Distributed Vocabulary Development with Version Control Systems

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Abstract. Vocabularies are increasingly being developed on platforms for hosting version-controlled repositories, such as GitHub. However, these platforms lack important features that have proven useful in vocabulary development. We present VoCol, an integrated environment that supports the development of vocabularies using *Version Control Systems*. VoCol is based on a fundamental model of vocabulary development, consisting of the three core activities modeling, population, and testing. It uses a loose coupling of validation, querying, analytics, visualization, and documentation generation components on top of a standard Git repository. All components, including the version-controlled repository, can be configured and replaced with little effort to cater for various use cases.

Introduction

Vocabulary development is currently a major bottleneck for the wide realization of semantic data integration. It requires a significant investment, which is difficult to make by a single person or organization. Identifying the terms and concepts by finding a consensus among the involved stakeholders and defining a shared vocabulary is an effective approach to tackle this problem. However, the main challenge for vocabulary engineers is to work collaboratively on a shared objective while avoiding misunderstandings, uncertainty, and ambiguity.
On the other hand, *Version Control Systems* (VCS), such as *Subversion* (SVN) or Git, are becoming increasingly popular for vocabulary development. In our previous work, we proposed Git4Voc[2], a set of best practices which transfer concepts of VCSs to vocabulary development, on the example of Git. Several aspects of vocabulary development, in particular with regard to revision management, access control, and some governance issues are already well covered by Git-based version control, especially if developers follow the proposed best practices.
Many of the current vocabulary development activities take place on *Repository Hosting Platforms* like GitHub, GitLab, or BitBucket. In addition to mere version-controlled repositories, these platforms provide features such as change tracking, issue tracking, wikis, and notifications. However, the platforms lack important features that have proven useful in vocabulary development. In particular, they do not provide an integrated environment typically found in tools such as WebProtégé, VocBench, or PoolParty.

Approach

We designed VoCol as a holistic approach for realizing a full-featured vocabulary development environment centered around version control systems (VCSs). It supports a fundamental round-trip model of vocabulary development, consisting of the three core activities *modeling*, *population*, and *testing*, as illustrated in Figure 1.

In the spirit of test-driven software engineering, VoCol allows to formulate queries, which represent competency questions for *testing* the expressivity and applicability of a vocabulary a priori. *Modeling* comprises the analysis and conceptualization of the domain and the specification of the vocabulary terms, including classes, properties, and the relationships between them VoCol integrates a number of techniques facilitating the conceptual work, such as automatically generated documentations and visualizations, providing different views on the vocabulary as well as an evolution timeline supporting traceability. The next activity is typically *population* which includes the definition of the mappings files such as R2RML in line with the defined classes and properties as well as querying the external data sources.

The governance of distributed vocabulary development is supported by the access control as well as branching and merging mechanisms of the underlying VCS system. As a result, VoCol bridges between the conceptual development of vocabularies and the operational execution in a concrete IT landscape. The implementation of VoCol is based on a loose coupling, leveraging the webhook mechanism combined with tools and techniques focusing on particular aspects of vocabulary development. By providing Vagrant and Docker containers bundling all tools and encapsulating dependencies, VoCol is easily deployable or even usable as-a-service in conjunction with arbitrary VCS installations.

