respectively.

3.1. SKOS

Simple Knowledge Organization System (SKOS) [1] is a standard for representing simple thesauri on the semantic web. Its main features involve representing *concepts*, and organizing them into hierarchies. E.g. it contains generic `skos:broader` relationship without requiring to specify the particular specialization semantics (e.g. super class, type, part of a whole). For example, when creating the concept of `pbr:building`,[2] it can have the following SKOS representation:

```
pbr:building a skos:Concept ;
    skos:prefLabel "Building"@en ;
    skos:inScheme pbr:vocabulary ;
    skos:definition "above ground construction
     including its subterranean parts,
     spatially concentrated and externally
     mostly enclosed by walls and roof." ;
    skos:broader pbr:construction .
```

However, neither the SKOS specification nor its XKOS extension [5] offers ontological categories for concepts – e.g. endurants (Objects) cannot be distinguished from perdurants (Events).

[2]Prefixes `pbr` and `skos` correspond to the namespaces `https://onto.fel.cvut.cz/ontologies/pbr` and `http://www.w3.org/2004/02/skos/core#` respectively.

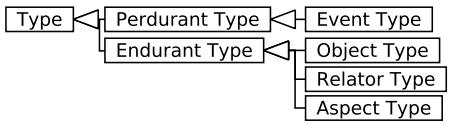

Fig. 2. UFO types

3.2. Unified Foundational Ontology

Unified Foundational Ontology (UFO) [2] is a top-level ontology designed for conceptual modeling, originally expressed in modal logic [2], but with recent partial translations to OWL 2 [6].

UFO covers static properties of endurants (UFO-A) [2], dynamic properties of perdurants (UFO-B) [7], a multi-level theory for modelling types (UFO-MLT) [8], and other extensions. A simplified part of the UFO hierarchy of types is depicted in Figure 2. The basic *semantic* categories of types involve events (e.g. football match, wedding), objects (e.g. Building, Person, Information system, Document), aspects (e.g. Person name,Building height), and relators (e.g. Marriage, Course enrollment). However, the Endurant types, can be partitioned not only according to their meaning, but also according to the rigidity and sortality of the type – their *ontological* characteristics. Taking an example from [9], while Marriage relator can be characterized as a kind (rigid sortal), Foreign Marriage is a Role (anti-rigid sortal), as the latter depends on a relationship to a Foreign person type (being itself a role). We developed an OWL version of UFO,[3] which is used to augment the thesauri content with UFO-based categories. To exemplify, the SKOS snippet from section 3.1 can be extended by one more triple

```
pbr:building rdf:type ufo:object-type .
```

4. TermIt Architecture

TermIt is a Web application with back-end written in Java[4] and front-end in React[5]. TermIt is backed by an RDF4J [10] compatible triple store (some TermIt features are optimized for GraphDB [11]). TermIt RDF4J repository uses custom rules allowing inference combining selected RDFS (class and property hierarchies) and OWL (inverse properties) features. The REST API supports both JSON and JSON-LD. A linked data API can be set up using Pubby [12] on top of the RDF4J SPARQL endpoint.

TermIt[6] consists of several modules, which will be introduced in the following sections. These modules support the use cases of thesauri creation, verification of their quality, and their usage for resource annotation and search. Figure 3 illustrates the system architecture and the aforementioned use cases.

4.1. Thesauri Management

In the thesauri management module, the user can maintain domain thesauri (called *vocabularies* in TermIt), as well as categorize the concepts using the UFO semantic categories (see section 3.2). Concept hierarchy can be constructed within a single thesaurus, but also across different thesauri to support cross-legislation links described in section 2. Concepts and thesauri can be searched using full-text matching in labels, definitions and description.

[3] `http://onto.fel.cvut.cz/ontologies/ufo`, cit. August 31, 2022. The ontology has a prefix `ufo` denoting the namespace `http://onto.fel.cvut.cz/ontologies/ufo/`.

