DRAOn : A Distributed Reasoner for Aligned Ontologies

Chan LE DUC, Myriam LAMOLLE,
Antoine ZIMMERMANN and Olivier CURE

Université Paris8-IUT de Montreuil, École Nationale Supérieure des Mines,
Université Marne La Vallée

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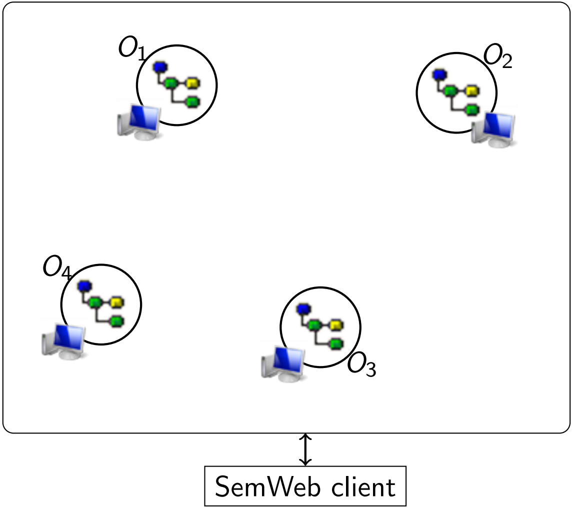
Motivation



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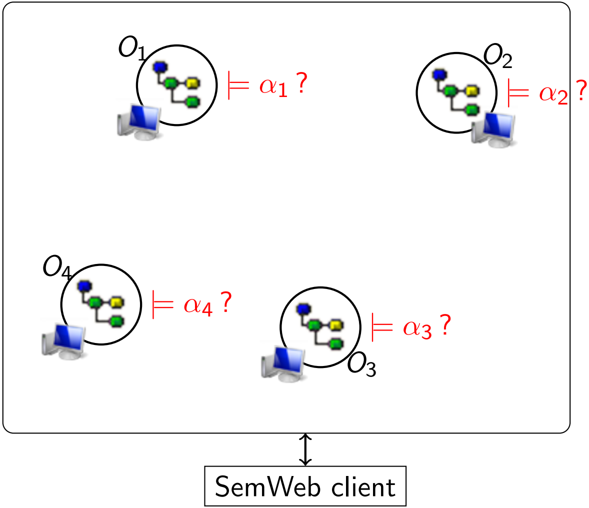
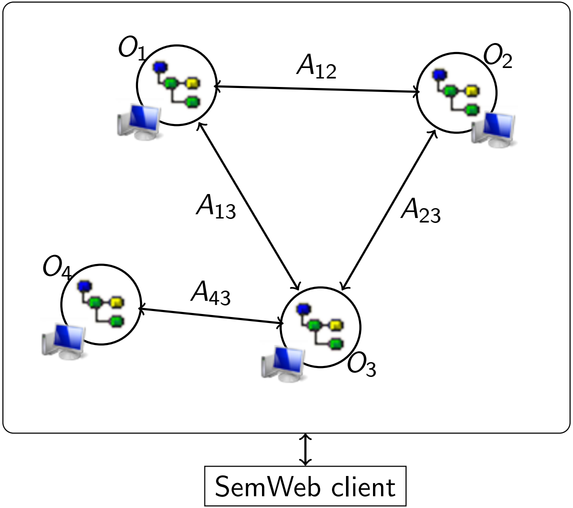

O_1
$\models \alpha_1$?
O_2
$\models \alpha_2$?
O_4
$\models \alpha_4$?
$\models \alpha_3$?
O_3
SemWeb client

