Ontoanimal tools for reusing ontologies, generating and editing ontology terms, and dereferencing ontology terms

Yongqun He[1*], Jie Zheng[2], Yu Lin[1]

[1]University of Michigan, Ann Arbor, Michigan, USA; [2]University of Pennsylvania, Philadelphia, PA, USA

ABSTRACT

Ontoanimal tools are a suite of web-based ontology tools developed to support efficient and integrated ontology development and applications. The Ontoanimal tools suite includes OntoFox, Ontodog, Ontorat, Ontobee, Ontobeep, and Ontobat. Each tool has specific functions; together, these tools support the extraction of a single or subset of terms and community views from existing ontologies, generation and editing of ontology terms, query and visualization of ontology terms, comparison among ontologies, and instance-level data representation and analysis. Based on the Web Ontology Language (OWL) and Semantics Web technologies, these tools have widely been used by thousands of ontology developers in over 20 communities.

1 INTRODUCTION

Biological/biomedical ontologies are sets of computer- and human-interpretable terms and relations that represent entities and their relations in the biological/biomedical world. Biomedical ontologies have emerged as a major tool for the integration and analysis of the large amounts of heterogeneous biological data available in the post-genomics era.

To support ontology development and applications, we have developed a collection of "Ontoanimal" tools, including OntoFox (Xiang et al., 2010), Ontodog (Zheng et al., 2014), Ontorat (Xiang et al., 2015), Ontobee (Xiang et al., 2011), Ontobeep (Xiang and He, 2010), and Ontobat (Xiang et al., 2015). The back-end of these Ontoanimal tools is the He group's RDF triple store (http://sparql.hegroup.org), which has become the default ontology RDF triple store for the Open Biological and Biomedical Ontologies (OBO) Foundry ontologies. Fig. 1 provides a summary of these tools.

Although initially developed to meet the needs of Vaccine Ontology (VO) development (He et al., 2009;Ozgur et al., 2011), the Ontoanimal tools have been widely used in a broader range of users for various applications. According to Google Analytics, in the past five years, over 8,000 and 35,000 users from >10 countries have routinely used the OntoFox and Ontobee web programs, respectively. According to Google Scholar, our Ontoanimal tools have been cited in over 200 publications.

To provide a whole picture of how these tools work and interact, here we briefly introduce general features of each Ontoanimal tool and how these tools can be used to support different applications.
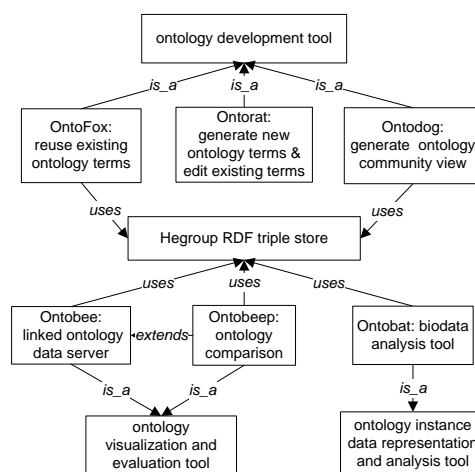
2 ONTOANIMAL TOOLS

Fig. 1. Ontoanimal tools and their features

2.1 OntoFox: Extract ontology terms and axioms

Reusing a portion of an existing ontology is often required in the ontology development process. After a user provides a single or a set of terms of interest, OntoFox (http://ontofox.hegroup.org/) is able to fetch selected classes, properties, annotations, and their related terms from source ontologies and save the results in the OWL format (Xiang et al., 2010). OntoFox implements the Minimum Information to Reference an External Ontology Term (MIREOT) strategy by extracting minimum information of requested terms (Courtot et al., 2011). In addition, by providing different options, OntoFox can extract different levels of intermediate terms between the required terms and a chosen higher level or top term. Inspired by existing ontology modularization techniques (Stuckenschmidt et al., 2009). OntoFox also implements a new SPARQL-based ontology term extraction algorithm that extracts all terms and axioms related to a given set of user-provided terms (Xiang et al., 2010).

2.2 Ontodog: Generate ontology community view

Similar to OntoFox, the web-based Ontodog program (http://ontodog.hegroup.org/) is able to extract a subset of ontology terms and axioms (Zheng et al., 2014). Unlike On-toFox, Ontodog includes two unique features. First, On-todog allows the generation of an ontology community view, which we have defined as "the whole or a subset of the source ontology with *user-specified annotations includ-*

* To whom correspondence should be addressed:yongqunh@umich.edu

ing user preferred labels" (Zheng et al., 2014). Second, Ontodog uses Excel input files to identify which terms to retrieve and to add user-specified annotations. Excel templates are also provided for easy implementation.

2.3   Ontorat: Adding new terms and new axioms to an ontology based on design pattern

The Ontorat program (http://ontorat.hegroup.org) automatically generates and edits ontology terms and axioms and provides term annotations (Xiang et al., 2015). Ontorat uses reusable ontology design patterns (ODPs) to solve recurrent modeling problems. A specific ODP can be used to derive an Excel template of different terms/annotations and a set of rules that define the relations among those terms/annotations. An Ontorat template is similar to a QTT (Quick Term Template) (Rocca-Serra et al., 2011). Such a template can be populated with specific terms or annotations to define or annotate specific ontology terms. With the support of the Ontorat settings, the populated template spreadsheet can then be converted into an OWL file with newly generated ontology terms and axioms.