[4] https://github.com/kbss-cvut/termit, cit. August 31, 2022

[5] https://github.com/kbss-cvut/termit-ui, cit. August 31, 2022.

[6] To access demo instance of TermIt, install Google Chrome Extension from https://chrome.google.com/webstore/detail/termit-annotate-semantic/penpnbbgbibnedeecnkbnemoilfdjlbh and use username/password: demo. TermIt UI can be accessed through https://kbss.felk.cvut.cz/termit-ann.

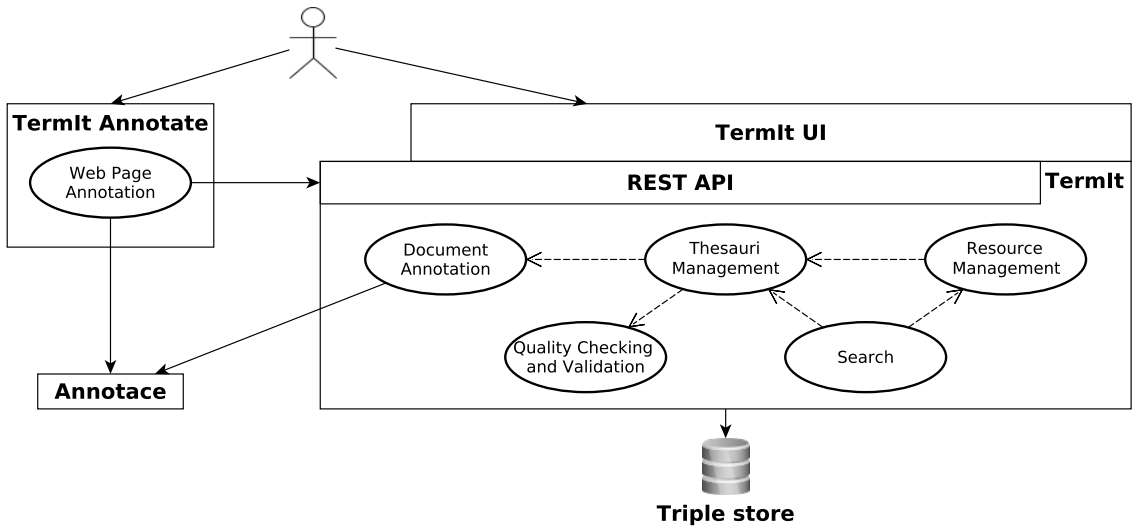

Fig. 3. Schematic depiction of the architecture of TermIt. Annotace is an external service utilized by TermIt. TermIt Annotate is browser plugin [13] to annotate web documents. Solid edges represent usage. Oval nodes within the TermIt box represent the main use cases with arrows indicating their interdependence. A client (human or machine) can access all the TermIt use cases through its UI or its REST API to get a domain-specific view of the data. The annotation of web resources (e.g. on-line legislation) can be done using a dedicated web browser plugin TermIt Annotate.

4.2. Document Annotation and Web Annotation

Linking documents and concepts is a key feature of TermIt. Users can attach documents to vocabularies, either by uploading an HTML file through TermIt UI, or directly by annotating a web page using the TermIt Annotate plug-in. Then, occurrences of terms and their definitions in text can be linked to the thesauri concepts. In this manner, documents and web pages linked to the given concept can be listed. To support document annotation, TermIt uses Annotace [14], a semantic text analysis service, to discover concept occurrences in documents and suggest new concepts based on their significance in the text.