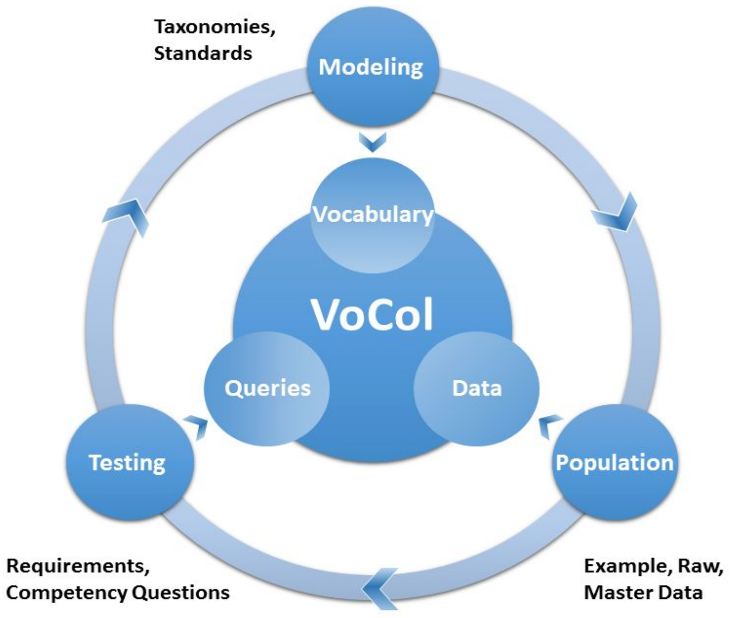


Figure 1. Round-trip vocabulary development supported by VoCol

Architecture

The integrated VoCol system architecture is illustrated in Figure 2. It is based on the principles of Component Based Software Development (CBSD) [1], which promote the reuse of (off-the-shelf) components to develop large-scale systems. Each of the VoCol components is exchangeable and can be replaced by alternatives.

