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An Evidential Approach for Modeling and Reasoning on Uncertainty in Semantic Applications

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- Introduction - Context
- Basis of Dempster-Shafer Theory
- DS-Ontology Modeling
- Evidential Reasoning on DS-Ontology
- Conclusion and Future Work

Introduction and Context

- Uncertainty
  - Important characteristic of data and information handled by real-world applications
  - Refers to a variety of forms of imperfect knowledge
    - such as incompleteness, vagueness, randomness, inconsistency and ambiguity



  - We consider
    - **epistemic** uncertainty
      - due to **lack of knowledge** (incompleteness)
    - **inconsistency**
      - due to **conflicting** testimonies or reports

- Objective : tackle the issue of representing and reasoning on this type of uncertainty in semantic applications, by using the Dempster–Shafer theory

Introduction and Context

- Context of our applications
  - Goal: form the most informative and consistent view of the situation
  - Situation observed by multiple sources
  - These observations populate our domain ontology

- Represent & Reason about uncertainty
  - Within the **instantiation of the domain ontology** → assertionnal knowledge

Uncertainty Theories and the Dempster-Shafer Theory

- Probability Theory, Possibility Theory, etc.
- Dempster-Shafer Theory
  - Enables the representation of uncertainty, imprecision and ignorance
  - Fundamental notions
    - Discernment Frame
      - Set of hypothetical states
      - Assumptions: **exhaustive** and **exclusivity**

$$\Omega = \{H_1, H_2, ..H_N\}$$

    - Basic Mass Assignment
      - Part of belief placed strictly on one or several elements of Ω

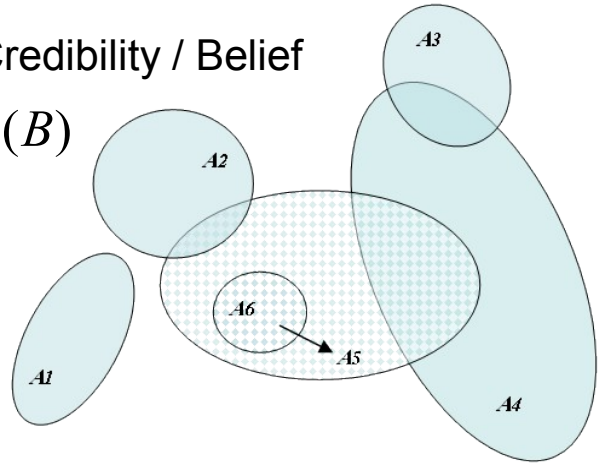
$$m : 2^{\Omega} \rightarrow [0,1] \qquad m(\emptyset) = 0 \qquad \sum_{A \in 2^{\Omega}} m(A) = 1$$