4.3. Quality Checking and Validation

To control the quality and completeness of concepts, TermIt employs two types of constraints – thesauri constraints and UFO constraints. Both types are encoded in SHACL [15] evaluated over the SKOS representation of a thesaurus, for example:

- g2 each concept has a skos:prefLabel in a language,
- g3 each concept has at most one skos:definition in a language,
- g4 each concept has at least one skos:definition in a language (the rule is currently for Czech only),
- g9 a concept has a skos:prefLabel which is unique in the thesaurus,
- g13 a concept should have a dc:source,
- g14 a concept should have a parent (either skos:broader, or skos:broadMatch)[7]

On the other hand, UFO constraints check the semantic coherency of the concept, e.g.:

- m1 each concept has at least one UFO semantic category (Object,Relator, Aspect, Event, or sub-types thereof),
- m2 The above categories are pairwise disjoint.

[7]This rule motivates users to properly ground the concepts in the foundational ontology UFO. The only element for which this rule would fail, would be the top-level *Entity* element from UFO. Since UFO is never directly managed by TermIt, we do not consider it a problem.

The full set of constraints (14 at present) is configurable per TermIt deployment based on the selection from the SGoV validator.[8] Currently, TermIt does not support choosing the set of constraints dynamically, or per thesaurus.

For example, a SHACL version of the constraint g2 looks like :[9]

```
[] a sh:NodeShape ;
  sh:targetClass skos:Concept ;
  sh:path                skos:prefLabel ;
  sh:qualifiedValueShape [ sh:languageIn ( "cs" ) ] ;
  sh:qualifiedMinCount   1 ;
  sh:minLength           1
.
```

Rule violations are presented to the user by the TermIt user interface (UI). Additionally, rules g4, g13, g14, and m1 form a *quality score* of the concept – failing any of these rules decreases the score of the concept by 25%, which is signalized to the user by the color of its quality badge.

5. Related Work

This section lists tools that can be used to address the use cases mentioned in section 2. VOCOL [16], ThManager [17], TemaTres,[10] and iQvoc [18] are open-source tools that can be used for collaborative thesauri management. A more comprehensive tool is VocBench 3 [19], an open-source SKOS thesauri manager, involving e.g. role-based access control, multiple multilingual projects, approval workflow, and editing history, it supports integrity constraint validation as well as version control.

Commercial offerings for thesauri management involve Multites[11] (with SKOS export support) and SKOS Shuttle [20], an online service, allowing to bind individual concepts to documents, execute SPARQL queries on the resulting repository and log changes. One of the comprehensive tools is TopBraid EDG,[12] a full knowledge modeling suite, supporting permission control, constraint validation, as well as enterprise search features. Probably the most relevant to our work is the PoolParty Semantic Suite [21], which is mainly focused on workflow-backed thesaurus design and management based on text corpora and its management. Thesauri can be used for faceted search or end-up as a linked data source.

More detailed discussion of how these tools relate to the mentioned scenario and TermIt is shown in section 6.

6. Evaluation

For testing, we have divided TermIt into functional features based on the use case mentioned in section 2

- F1 browsing and searching for thesauri and concepts,
- F2 creating/editing new thesauri and concepts, interlinking concepts,
- F3 handling documents and web resources,
- F4 thesauri quality control,
- F5 annotation of resources and their content.

Referring to section 2, while features F1 and F2 reflect general thesauri management capabilities and are linked to P1, feature F4 addresses P2, and features F3 and F5 address P3.

We compare the tools w.r.t. features F1-F5 and test them from the user experience perspective within TermIt.

[8] https://github.com/kbss-cvut/sgov-validator, cit. August 31, 2022
[9] Prefix `sh` corresponds to the namespace `http://www.w3.org/ns/shacl#`.
[10] https://github.com/tematres/TemaTres-Vocabulary-Server, cit. August 31, 2022
[11] http://www.multites.com, cit. August 31, 2022
[12] https://www.topquadrant.com/products/topbraid-enterprise-data-governance/, cit. August 31, 2022

