

# PR-OWL: Probabilistic Web Ontology Language

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# Outline

- 1 Motivation
- 2 Ontologies
- 3 Probabilistic Ontologies

## Motivation

## Semantic Web

*“The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation” [5]*

- Extension of the web through standards by W3C
- Change focus from data driven to knowledge driven

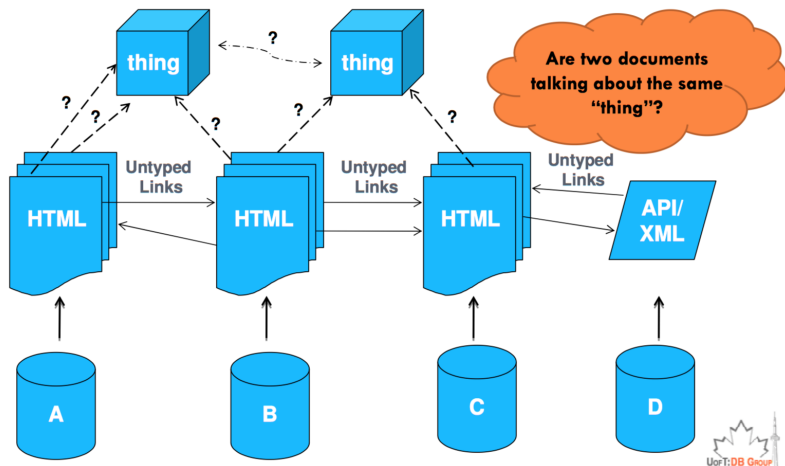


Figure 1: Document-oriented Web

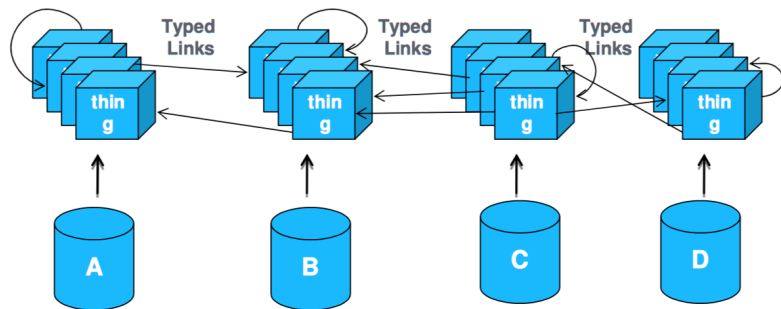


Figure 2: Data-oriented web

The main challenges that automated reasoning systems will have to deal in order to deliver on the promise of the Semantic Web are:

- Vastness
- Vagueness
- Uncertainty
- Inconsistency
- Deceit

The most used solution for Semantic Web are **Ontologies** (W3C).

# Ontologies



An ontology is an explicit, **formal knowledge representation** that express knowledge about a domain of application. This includes:

- Types of entities that exist in the domain
  - e.g.: Person, Enterprise, ...
- Properties of those entities
  - e.g.: firstName, lastName, ...
- Relationships among entities
  - e.g.: motherOf, ownerOf, ...
- Processes and events that happen with those entities
  - e.g.: choosing best proposal, ...

# How to represent ontologies?

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## Web Ontology Language (OWL)

- Created at 2004
- Developed by the W3C
- As a language to represent ontologies for the Semantic Web

Starship16 Protégé 3.2 beta (file:/Users/pc/Documents/Academia/Ontologies/Starship16.pprj, OWL / RDF Files)

File Edit Project OWL Code Tools Window Help

OWLClasses Properties Forms Individuals Metadata (starship.owl)