Basis of Dempster-Shafer Theory

- Fundamental notions (con't)
  - Other belief functions

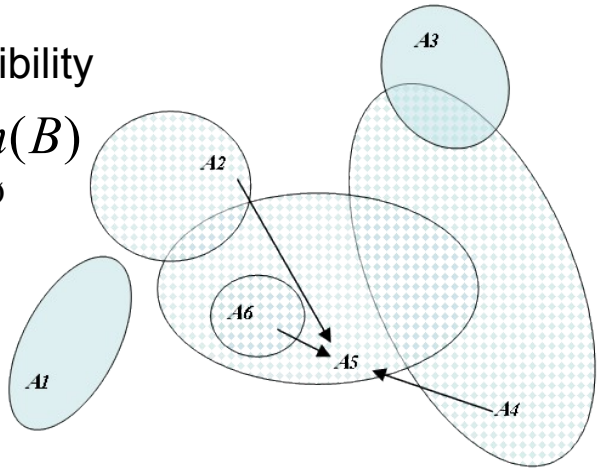
Credibility / Belief

$$bel(A) = \sum_{B \mid B \subseteq A} m(B)$$



Plausibility

$$pl(A) = \sum_{B \mid B \cap A \neq \emptyset} m(B)$$



  - Combination rules

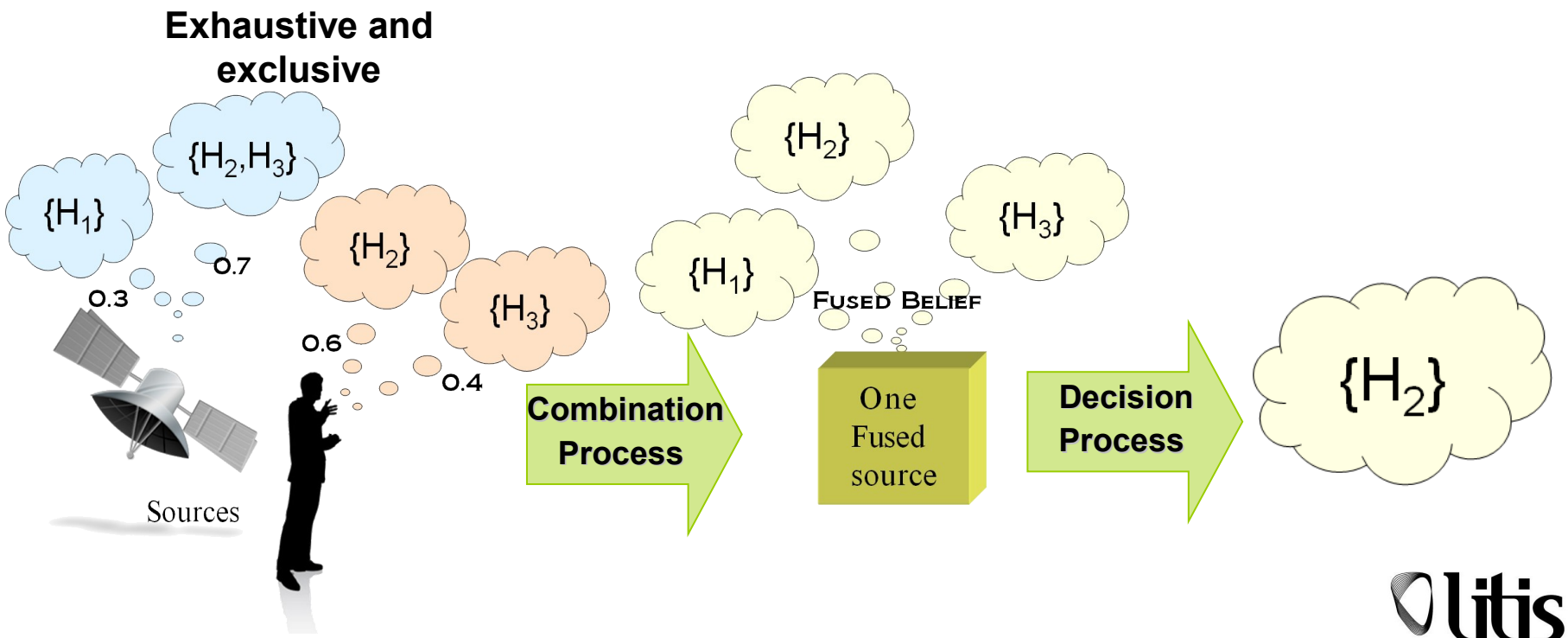
$$(m_1 \oplus m_2)(A) = \begin{cases} \dfrac{\sum_{B \cap C = A} m_1(B) m_2(C)}{1 - K_{12}} & A \neq \emptyset \\ 0 & A = \emptyset \end{cases}$$