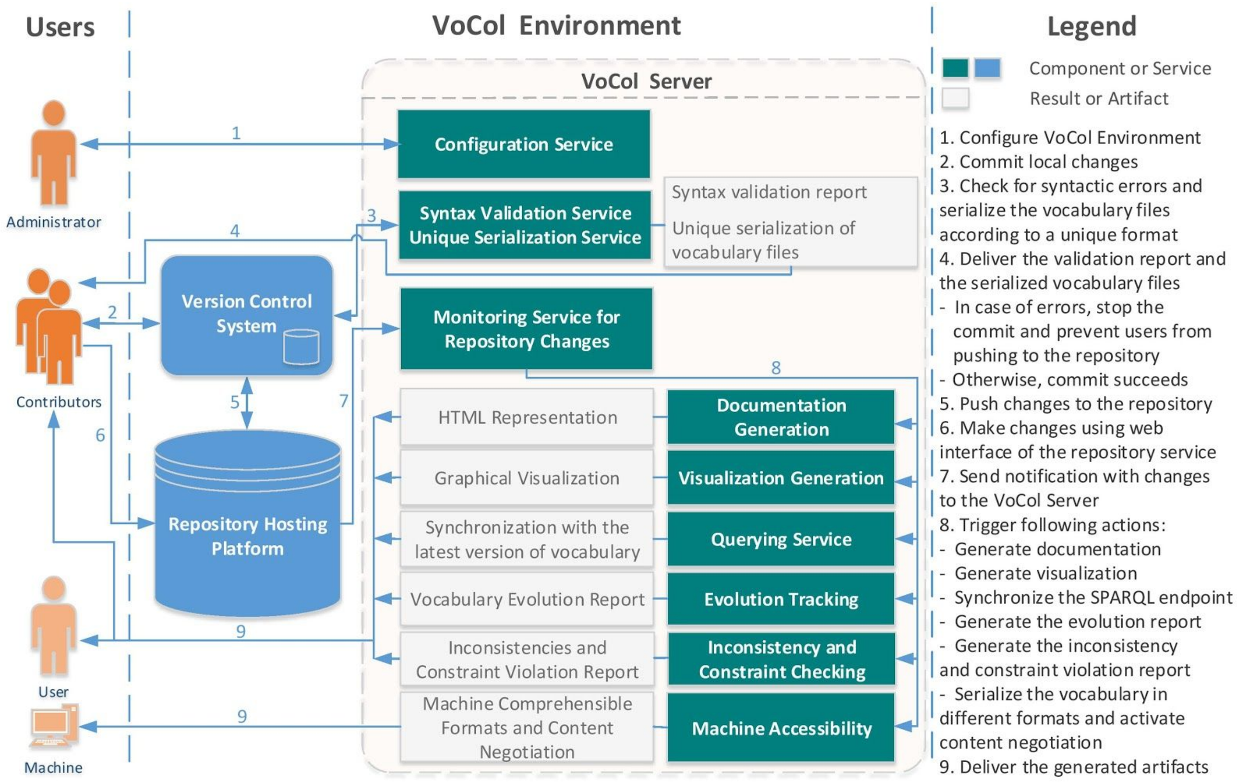

Users
VoCol Environment
Legend
Component or Service
Result or Artifact
VoCol Server
Administrator
Contributors
User
Machine
Version Control System
Repository Hosting Platform
Configuration Service
Syntax Validation Service
Unique Serialization Service
Syntax validation report
Unique serialization of vocabulary files
Monitoring Service for Repository Changes
HTML Representation
Documentation Generation
Graphical Visualization
Visualization Generation
Synchronization with the latest version of vocabulary
Querying Service
Vocabulary Evolution Report
Evolution Tracking
Inconsistencies and Constraint Violation Report
Inconsistency and Constraint Checking
Machine Comprehensible Formats and Content Negotiation
Machine Accessibility
1. Configure VoCol Environment
2. Commit local changes
3. Check for syntactic errors and serialize the vocabulary files according to a unique format
4. Deliver the validation report and the serialized vocabulary files
- In case of errors, stop the commit and prevent users from pushing to the repository
- Otherwise, commit succeeds
5. Push changes to the repository
6. Make changes using web interface of the repository service
7. Send notification with changes to the VoCol Server
8. Trigger following actions:
- Generate documentation
- Generate visualization
- Synchronize the SPARQL endpoint
- Generate the evolution report
- Generate the inconsistency and constraint violation report
- Serialize the vocabulary in different formats and activate content negotiation
9. Deliver the generated artifacts

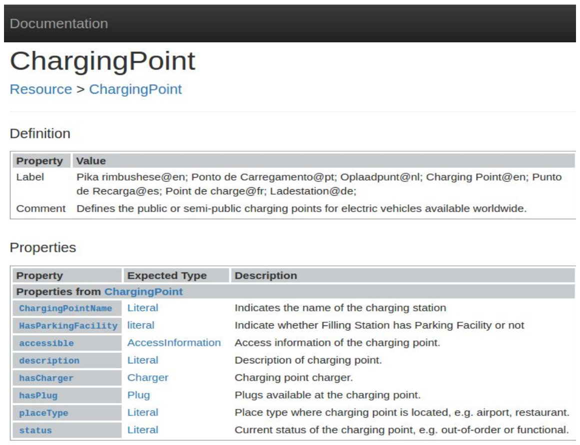
Figure 2. VoCol architecture and workflow.

Version Control System - is an essential component for supporting the loosely coupled collaboration between vocabulary engineers without risking to lose data. It is responsible for the management of vocabulary changes, such as change capturing and propagation: by capturing and storing the changes, various revisions of the vocabulary are created. To ensure a consistent development process, any change should be propagated to all other contributors. In addition, conflicts inevitably arise in an environment where multiple contributors are working simultaneously and changing vocabulary terms. The VCS ensures conflict resolution and allows integration of conflicting changes in an effective and easy way.
On the other hand, the *Repository hosting platforms*, such as GitHub, GitLab, and Bitbucket act as repository storage where the vocabulary files are saved and accessed. The integrated access control mechanisms authenticate users with the right permissions. Furthermore, contributors can discuss vocabulary terms or definitions and suggest changes or new terms using the issue tracking functionality of the platform.

Syntax Validation - ensures that the latest revision in the VCS is always syntactically correct. Syntax validation could be realized at different stages of the overall workflow. However, with the aim to keep the requirements on the client side at a minimum level, we realized a syntax validation service on the server. As a result, syntactically incorrect commits are rejected and a detailed error report is provided.

Unique Serialization - Different editors may produce different serializations of the vocabulary files. To overcome this problem, VoCol creates a unique serialization of vocabulary files before changes are pushed to the remote repository, thus preventing false-positive merge conflicts.

Documentation Generation - produces an HTML representation of the vocabulary. This permits contributors to easily navigate through the entire vocabulary and provides a concise but still detailed overview (cf. generated documentation for the *ChargingPoint* term in Figure 3).