	PoolParty Semantic Suite	TopBraid EDG	SKOS Shuttle	TermIt
F1	- faceted search - advanced search filters	- faceted search - advanced search filters		
F2	- discussion about concept - customizable collaboration workflows	- discussion about concept - customizable collaboration workflows		- discussion about concept - simple concept approving workflow - differentiate between concept use and concept definition - navigable link to concept definition
F3	- crawling web resources - full-text search within documents	- crawling web resources - full-text search within documents	- crawling web resources	
F4	- customizable validation rules - customizable metrics - generation of reports	- customizable validation rules - customizable metrics - generation of reports		- predefined validation rules - predefined metrics
F5	- different content types - annotated content visualization in plain text	- different content types	- different content types	- HTML content type only - annotated content visualization respecting document layout - manual annotation support

Table 1

Differences among the tools w.r.t. features F1-F5. Commonalities of the tools are described in section 6.1.

6.1. Tool Comparison

To compare the tools, we disregarded open-source tools that are 2 or more years without activity as well as tools that do not support document/web source management or do not consider textual content, ending-up with the PoolParty Semantic Suite (PP), TopBraid Enterprise Data Governance (EDG), SKOS Shuttle (SKS), and TermIt.

Table 1 highlights key differences among the tools w.r.t. the testing scenario in section 6.2.

F1 is well supported in SKS and has excellent support in other tools. All the tools support hierarchical visualization of concepts, search within key metadata of concepts (like label, synonyms, or definitions) and thesauri (like description). Search for non-label metadata can be done in SKS only using SPARQL queries. In addition, EDG and PP implement a faceted search and advanced search filters.

F2 support is diverse across the tools. Although all of them support multi-user access, change tracking, multilingual concepts and their linking across thesauri, only TermIt can link the concept to the place where it is defined. PP and EDG support customizable collaboration workflows, while TermIt only supports draft/confirmed status of a concept. PP, EDG and TermIt provide a discussion thread about a concept.

F3 is well supported in all tools, including management of local files or resources identified by URLs. In addition, the competitors support web crawling of documents. PP and EDG also support full-text search within documents.

F4 is well supported in EDG and PP, featuring customizable validation rules, metrics and generation of reports. F4 is also well supported in TermIt, offering validation rules and metrics for concepts and thesauri that are configured during deployment. SKS has support only for concept deorphanization.

F5. TermIt competitors allow to import different content types (e.g., PDF, XLSX, HTML) but do not support manual annotations. Only PP can visualize annotated content as plain text. In contrast, TermIt allows both online annotation in the web browser and importing HTML documents supporting manual annotations. Complex HTML documents often need to be adjusted manually before the import.

To sum up, EDG and PP are professional tools that provide many additional features that are more or less relevant for the presented use case. PP is intuitive and provides the best support in F1 and F4. EDG provides similar features as PP, yet, with a more complex UI. SKS is a very promising alternative to PP but lacks F4. F5 has the weakest support across the tools except TermIt. TermIt can create or approve suggested concepts directly from the document without needing to leave the document's view. Moreover, the user can navigate from a concept to its definition within a document to get the proper context for understanding the concept.

6.2. User Experience Evaluation

For testing user experience, we have set up a set of tasks testing the features F1-F5, which are evaluated w.r.t. the following criteria:

1. the time needed to finish the task,
2. the understanding of the task,
3. the understanding of the TermIt content,
4. the importance of tested features,
5. the difficulty of the tasks, and
6. the error detection.

Testing scenarios[13] were applied to a group of five users with different level of experience with the TermIt tool. The testers were recruited from the people working as domain experts for urban planning, aviation and medicine and also developers, none of which participated in the TermIt development. Testing scenario was divided into five specific tasks.

Searching for a concept based on the name (T1) seemed quite easy, yet one of testers did not succeed. The average time to complete the task is almost 4 and half minutes (2 minutes for the fastest user and 6 minutes to the slowest one). According to the user evaluation, most users understood what to do and how to do it, including the one who had it wrong.