where $K_{12} = \sum_{B \cap C = \emptyset} m_1(B) m_2(C)$

Basis of Dempster-Shafer Theory

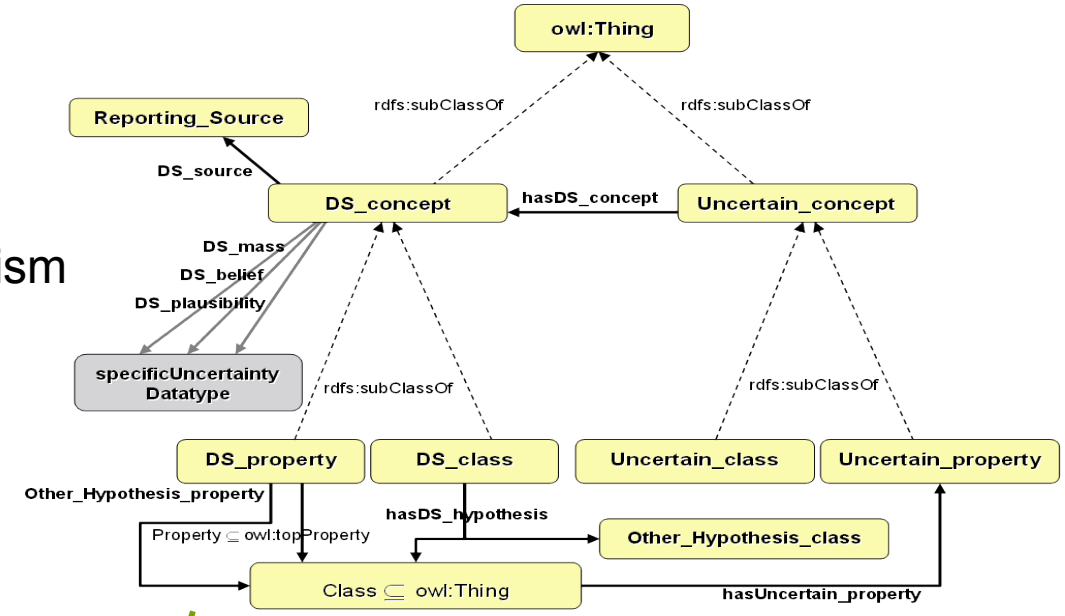
- Classical and global Dempster-Shafer Process

$$\Omega = \{H_1, H_2\ H_3\}$$

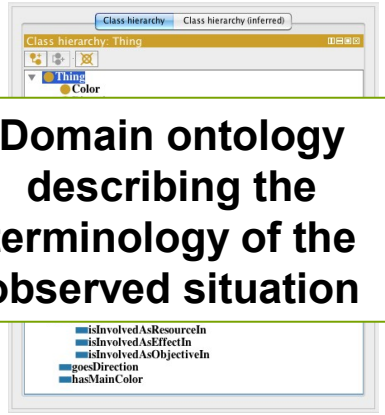


DS-Ontology Modeling

- **DS-Ontology**
  - Ontology representing Dempster-Shafer (DS) formalism
    - Principal concepts:
      - mass,
      - belief,
      - plausibility,
      - source,
      - etc.
  - Process of use

