

Learning and Reasoning about Uncertainty in the Semantic Web

Pedro Oliveira and Paulo Gomes

pcoliv@student.dei.uc.pt, pgomes@dei.uc.pt

EPIA 2009

*University of Coimbra
Faculty of Sciences and Technology
Department of Informatics Engineering*



*Knowledge and Intelligent Systems Laboratory
Cognitive and Media Systems Group
Centre of Informatics and Systems of the University of Coimbra*



Overview

- **Semantic Web**
- **Markov Logic**
- **Markov Logic + Semantic Web**
 - Formulas
 - Weights
- **Experimentation**
- **Conclusions**

Semantic Web

■ Semantic Web

- Bring structure to the meaningful content of Web pages
- Knowledge represented by ontologies
 - OWL (Full,DL,Lite), OWL2, ...
- None of them provide means of dealing with uncertainty

Markov Logic

■ Markov Logic

- First-order logic and Markov networks in the same representation
- A world that violates a formula is not invalid, but less probable
- Attaching weights to first-order logic formulas
 - The higher the weight, the bigger is the difference between a world that satisfies the formula and one that does not

$$P(X = x) = \frac{1}{Z} \exp \left(\sum_{i=1}^F w_i n_i(x) \right)$$

Markov Logic + Semantic Web

■ Markov Logic = Formulas+Weights

■ Formulas

- Semantic Web ontology languages like OWL2 follow a model-theoretic semantics

| OWL2 Axiom | First-order logic formula |
|-------------------------------------|--|
| <i>SubClassOf</i> (CE_1, CE_2) | $\forall x : CE_1(x) \Rightarrow CE_2(x)$ |
| <i>TransitiveProperty</i> (OPE) | $\forall x, y, z : OPE(x, y) \wedge OPE(y, z) \Rightarrow OPE(x, z)$ |
| <i>ClassAssertion</i> (CE, a) | $CE(a)$ |

Markov Logic + Semantic Web

■ Weights

- Given by ontology creators
 - Cumbersome and difficult task
- Learned
 - Weights can be learned generatively through example data
 - Maximize the *pseudo-log-likelihood* of that data
 - Ontology Individuals = Example Data

Experimentation

■ The Financial Experiment

- Ontology about a bank and its services
 - 116 class/property axioms and 297 individuals
- Predict the probability of a certain loan satisfying the conditions necessary for being a problematic loan

Experimentation

■ The Social Network Experiment

■ Advogato FOAF network

- 6688 individuals (4198 users, 2487 projects, and 3 groups)

- $\text{knows}(x,y)$ $\text{currentProject}(x,y)$ $\text{member}(x,y)$

■ Link Prediction

- Predict the existence of a link between two users

| Weight | Formula |
|--------|--|
| 0.09 | $\text{knows}(x,y) \wedge \text{knows}(y,z) \Rightarrow \text{knows}(x,z)$ |
| 2.70 | $\text{knows}(x,y) \Leftrightarrow \text{knows}(y,x)$ |
| 1.11 | $\text{currentProject}(x,z) \wedge \text{currentProject}(y,z) \Rightarrow \text{knows}(x,y)$ |

Experimentation

■ The Social Network Experiment

■ Link-based Classification

- Predict the experience group (*Apprentice*, *Journeyer*, or *Master*) of an user

| Weight | Formula |
|--------|--|
| 0.19 | $\text{knows}(x,y) \wedge \text{member}(x,z) \Rightarrow \text{member}(y,z)$ |

■ Link-based cluster analysis

- Cluster users into groups that show similar relational characteristics.

Conclusions

■ Contributions

- Applied Markov Logic techniques to Semantic Web reasoning
- Studied not only reasoning under uncertainty in the Semantic Web, but also how to learn this uncertainty
- Unlike other approaches, use undirected probabilistic models

Conclusions

■ Future Work

- More experimentation
- Other ways to automatically learn the uncertainty of ontology axioms
 - Learn individuals
 - Learn the uncertainties directly from textual corpus
 - Use the structure of the ontology
 - Collective learning of weights
 - Trust propagation

Conclusions

■ More Information

- Incerto – A Probabilistic Reasoner for the Semantic Web based on Markov Logic

- <http://code.google.com/p/incerto>

- Pedro Oliveira. “Probabilistic Reasoning in the Semantic Web using Markov Logic”, MSc Thesis, University of Coimbra, 2009

- <http://student.dei.uc.pt/~pcoliv>

Learning and Reasoning about Uncertainty in the Semantic Web

Pedro Oliveira and Paulo Gomes

pcoliv@student.dei.uc.pt, pgomes@dei.uc.pt

EPIA 2009

Thank You!

<http://code.google.com/p/incerto> <http://student.dei.uc.pt/~pcoliv>