Finding a concept, writing its definition and checking its quality (T2) was completed incorrectly by one tester, again. Although the others succeeded, concept quality didn't seem to be well understood by most. Namely, how detected errors (e.g. missing UFO type of a concept) are related to the quality score, or even finding the errors on the concept detail page.

Creating a new thesaurus and concepts and marking new concepts in the document supported by automatic text analysis (T3). The task took over 35 minutes on average to finish (15 minutes for the fastest user and 73 minutes for the slowest one). The most problematic part appeared to be marking definitions in the document. All users have marked it as impossible to do, but as very useful. It is interesting that most of the users mark file analysis and concept detection in the documents useful, yet some of them consider it not essential.

As a response to the feedback a new web browser plugin (TermIt Annotate) has been designed, allowing testers to create the concepts directly by annotating web resources in the browser, without the need of (re-)importing web documents to TermIt and modifying their appearance. Out of five testers, three responded they would favour it over the internal TermIt annotator, one is not sure, and the last one would not. Overall usability of the web annotator plugin scored high in the evaluation (average score 4.6 out of 5). More details can be found in [13].

Improving thesaurus quality (T4) involved filling-up all attributes of concepts to increase the quality score. Average time needed for this task is 20 minutes (5 minutes for the fastest one and 47 minutes for the slowest one). As expected, more advanced attributes caused problems to the testers. The reason seems to be that UFO-based values of the 'Type of concept' field were too general to most users. Also, some of the quality checks turned out to be rather irrelevant - e.g. checking the length of concept definition and requiring each concept (except one) to have a parent in the thesaurus.

Distinguishing different concepts with the same label (T5) addresses another problem in section 2. First, we asked users for any ideas on how to solve the problem of two concepts with the same label and a different meaning. Only one of the testers had an idea. After presenting the options to link concepts, they all succeeded. Then we asked them to create relations between concepts from different thesauri. Two of the testers had minor problems, but the functionality was evaluated positively.

In summary, less experienced users needed more time to finish the tasks. Also, users found it difficult to create definitions from the text. With the browser plugin, however the testing showed its feasibility. Another feature difficult to understand was concept quality. On the other hand, it took only very little explanation for the users to finally

[13] An english version available at
https://forms.gle/JSDhFb5PNfAgbvdw5, cit. August 31, 2022

understand it – in T2, users did not understand what it meant, but in T4, everyone was able to fix the errors. Interlinking and recognition of concepts raised some minor issues caused by the UI.

7. Impact

While TermIt has been designed and tested w.r.t. the Metropolitan plan scenario introduced in section 2, it has been later used in other setups. While several projects in the aviation and healthcare industry used TermIt more for research purposes, let's take a brief look at two uses of TermIt which go strictly beyond the academic sphere.

7.1. Digital Technical Map of the Czech Republic

Institute of Planning and Development uses TermIt also to systematize the terminology of the Digital Technical Maps across the Czech Republic, based on the Decree No.393/2020 Coll, with technical support for TermIt provided by the Czech Technical University in Prague. The community has been steadily growing, with approx. 80 registered TermIt users as of July 2022. Within the past year, the authors of this paper organized several online webinars for the community (public administration and commercial professionals in urban planning, architects and civil engineering) to become familiar with TermIt and basics of knowledge modeling.

7.2. eGovernment

The second usage of TermIt goes beyond the Czech Technical University in Prague. TermIt has been adopted by the Department of the eGovernment Chief Architect of the Ministry of Interior of the Czech Republic (MI) within the EU-funded project No. CZ.03.4.74/0.0/0.0/15_025/0013983. TermIt has been used here as a part of the Assembly line[14] – a larger ecosystem of tools supporting creation of conceptual models of public administration agendas. For example, TermIt has been used for managing the terminology of the eGovernment vocabulary[15]. This year, two training sessions for more than 150 attendees in total were organized, each of which included a dedicated session on Termit usage and applicability.