Motivation



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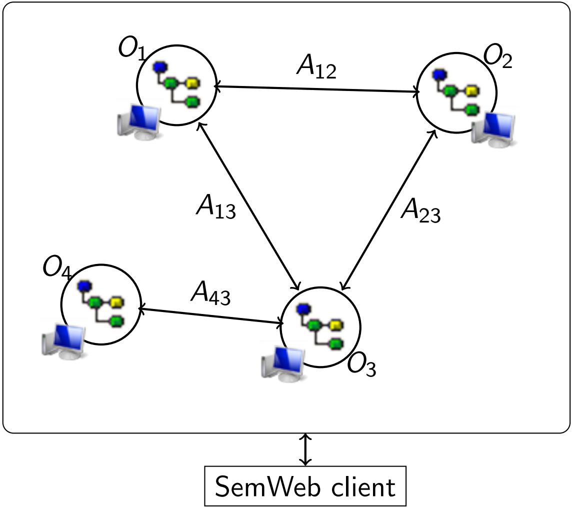


Is this network consistent ?

$\models$?

Formalizing a network of aligned ontologies

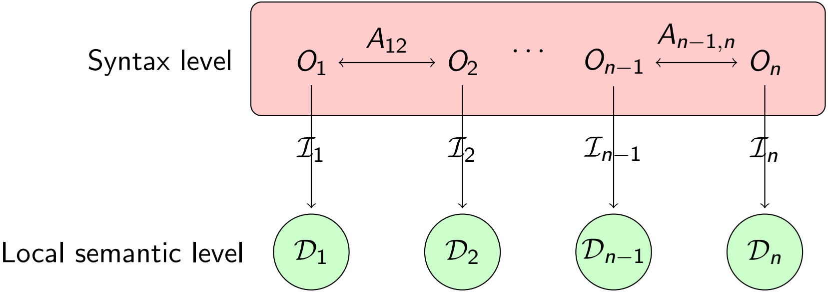
- Standard DL (merge of all ontologies and alignments) ;
- DDL (Distributed Description Logics) : Drago ;
- $\mathcal{E}$-connections : Pellet ;
- ...
- IDDL (Integrated Distributed Description Logics) :
  The decision procedure for IDDL (RR2008) can be implemented in a distributed way.

IDDL Semantics

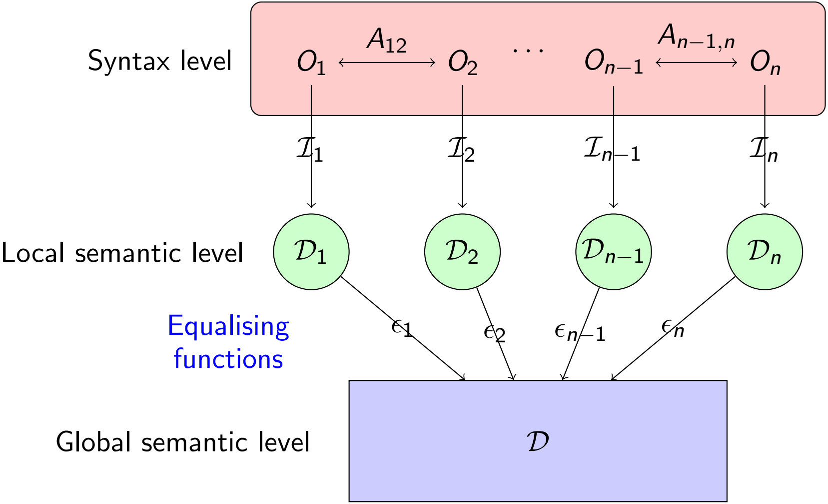
Syntax level

$$O_1 \xleftrightarrow{A_{12}} O_2 \quad \cdots \quad O_{n-1} \xleftrightarrow{A_{n-1,n}} O_n$$