**SUBCLASS EXPLORER**

For Project: Starship16

Asserted Hierarchy

- owl:Thing
  - pr-owl:ArgRelationship
  - pr-owl:Axiom\_1
  - pr-owl:BuiltinRV
  - pr-owl:CondRelationship
  - pr-owl:Entity
    - pr-owl:BooleanRVStates
    - pr-owl:CategoricalRVStates
    - pr-owl:MetaEntity
    - pr-owl:ObjectEntity
      - Zone
      - TimeStep
      - Starship**
      - SensorReport
    - pr-owl:MFRag
      - pr-owl:Domain\_MFRag
      - pr-owl:Finding\_MFRag
    - pr-owl:MTheory
    - pr-owl:Node
      - pr-owl:Context
      - pr-owl:Input
        - pr-owl:Finding\_input
        - pr-owl:Generative\_input
      - pr-owl:Resident
        - pr-owl:Domain\_Res
        - pr-owl:Finding\_res
    - pr-owl:OVariable

**CLASS EDITOR**

For Class: Starship (Instance of owl:Class) ☐ Inferred View

Property	Value	Lang
rdfs:comment	according to the Treknology Encyclopedia L-2 # (http://www.ex-astris-scientia.org/treknology2.htm#s) Starship is the designation for a large type of space vessel with warp drive. A starship typically consists of more than one deck and has separate departments such as the bridge, engineering or sickbay. In our model, we use this word to designate any space vessel	

**Asserted Conditions**

NECESSARY & SUFFICIENT

NECESSARY

INHERITED

- pr-owl:ObjectEntity
  - pr-owl:hasType only pr-owl:MetaEntity [from pr-owl:Entity] C
  - pr-owl:hasType some pr-owl:MetaEntity [from pr-owl:Entity] C
  - pr-owl:hasType exactly 1 [from pr-owl:Entity] C
  - pr-owl:hasUID exactly 1 [from pr-owl:Entity] C
  - pr-owl:IsConditionantOf only pr-owl:ProbAssign [from pr-owl:Entity] C
  - pr-owl:IsPossibleValueOf only (pr-owl:Node or pr-owl:BuiltinRV) [from pr-owl:Entity] C
  - pr-owl:subOVar only pr-owl:OVariable [from pr-owl:ObjectEntity] C

**Disjoints**

- Zone
- TimeStep
- SensorReport

Logic View Properties View

Figure 3: Protégé program

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On the Web exists **uncertainty**.

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- Python
  - Result entity with types: animal or programming language?
- Python Cascabel
  - Result entity with types: animal or python library?

How to deal with uncertainty?

## Probabilistic Ontologies



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A **probabilistic** ontology is an explicit, formal knowledge representation that express knowledge about a domain of application. This includes:

- Types of entities that exist in the domain
- Properties of those entities
- Relationships among entities
- Processes and events that happen with those entities
- Statistical regularities that characterize the domain
- Inconclusive, ambiguous, incomplete, unreliable, and dissonant knowledge related to entities of the domain
- Uncertainty about all the above forms of knowledge

How to represent **probabilistic** ontologies?

# How to represent **probabilistic** ontologies?

## Some possible solutions

- Plates
  - Represent fragments of graphical models
  - Very useful with continuous attribute values
  - Can not represent directly uncertainty

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  - Represent uncertainty
  - Limited to attribute-value representation

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  - Limited to attribute-value representation
- Hidden Markov Models
  - They are a special case of Dynamic BNs
  - Capability for recursion

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## Some possible solutions

- Probabilistic Relational Models
  - Extend BNs to handle multiple entity types
  - Can not express quantified first-order sentences
  - Does not support recursion

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## Some possible solutions

- Probabilistic Relational Models
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  - Can not express quantified first-order sentences
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- DAPER
  - Combine entity-relational model with DAGs models
  - Express probabilistic knowledge
  - Does not support quantifiers

All of these representations can not successfully combine **Logic** and **Uncertainty**



## Multi-Entity BNs [2]

- Extends Bayesian Networks to provide first-order expressive power
- Extends first-order logic to provide probability distributions
- Support for recursion and quantifiers
- Built up from MEBN fragments or MFrag
- Every first-order sentence can be represented by an MFrag