8. Conclusions

We presented TermIt as a tool for managing contextual (typically document-based) thesauri, interlinking their concepts, and connecting the concepts to their occurrences and definitions in documents. Especially the latter seems to be rather neglected in the existing open-source solutions, which is however crucial to keeping the link between a normative document and a vocabulary concept maintainable.

The usability testing proved the suitability of our approach, yet revealed problems which made some tasks difficult to complete for non-trained TermIt users – e.g. Concept quality revealed that concept identification (e.g. unique concept definition, unique label) is a problem in our scenario and was not well understood by our users. On the other hand, linking a concept to its defining occurrence in the document was well understood and doable using the web annotation TermIt plugin.

In the future, we plan to test TermIt in the eGovernment domain for managing interlinked thesauri of the core Czech legislation related to governmental data management. As for the TermIt features, we plan to support validation constraints management in the tool, as well as creation of formal concept definitions extracted from the textual ones.

Acknowledgements

The work was supported by grant No. SGS19/110/OHK3/2T/13 Efficient Vocabularies Management Using Ontologies of the Czech Technical University in Prague.

[14] https://github.com/opendata-mvcr/sgov-assembly-line, in Czech only, cit. 25.7.2022

[15] draft version of the dedicated explorer of the vocabulary is available at https://archi.gov.cz/playgroud:tezaurus, cit. 25.7.2022

References

[1] A. Miles and S. Bechhofer, SKOS Simple Knowledge Organization System Reference, W3C Recommendation, W3C, 2009, http://www.w3.org/TR/skos-reference, accessed 2020-01-20.

[2] Guizzardi, Giancarlo, Ontological Foundations for Structural Conceptual Models, PhD thesis, University of Twente, 2005.

[3] M. Verdonck, F. Gailly, R. Pergl, G. Guizzardi, B. Martins and O. Pastor, Comparing traditional conceptual modeling with ontology-driven conceptual modeling: An empirical study, *Information Systems* (2019). doi:10.1016/j.is.2018.11.009.

[4] M. Ledvinka, P. Kremen, L. Saeeda and M. Blasko, TermIt: A Practical Semantic Vocabulary Manager, in: *ICEIS 2020*, SCITEPRESS, 2020, pp. 759–766. doi:10.5220/0009563707590766.

[5] D.W. Gillman, F. Cotton and Y. Jaques, XKOS: Extending SKOS for Describing Statistical Classifications, in: *SemStats@ISWC 2013*, CEUR Workshop Proceedings, Vol. 1549, CEUR-WS.org, 2013. http://ceur-ws.org/Vol-1549/article-03.pdf.

[6] A. Benevides, J.-R. Bourguet, G. Guizzardi, R. Peñaloza and J. Almeida, Representing a reference foundational ontology of events in SROIQ, *Applied Ontology* **14** (2019), 1–42. doi:10.3233/AO-190214.

[7] G. Guizzardi, G. Wagner, R. De Almeida Falbo, R.S.S. Guizzardi and J.P.A. Almeida, Towards ontological foundations for the conceptual modeling of events, in: *LNCS*, Vol. 8217 LNCS, 2013, pp. 327–341. ISSN 03029743. ISBN 9783642419232. doi:10.1007/978-3-642-41924-9_27.

[8] V.A.d. Carvalho, J.P.A. Almeida, C.M. Fonseca and G. Guizzardi, Extending the Foundations of Ontology-Based Conceptual Modeling with a Multi-level Theory, in: *ER 2015, LNCS*, Springer, 2015, pp. 119–133. doi:10.1007/978-3-319-25264-3_9.

[9] G. Guizzardi, C.M. Fonseca, A.B. Benevides, J.P.A. Almeida, D. Porello and T.P. Sales, Endurant Types in Ontology-Driven Conceptual Modeling: Towards OntoUML 2.0, in: *ER 2018*, LNCS, Vol. 11157, Springer, 2018, pp. 136–150. doi:10.1007/978-3-030-00847-5_12.

