Package-based Description Logics - Preliminary Results

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Many representative applications on the semantic web, including collaborative ontology building, partial ontology reuse, selective knowledge hiding and distributed data management, call for modular ontologies,. However, although OWL allows using `owl:imports` to connect multiple ontologies, its current semantics requires all involved ontologies to have a single global semantics, thus providing only a syntactical solution to modularity. As a result, there is a growing interest in modular ontology languages such as Distributed Description Logics (DDL) [7] and $\mathcal{E}$-connections [8]. However, these proposals are also limited in expressivity and reasoning soundness [2,3].

Package-based Description Logics (P-DL) [4] is aimed at solving several problems presented in existing approaches, by offering a tradeoff between the strong *module disjointness* assumption of DDL and $\mathcal{E}$-connections, and the *complete overlapping* of models required by the OWL importing mechanics. P-DL language features are aimed at providing fine-grained modular organization and controllable selective knowledge sharing of an ontology.

P-DL syntax adopts a selective "importing" approach that allows a subset of terms defined in one ontology module to be directly used in another module. In a P-DL ontology, an ontology is composed of a set of packages. A package can use terms defined other packages i.e., an existing package or some of the terms defined in an existing package can be *imported* into another package. Foreign terms can be used to construct local concepts.

P-DL also allows selective knowledge hiding in ontology modules to address the needs of privacy, copyright, security concerns in ontologies. P-DL supports *scope limitation modifiers* (SLM) that can be associated with terms and axioms defined in a package [4]. A SLM (such as *public* and *private*) controls the visibility of the corresponding term or axiom to entities (e.g. a user, a reasoner) on the web, in particular, to other packages. Different from the encryption of ontology which is aimed at safe access of ontologies on a *syntactic* level, SLM in P-DL aims at knowledge hiding on a *semantic* level, where the hiding is *partial*, i.e., hidden parts of an ontology can be used in *safe* indirect inferences [5].

The semantic importing approach adopted by P-DL is different from the "linking" approach adopted by DDL and $\mathcal{E}$-Connections in that it partially relaxes the local model disjointness assumption of the other two formalisms. Such a relaxation enables P-DL to obtain stronger expressivity power. Concept bridge rules in DDL and $\mathcal{E}$-Connection links can be easily reduced to P-DL axioms [3]. P-DL also offers the possibility of avoiding semantic difficulties of DDL and $\mathcal{E}$-

Connections. For example, knowledge in one P-DL package can be transitively reused by other packages. The answer to a P-DL reasoning problem is the same as that obtained by reasoning over the integrated ontology [3].

The reasoning procedure for P-DL can be extended from existing DL tableau algorithms [1]. We adopt a tableau-based federated reasoning approach to strictly avoid reasoning with an integrated ontology, thus ensure the autonomy of constituting modules. The whole reasoning process is preformed by a federation of local reasoners, each for a specific package, to construct a collection of local tableaux instead of a single global tableau. The connection between local tableaux is enabled by a set of messages and a local tableau may share nodes with other local tableaux. It is shown that this approach can solve many reasoning difficulties presented in existing approaches [1].

P-DL provides language features needed for efficient *collaborative* construction of large, modular ontologies. We have developed COB-Editor [6] that provides 'proof of concept' of this approach. COB-Editor is a modular ontology editor that enables building biological ontologies such as Gene Ontology. The editor allows ontology developers to create a community-shared ontology server, with the support for concurrent browsing and editing of the ontology. Multiple users can work on the same ontology on different packages (through locking mechanisms), without inadvertent overwriting the work of others.

Work in progress includes reasoning for more expressive P-DL languages and with knowledge hiding, and improved collaborative ontology building tools.

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