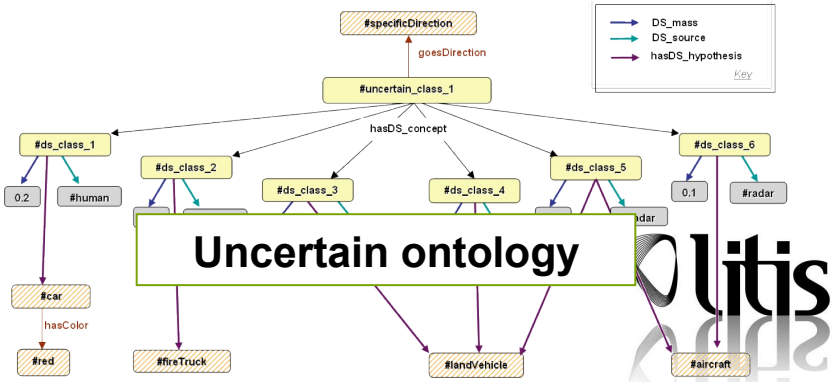


Import



Domain ontology describing the terminology of the observed situation

Instantiate in an uncertain manner



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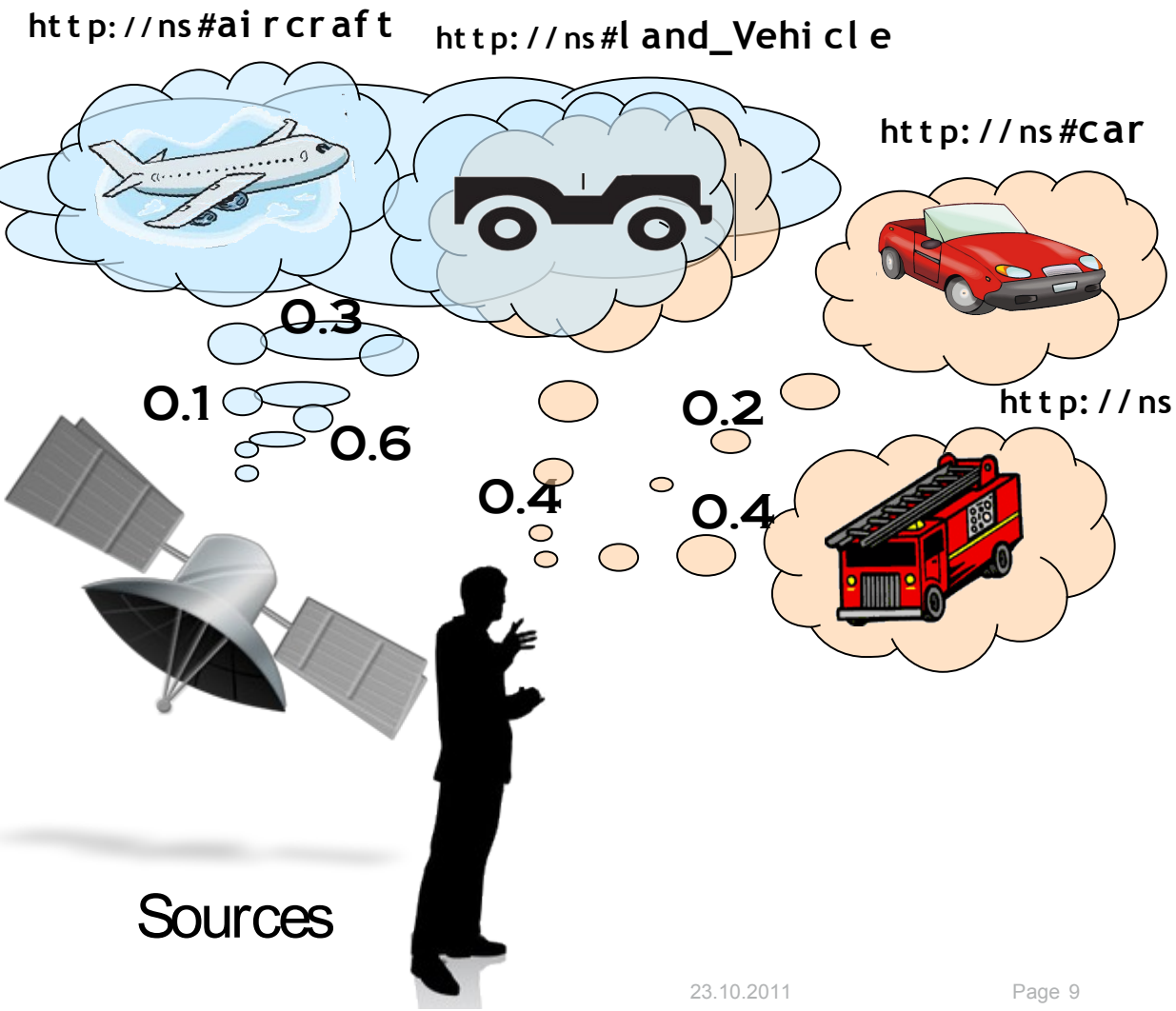
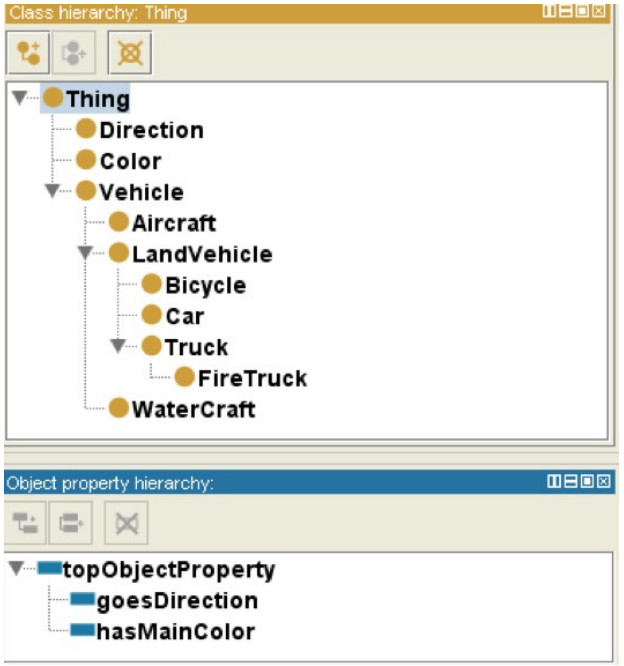
DS-Ontology Modeling