[10] J. Broekstra, A. Kampman and F. van Harmelen, Sesame: A Generic Architecture for Storing and Querying RDF and RDF Schema, in: *Proceedings of the First International Semantic Web Conference on The Semantic Web*, 2002, pp. 54–68.

[11] B. Bishop, A. Kiryakov, D. Ognyanoff, I. Peikov, Z. Tashev and R. Velkov, OWLIM: A family of scalable semantic repositories, *Semantic Web – Interoperability, Usability, Applicability* (2010).

[12] R. Cyganiak and C. Bizer, Pubby – A Linked Data Frontend for SPARQL Endpoints, 2007, http://wifo5-03.informatik.uni-mannheim.de/pubby/, accessed 2020-01-23. http://wifo5-03.informatik.uni-mannheim.de/pubby/.

[13] Alan Buzek, Web browser plug-in for semantic vocabulary creation, 2022, Bachelor Thesis. Czech Technical University in Prague. http://hdl.handle.net/10467/100959, accessed 2022-07-25..

[14] L. Saeeda, M. Med, M. Ledvinka, M. Blaško and P. Křemen, Entity Linking and Lexico-Semantic Patterns for Ontology Learning, in: *The Semantic Web*, Springer International Publishing, Cham, 2020, pp. 138–153. ISBN 978-3-030-49461-2. doi:10.1007/978-3-030-49461-2_9.

[15] H. Knublauch and D. Kontokostas, Shapes Constraint Language (SHACL), W3C Recommendation, W3C, 2017, https://www.w3.org/TR/2017/REC-shacl-20170720/.

[16] L. Halilaj, N. Petersen, I. Grangel-González, C. Lange, S. Auer, G. Coskun and S. Lohmann, VoCol: An Integrated Environment to Support Version-Controlled Vocabulary Development, in: *EKAW 2016*, LNCS, Vol. 10024, 2016, pp. 303–319. doi:10.1007/978-3-319-49004-5_20.

[17] J. Lacasta, J. Nogueras-Iso, F.J. López-Pellicer, P.R. Muro-Medrano and F.J. Zarazaga-Soria, ThManager: An Open Source Tool for Creating and Visualizing SKOS, *Information Technology and Libraries* **26** (2007), 39–51.

[18] T. Bandholtz, T. Schulte-Coerne, R. Glaser, J. Fock and T. Keller, iQvoc - Open Source SKOS(XL) Maintenance and Publishing Tool, in: *Sixth Workshop on Scripting and Development for the Semantic Web*, CEUR Workshop Proceedings, Vol. 699, 2010. http://ceur-ws.org/Vol-699/Paper2.pdf.

[19] A. Stellato, M. Fiorelli, A. Turbati, T. Lorenzetti, W.V. Gemert, D. Dechandon, C. Laaboudi-Spoiden, A. Gerencsér, A. Waniart, E. Costetchi and J. Keizer, VocBench 3: A collaborative Semantic Web editor for ontologies, thesauri and lexicons, *Semantic Web* **11**(5) (2020), 855–881. doi:10.3233/SW-200370.

[20] F. Ricci and D. Wikarski, SKOS Shuttle - ein Service zur Taxonomy Governance am Beispiel von Umweltinformationssystemen (SKOS Shuttle - a service for Taxonomy Governance using the example of environmental information systems), in: *Umweltinformationssysteme 2017*, CEUR Workshop Proceedings, Vol. 1919, CEUR-WS.org, 2017, pp. 177–192. http://ceur-ws.org/Vol-1919/paper13.pdf.

[21] T. Schandl and A. Blumauer, PoolParty: SKOS Thesaurus Management Utilizing Linked Data, in: *ESWC 2010*, LNCS, Vol. 6089, Springer, 2010, pp. 421–425. doi:10.1007/978-3-642-13489-0_36.