ChargingPoint

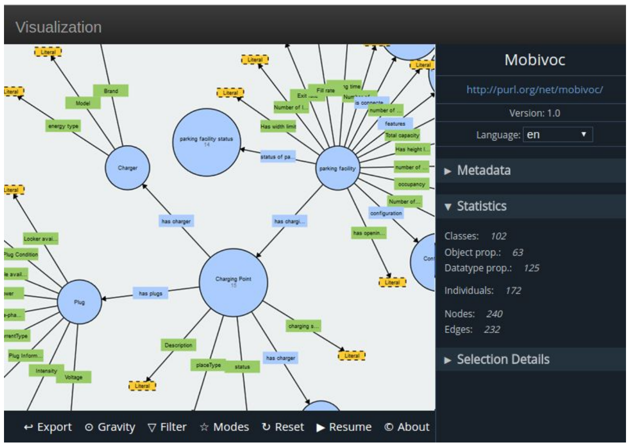
Resource > ChargingPoint

Definition

Property	Value
Label	Pika rimbushese@en; Ponto de Carregamento@pt; Oplaadpunt@nl; Charging Point@en; Punto de Recarga@es; Point de charge@fr; Ladestation@de;
Comment	Defines the public or semi-public charging points for electric vehicles available worldwide.

Properties

Property	Expected Type	Description
Properties from ChargingPoint		
`ChargingPointName`	Literal	Indicates the name of the charging station
`HasParkingFacility`	literal	Indicate whether Filling Station has Parking Facility or not
`accessible`	AccessInformation	Access information of the charging point.
`description`	Literal	Description of charging point.
`hasCharger`	Charger	Charging point charger.
`hasPlug`	Plug	Plugs available at the charging point.
`placeType`	Literal	Place type where charging point is located, e.g. airport, restaurant.
`status`	Literal	Current status of the charging point, e.g. out-of-order or functional.



Mobivoc

http://purl.org/net/mobivoc/

Version: 1.0

Language: en

Classes: 102
Object prop.: 63
Datatype prop.: 125
Individuals: 172
Nodes: 240
Edges: 232

Figure 3. Generated documentation *Figure 4. Generated visualization*

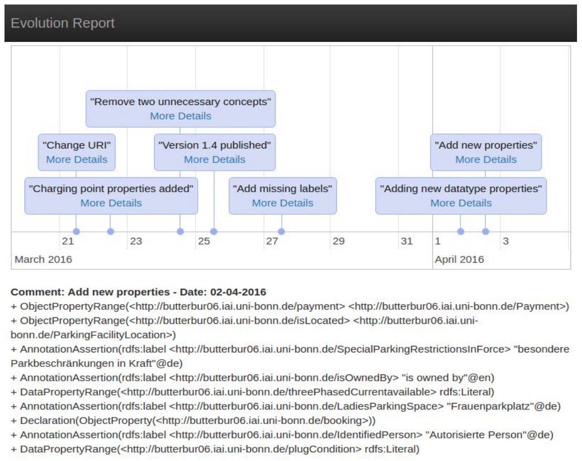
Visualization Generation - By visualizing classes, properties and their connections, users are provided with a coherent view of the vocabulary. In addition, this service enables to explore multilingual vocabulary terms (cf. Figure 4).

Querying Service - VoCol integrates a SPARQL endpoint synchronized with the latest version of the vocabulary. During testing, queries derived from competency questions can be used to verify whether the vocabulary fulfills the domain requirements. All defined queries are stored in the repository and pre-loaded in the query user interface.

Inconsistency and Constraint Checking - After the changes have been pushed to the remote repository, checks for semantic inconsistencies and constraint violation are performed and their results are compiled in a detailed report.

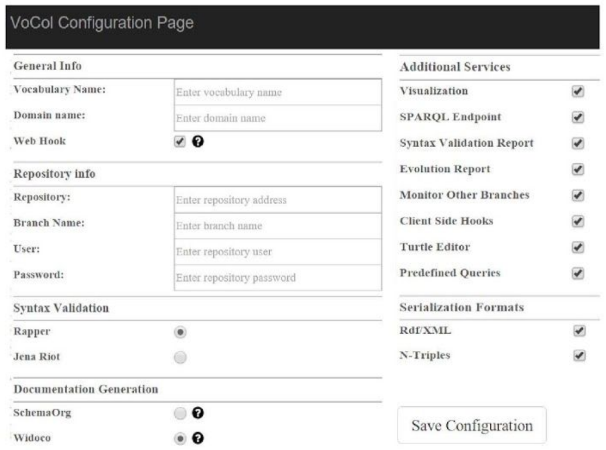
Machine Accessibility - Using the content negotiation mechanism and dereferenceable URIs, VoCol delivers various machine-comprehensible representations. By specifying the content type in the HTTP header along with the resource URI, the vocabulary can be accessed by different software agents compliant with the linked data principles.