## MEBN Fragment

An MFrags is a 5-tuple  $F = (C, I, R, G, D)$  where

- $C$  = finite set of *context* value assignments
- $I$  = finite set of *input* random variable terms
- $R$  = finite set of *resident* random variable terms
- $G$  = a fragment graph
- $D$  = local probability distributions for each  $r \in R$

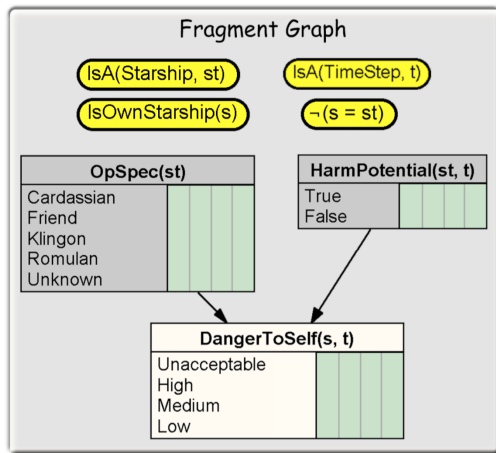


Figure 4: Danger To Self MFrags

## Multi-Entity Bayesian Networks

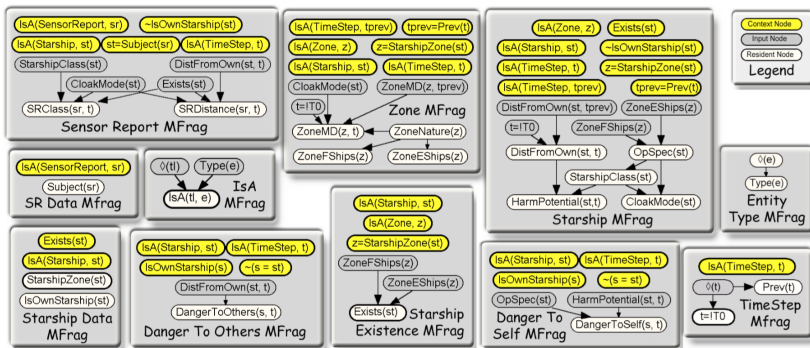


Figure 5: Star Trek MEBN

- Extension of OWL used for Ontologies
- Used to represent probabilistic ontologies
- Based on MEBN theory
- Still an active area for research

## Main Researchers

- Marcelo Ladeira, PhD (Universidade de Brasilia)
- Kathryn B. Laskey, PhD (George Mason University)



## Applications and studies

- UnBBayes: A probabilistic network framework for Probabilistic Ontologies [4]
- Probabilistic Ontology and Knowledge Fusion for Procurement Fraud Detection in Brazil [1]
- PR-OWL 2 Case Study: A Maritime Domain Probabilistic Ontology [3]

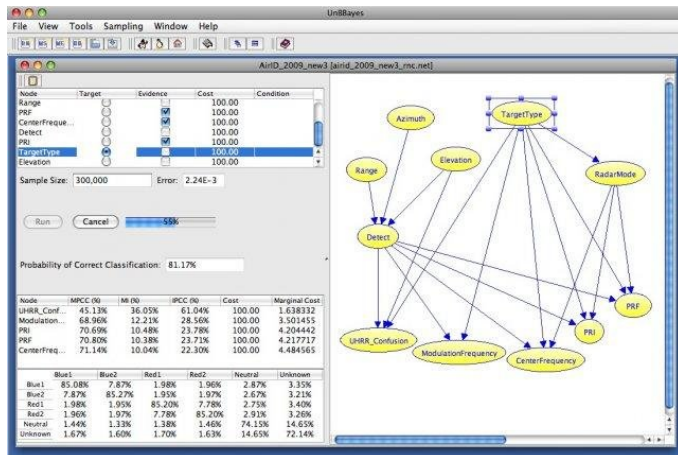


Figure 6: UnBBayes GUI



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