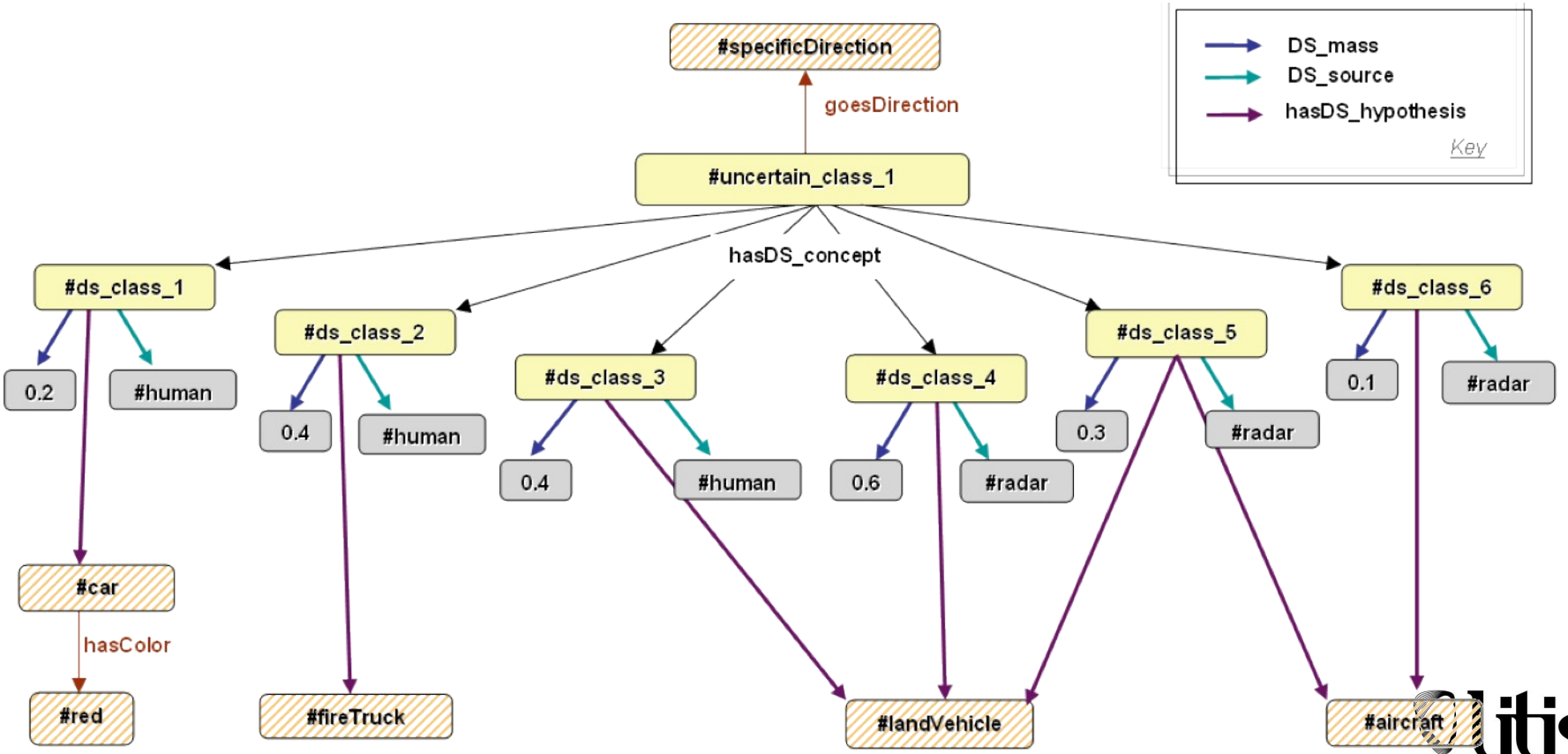
- Instantiation Example
  - Uncertain individuals scenario