Evolution Tracking - detects semantic differences between vocabulary versions. It shows which classes and properties have been added, removed or modified, enabling users to see the vocabulary evolution over time (cf. Figure 5).



```
Comment: Add new properties - Date: 02-04-2016
+ ObjectPropertyRange(<http://butterbur06.iai.uni-bonn.de/payment> <http://butterbur06.iai.uni-bonn.de/Payment>)
+ ObjectPropertyRange(<http://butterbur06.iai.uni-bonn.de/isLocated> <http://butterbur06.iai.uni-
bonn.de/ParkingFacilityLocation>)
+ AnnotationAssertion(rdfs:label <http://butterbur06.iai.uni-bonn.de/SpecialParkingRestrictionsInForce> "besondere
Parkbeschränkungen in Kraft"@de)
+ AnnotationAssertion(rdfs:label <http://butterbur06.iai.uni-bonn.de/isOwnedBy> "is owned by"@en)
+ DataPropertyRange(<http://butterbur06.iai.uni-bonn.de/threePhasedCurrentavailable> rdfs:Literal)
+ AnnotationAssertion(rdfs:label <http://butterbur06.iai.uni-bonn.de/LadiesParkingSpace> "Frauenparkplatz"@de)
+ Declaration(ObjectProperty(<http://butterbur06.iai.uni-bonn.de/booking>))
+ AnnotationAssertion(rdfs:label <http://butterbur06.iai.uni-bonn.de/IdentifiedPerson> "Autorisierte Person"@de)
+ DataPropertyRange(<http://butterbur06.iai.uni-bonn.de/plugCondition> rdfs:Literal)
```

Figure 5. Evolution tracking



General Info

Vocabulary Name:	Enter vocabulary name
Domain name:	Enter domain name
Web Hook	✓

Repository info

Repository:	Enter repository address
Branch Name:	Enter branch name
User:	Enter repository user
Password:	Enter repository password

Syntax Validation

Rapper	●
Jena Riot	○

Documentation Generation

SchemaOrg	○
Widoco	●

Additional Services

Visualization	✓
SPARQL Endpoint	✓
Syntax Validation Report	✓
Evolution Report	✓
Monitor Other Branches	✓
Client Side Hooks	✓
Turtle Editor	✓
Predefined Queries	✓

Serialization Formats

Rdf/XML	✓
N-Triples	✓

Figure 6. Configuration page

Configuration Service - provides a Graphical User Interface to facilitate the configuration of VoCol. The VoCol administrator can choose between various alternative tools for syntax validation and documentation generation. Furthermore, other services can be activated or deactivated (cf. VoCol Configuration Page in Figure 6).

Monitoring Service - Repository hosting platforms expose most of their functionality via web service APIs. Any change pushed to the repository is delivered as a payload event to a VoCol monitoring service, which automatically invokes services for documentation generation, visualization, evolution tracking, etc.

Conclusions

VoCol is an integrated environment for the distributed development of vocabularies based on version control systems. Tasks such as content negotiation, documentation and visualization generation, as well as evolution tracking are performed in a fully automated way. In addition, a querying service, synchronized with the latest version of the vocabulary, enables users to execute SPARQL queries. The VoCol environment is easily expandable with other tools to provide additional functionalities. For the future, we plan to provide VoCol as a service where users can simply subscribe their repositories and benefit from all functionalities.

References

[1] Kaur, A., Mann, K.S.: Component based software engineering. *International Journal of Computer Applications 2(1):105–108 (2010).*

[2] Halilaj, L., Grangel-González, I., Coskun, G., Lohmann, S., Auer, S.: Git4Voc: Collaborative vocabulary development based on git. *International Journal on Semantic Computing* 10(2): (2016) 167–192