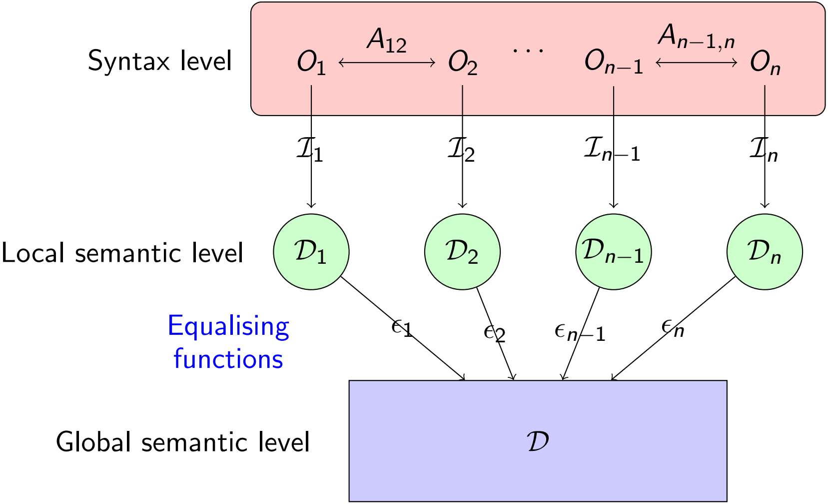
IDDL Semantics



IDDL Semantics



IDDL Semantics

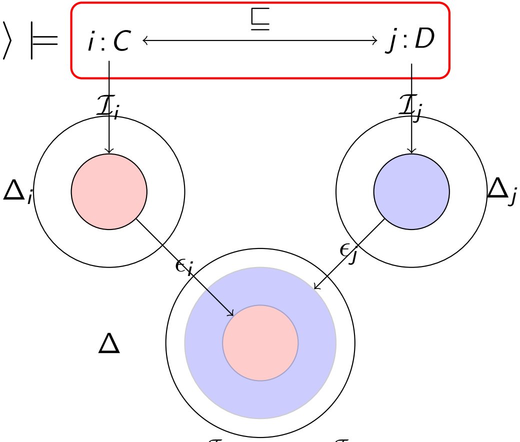


Global interpretation : $\mathcal{I} = \langle (\mathcal{I}_i), (\epsilon_i) \rangle$

IDDL Semantics

cross-ontology subsumption

$$\mathcal{I} = \langle (\mathcal{I}_i), (\epsilon_i) \rangle \models i : C \sqsubseteq j : D$$

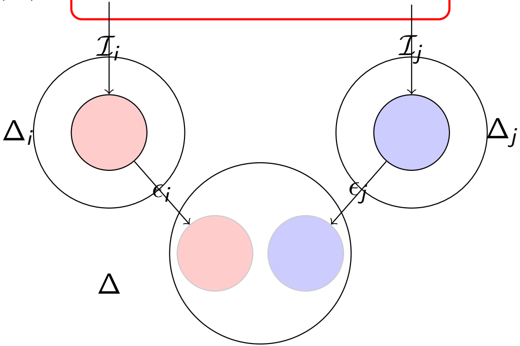


$$\epsilon_i(C^{\mathcal{I}_i}) \subseteq \epsilon_j(D^{\mathcal{I}_j})$$

IDDL Semantics

cross-ontology disjointness

$$\mathcal{I} = \langle(\mathcal{I}_i), (\epsilon_i)\rangle \models i : C \xleftrightarrow{\perp} j : D$$



$$\epsilon_i(C^{\mathcal{I}_i}) \cap \epsilon_j(D^{\mathcal{I}_j}) = \emptyset$$

$\langle \mathbf{O}, \mathbf{A} \rangle$ consistent iff there is a $\mathcal{I} = \langle(\mathcal{I}_i), (\epsilon_i)\rangle$ satisfying local axioms and correspondences

Global concepts and alignment ontology

Global concepts are concepts that appear on the right or left side of a correspondence :

$$\begin{array}{llcl} A_{12}: & 1{:}Superman & \stackrel{\sqsubseteq}{\longleftrightarrow} & 2{:}Person \\ A_{23}: & 2{:}Person & \stackrel{\sqsubseteq}{\longleftrightarrow} & 3{:}Vertebrate \end{array}$$

The global concepts are $1{:}Superman$, $2{:}Person$ and $3{:}Vertebrate$

The *alignment ontology* renders the correspondences in the form of DL axioms :

The alignment ontology $\widehat{\mathbf{A}}$ contains the axioms

$$\begin{array}{c} 1{:}Superman \sqsubseteq 2{:}Person \\ 2{:}Person \sqsubseteq 3{:}Vertebrate \end{array}$$

Configuration

With only cross-ontology concept subsumption :

Definition

A *configuration* Ω asserts explicitly the emptiness or non emptiness of global concepts.