DS-Ontology Modeling

- Instantiation Example (Con't)
  - Uncertain individuals scenario



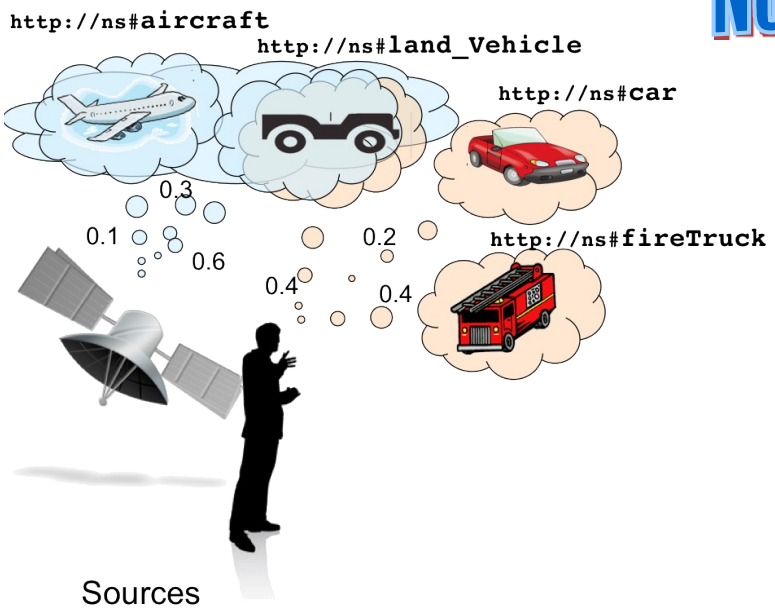
Evidential Reasoning on DS-Ontology

- Dempster-Shafer Process in Semantic application

Set of candidate instances = {**http://ns#aircraft**, **http://ns#car**, **http://ns#fireTruck**, **http://ns#land_Vehicle**}

NOT Exclusive ➔ ≠ Ω

Not ideal and academic case !



Combination Process

Evidential Reasoning on DS-Ontology

- **Automatic generation** of the discernment frame Ω
  - Reorganisation of the set of candidate instances
    - in order to satisfy the exclusivity assumption
  - Compute « semantic inclusion and intersection »
    - Computed for each couple of candidate instances
    - Semantic Inclusion
      - For property
        - » If P1 has for ancestor P2, then P1 ⊂ P2
      - For individuals
        - » If I1 has the class - or an ancestor of the class - of I2, and properties of I2 are also properties of I1, then I1 ⊂ I2
    - Semantic Intersection
      - (see next slide)

Evidential Reasoning on DS-Ontology

- Semantic Intersection
  = semantic similarity measure exceeding a specific threshold

  – Similarity Measure relying on the domain ontology
    = global function combining existing similarity measures defined in literature

    » Class of individuals
      » Wu and Palmer measure

$$conSim(C1, C2) = \frac{2 * depth(C)}{depth_C(C1) + depth_C(C2)}$$

    » Relations between individuals
      » Nb of common properties vs. different properties

$$propSim(I1, I2) = \frac{2 * nbPropComm(I1, I2)}{nbProp(I1) + nbProp(I2)}$$

  – Granularity of the set of candidate instances
    » E.g.: 1st set of candidate instances {#car, #minivan, #aircraft}
      » #car ∩ #aircraft = ∅
      2nd set of candidate instances {#car, #aircraft, #book}
      » #car ∩ #aircraft ≠ ∅
    » Threshold automatically calculated
      » clustering method