2.4   Ontobee: Linked data server for web displaying and dereferencing ontology terms

Ontobee (http://www.ontobee.org) is an ontology browser and a linked ontology data server for dereferencing ontology terms (Xiang et al., 2011). To date, there are 156 ontologies listed on Ontobee. Ontobee loads individual page for each term in an ontology. All related information of a single term, such as label, definition, synonyms, superclass hierarchy, logical axioms, and term usage by other ontologies is displayed. In addition, for each ontology, Ontobee generates statistics with counts of classes, object properties, annotation properties, and datatype properties based on term ontology prefixes. Furthermore, Ontobee automatically provides an Excel document listing all terms in an ontology. Ontobee provides ontology term search and SPARQL query service supported by the He group triple store. Ontobee is a *de facto* search engine for OBO Foundry ontologies.

2.5   Ontobeep: Ontology comparison

Ontobeep (http://www.ontobee.org/ontobeep/) is an ontology comparison program. Ontobeep can be used to compare different ontologies by aligning them from the roots of these ontologies. The alignment identifies common terms existing in two or three ontologies. Ontobeep also provides a statistic report of the alignment analysis. Ontobeep may be utilized to detect inconsistency and term duplication in one or more ontologies.

2.6   Ontobat: Ontology-based data analysis

Unlike other Ontoanimal tools, Ontobat (http://ontobat.hegroup.org) focuses on instance level ontology data generation and analysis (Xiang et al., 2014). Ontobat aims to support Linked Open Data (LOD) generation,

upload, query, browsing, and statistical analysis. Many features of Ontobat are still under development. .

3   SUMMARY

The web-based Ontoanimal tools suite provides a set of comprehensive tools to support ontology development and applications. These tools save time and efforts for ontology developers and users, especially those who do not have or have limited software programming background.

ACKNOWLEDGEMENTS

REFERENCES

Courtot, M., Gibson, F., Lister, A., Malone, J., Schober, D., Brinkman, R., and Ruttenberg, A. (2011). MIREOT: the Minimum Information to Reference an External Ontology Term. *Applied Ontology* 6, 23-33.

He, Y., Cowell, L., Diehl, A.D., Mobley, H.L., Peters, B., Ruttenberg, A., Scheuermann, R.H., Brinkman, R.R., Courtot, M., Mungall, C., Xiang, Z., Chen, F., Todd, T., Colby, L.A., Rush, H., Whetzel, T., Musen, M.A., Athey, B.D., Omenn, G.S., and Smith, B. (Year). "VO: Vaccine Ontology", in: *The 1st International Conference on Biomedical Ontology (ICBO-2009)*: Nature Precedings), http://precedings.nature.com/documents/3552/version/3551.

Ozgur, A., Xiang, Z., Radev, D.R., and He, Y. (2011). Mining of vaccine-associated IFN-gamma gene interaction networks using the Vaccine Ontology. *J Biomed Semantics* 2 Suppl 2, S8.

Rocca-Serra, P., Ruttenberg, A., O'connor, M.J., Whetzel, P.L., Schober, D., Greenbaum, J., Courtot, M., R.R., B., S.A., S., R., S., Consortium, T.O., and Peters, B. (2011). Overcoming the ontology enrichment bottleneck with quick term tem-plates. *Applied Ontology* 6, 13-22.

Stuckenschmidt, H., Parent, C., and Spaccapietra, S. (2009). *Modular Ontologies: Concepts, Theories and Techniques for Knowledge Modularization.* Springer.

Xiang, Z., Courtot, M., Brinkman, R.R., Ruttenberg, A., and He, Y. (2010). OntoFox: web-based support for ontology reuse. *BMC Res Notes* 3:175, 1-12.

Xiang, Z., and He, Y. (2010). IDO extensions alignment using Ontobeep. IDO Workshop 2010. URL: http://ontology.buffalo.edu/2010/IDO/xiang.pptx.

Xiang, Z., Lin, Y., and He, Y. (Year). "Ontobat: An Ontology-based semantic web approach for linked data processing and analysis", in: *Proceedings of the 5nd International Conference on Biomedical Ontologies (ICBO)*: CEUR Workshop Proceedings), Pages 93-95 [http://ceur-ws.org/Vol-1327/icbo2014_paper_1358.pdf]

Xiang, Z., Mungall, C., Ruttenberg, A., and He, Y. (Year). "Ontobee: A linked data server and browser for ontology terms", in: *The 2nd International Conference on Biomedical Ontologies (ICBO)*: CEUR Workshop Proceedings), Pages 279-281 [http://ceur-ws.org/Vol-833/paper248.pdf].

Xiang, Z., Zheng, J., Lin, Y., and He, Y. (2015). Ontorat: Automatic generation of new ontology terms, an-notations, and axioms based on ontology design patterns. *Journal of Biomedical Semantics* 6, 4 (10 pages).

Zheng, J., Xiang, Z., Stoeckert, C.J., Jr., and He, Y. (2014). Ontodog: a web-based ontology community view generation tool. *Bioinformatics* 30, 1340-1342.