Example

$$\Omega = \{ \quad 1 : Superman \sqsubseteq \bot, \quad 2 : Person \sqsubseteq \bot, \quad 3 : Vertebrate(a) \quad \}.$$

a is a new individual name.

Algorithm (sketched)

With only cross-ontology concept subsumption :

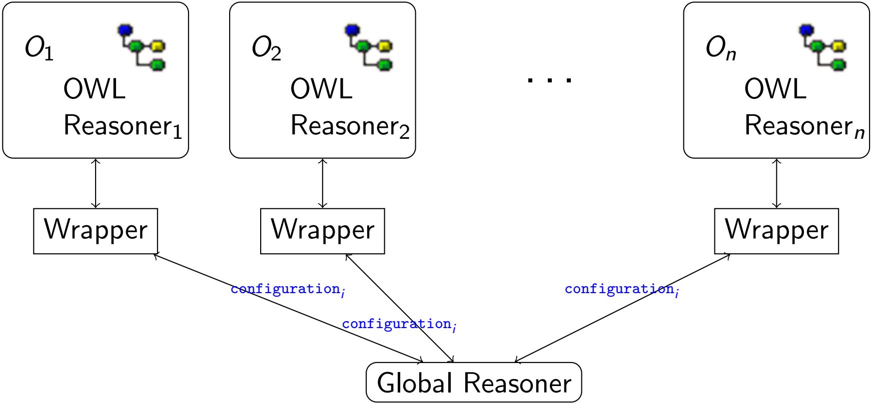
1. **Choose** a configuration Ω ;
2. **If Not** Consistent($\widehat{\mathbf{A}} \cup \Omega$), **Go To** 1
3. **For All** i,
   - **If Not** LocallyConsistent($\Omega \cup O_i$), **Go To** 1
4. **Return TRUE** ;

If all configurations were tested, **Return FALSE** ;

Properties of The Algorithm

- Encapsulated and parallelised local reasoners ;
- No upper bound on local expressiveness ;
- If a local reasoner is in EXPTIME class or higher, global consistency remains in the same class : $\mathrm{EXPTIME}^{(\mathrm{DL}_1,\cdots,\mathrm{DL}_n)}$ (no disjoint correspondences).

Architecture of DRAOn



Optimizations and Experiments

- Optimizations :
  - Eliminating from configurations equivalent concepts and roles
  - Eliminating from configurations $i : C$ if $O \models i : C(x)$ or $O \models (i : C \sqsubseteq \bot)$ where $O = \widehat{\mathbf{A}}$ or $O = O_i$
  - Testing configurations containing $(i : C(x))$ prior to $(i : C \sqsubseteq \bot)$
  - Building configurations in an incremental way

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  - Building configurations in an incremental way
- Experiments :

Ontology 1	Ontology 2	Alignment	DL	non-distr. IDDL	distr. IDDL
Small NCI (10,000 axioms, 6,500 entities)	Small FMA (3,800 axioms, 3,700 entities)	Alcomo Map. (2,800 corr.)	7,5s	46s	30s
Human (5,500 axioms, 3,300 entities)	Mouse (4,500 axioms, 2,750 entities)	Ref. Map. (1516 corr.)	6s	4.5s	4s

Further Work

- Further experiments for a large network of aligned ontologies
- Optimizations for disjoint correspondences
- Performance of DRAOn depends on services offered by OWL Reasoners :
  DRAOn has to use

  ```
  OWLReasoner.getUnsatisfiableClasses()
  OWLReasoner.getTypes(OWLNamedIndividual)
  ```

  to check whether a given set of concepts is unsatisfiable or non-empty.