Evidential Reasoning on DS-Ontology

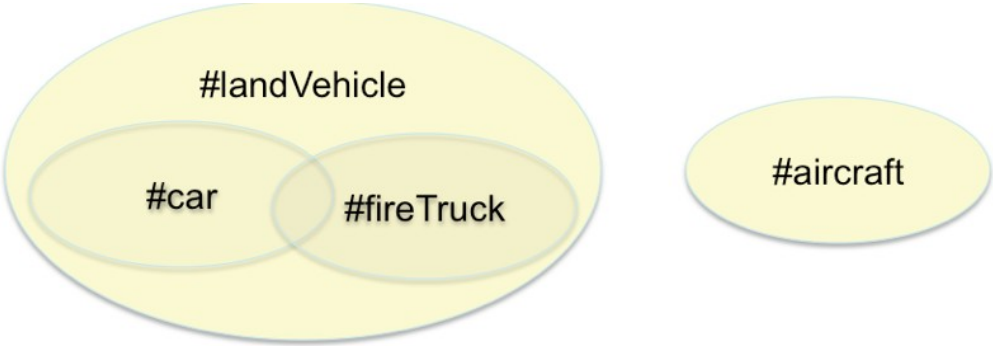
- Translation to Ω

If #inst1 ∩ #inst2,
Then, #inst1 := {H1, Hinters} and #inst2 :={H2, Hinters}

If #inst1 ⊂ #inst2,
Then, #inst1 := {H1} and #inst2 := {H2, H1}

- E.g.:

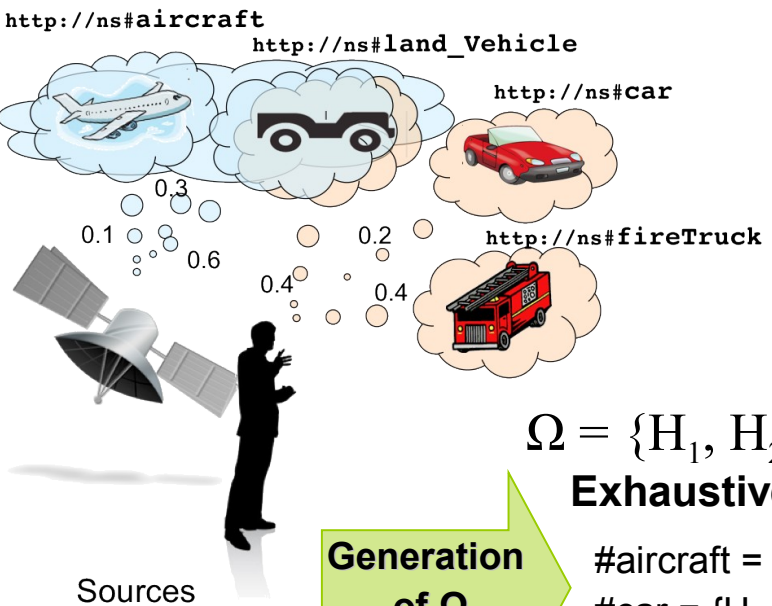
Set of candidate instances
= {http://ns#aircraft,
http://ns#car,
http://ns#fireTruck,
http://ns#land_Vehicle}



  - Results of translation to Ω
    - #aircraft = $\{H_1\}$
    - #car = $\{H_2, H_3\}$
    - #fireTruck = $\{H_3, H_4\}$
    - #land_Vehicle = {H2, H3, H4, H5}

Evidential Reasoning on DS-Ontology

Set of candidate instances = {**http://ns#aircraft**, **http://ns#car**, **http://ns#fireTruck**, **http://ns#land_Vehicle**}



Sources

Generation of Ω

$\Omega = \{H_1, H_2, H3, H4, H5\}$

Exhaustive and exclusive

#aircraft = $\{H_1\}$
#car = $\{H_2, H_3\}$
#fireTruck = $\{H_3, H_4\}$
#land_Vehicle = $\{H_2, H_3, H_4, H_5\}$

Combination Process

One Fused source

Decision Process

Conclusion

- Possible solution in order to handle uncertainty within ontologies
  - Relying on current W3C standards
  - **Uncertain instantiation** of a domain ontology enabled by DS-Ontology
  - **Reasoning** on uncertainty is made possible through an automatic **generation of the frame of discernment**
- Future Works
  - Protégé plugin
  - Extend the reasoning over the Boolean inclusion and intersection of candidate instances?
    - Rearranging measures of belief and plausibility and of the rules of combination

Thank you for your attention!