BeliefOWL: An Evidential Representation in OWL ontology

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1. Motivation
2. Uncertainty in OWL
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- Interoperability between human and computers.
Motivation

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- Interoperability between human and computers.
- Information exchange among web applications.
**Motivation**

The semantic web envisions:
- Interoperability between human and computers.
- Information exchange among web applications.

So...

A need to a powerful tool to capture knowledge about concepts and their relations.

Ontology
<table>
<thead>
<tr>
<th>XML Markup Languages</th>
<th>OIL</th>
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<th>OWL</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
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</tr>
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## Motivation

### XML Markup Languages

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Motivation

XML Markup Languages

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<tr>
<th>Language</th>
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<tr>
<td>OWL</td>
<td>OWL is a crisp language. How to represent uncertainty?</td>
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Our approach

We propose a new approach for representing uncertain information in an OWL ontology:
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- **Ontology Tasks**: Representation and Reasoning
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- **Formalism for the reasoning**: Directed Evidential Network
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We propose a new approach for representing uncertain information in an OWL ontology:

- **Ontology Tasks**: Representation and Reasoning
- **Formalism for the representation**: Evidence Theory
- **Formalism for the reasoning**: Directed Evidential Network
- Only **classes** and the **relations** between them will be considered.
How uncertainty is used in OWL?

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Probability Theory

- Representation of probabilistic information using OWL or RDF(s) ontology (Fukushige, 2004).
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**But...**
Not all the problems can be solved with one of these theories.
Motivation for The Dempster-Shafer theory

Dempster-Shafer theory vs probability theory

A generalization of the probability theory.
Motivation for The Dempster-Shafer theory

Dempster-Shafer theory vs probability theory

A generalization of the probability theory.

Ignorance

Models easily the partial and the total ignorance.
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Models easily the partial and the total ignorance.

Beliefs Assignment
Beliefs can be assigned to sets of elements rather than to each element.
## Motivation for The Dempster-Shafer theory

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<td>Dempster’s combination rule [Shafer, 1976]</td>
<td>Dempster’s combination rule is used to combine heterogeneous information.</td>
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</table>
Directed Evidential Network

Qualitative Level: DAG
Directed Evidential Network

Quantitative Level: Conditional belief functions for each variable given its parents

```
bel(A)  bel(S)
bel[I,L](E)  bel[S](L)  bel[S](H)
bel[I,L](E)  bel[S](L)  bel[S](H)
bel[E](X)  bel[E](X)
```
BeliefOWL Framework
BeliefOWL Framework

OWL Ontology → Belief Extension to OWL → Evidential Ontology → Extraction of Belief Information
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Structural Translation Rules
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- OWL Ontology
- Belief Extension to OWL
- Evidential Ontology
- Extraction of Belief Information
- Structural Translation Rules
- DAG of the network
- Conditional Belief Tables Attribution
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- **OWL Ontology**
- **Belief Extension to OWL**
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- **Extraction of Belief Information**

**Steps in the BeliefOWL Framework**

1. ** structural translation rules**
2. **DAG of the network**
3. **Conditional Belief Tables**
4. **Attribution**
5. **Directed Evidential Network (DEVN)**
6. **Inference and Reasoning Tasks**

**Our solution:** BeliefOWL
Step 1: Belief Extension to OWL

- **OWL Ontology**
- **Belief Extension to OWL**
- **Evidential Ontology**
- **Extraction of Belief Information**

- **Structural Translation Rules**
- **DAG of the network**
- **Conditional Belief Tables Attribution**
- **Directed Evidential Network (DEVN)**
- **Inference and Reasoning Tasks**
Step 1: Belief Extension to OWL

Prior Evidence

The ontology taken as an example is from the Zhongli Ding's thesis (BayesOWL: A Probabilistic Framework for Semantic Web).
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Prior Evidence

- `<beliefDistribution>` enumerates the different masses of the elements of the frame of discernment. It has an object property `<hasPriorBel>`

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- `<priorBelief>` expresses the prior evidence and has a datatype property `<massValue>`.

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- `<beliefDistribution>` enumerates the different masses of the elements of the frame of discernment. It has an object property `<hasPriorBel>`
- `<priorBelief>` expresses the prior evidence and has a datatype property `<massValue>`.

**Example**

```xml
<beliefDistribution rdf:ID="bel(Animal)">
  <hasPriorBel rdf:resource="# m(a)/"/>
  <hasPriorBel rdf:resource="# m(\bar{a})/"/>
  <hasPriorBel rdf:resource="# m(\theta a)/"/>
</beliefDistribution>

<PriorBelief rdf:ID= "m(a)">
  <massValue>0.4</massValue>
</PriorBelief>

<PriorBelief rdf:ID= "m(\bar{a})">
  <massValue>0.5</massValue>
</PriorBelief>

<PriorBelief rdf:ID= "m(\theta a)">
  <massValue>0.1</massValue>
</PriorBelief>
```

The ontology taken as an example is from the Zhongli Ding’s thesis (BayesOWL: A Probabilistic Framework for Semantic Web).
Step 1: Belief Extension to OWL

Conditional Evidence
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Conditional Evidence

<beliefDistribution>
enumerates the different masses of the elements of
the frame of discernment. It has an object property
<hasCondBel>
**Step 1: Belief Extension to OWL**

**Conditional Evidence**

- `<beliefDistribution>` enumerates the different masses of the elements of the frame of discernment. It has an object property `<hasCondBel>`.

- `<condBelief>` expresses the conditional evidence and has a datatype property `<massValue>`.
Step 1: Belief Extension to OWL

Conditional Evidence

- `<beliefDistribution>` enumerates the different masses of the elements of the frame of discernment. It has an object property `<hasCondBel>`.
- `<condBelief>` expresses the conditional evidence and has a datatype property `<massValue>`.

Example

```xml
<beliefDistribution rdf:ID= "bel[A](ml)"/>
   <hasCondBel rdf:resource = "# m[{a}](ml)="/>
   <hasCondBel rdf:resource = "# m[{a}](\bar{ml})="/>
   <hasCondBel rdf:resource = "# m[{a}](\theta ml)="/>
</beliefDistribution>

<condBelief rdf:ID= "m[{a}](ml)"/>
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Step 2: Construction of the DAG

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   - Structural Translation Rules
     - DAG of the network
     - Conditional Belief Tables Attribution
       - Directed Evidential Network (DEVN)
       - Inference and Reasoning Tasks

2. **Belief Extension to OWL**
   - Evidential Ontology
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Step 2: Construction of the DAG

Primitive Class <owl:Class>

Animal
Step 2: Construction of the DAG

Subsumption Hierarchy \(<\text{rdfs:subClassOf}>\)

- Animal
  - Male
  - Human
Step 2: Construction of the DAG

\(<\text{owl:intersectionOf}>, \text{<owl:unionOf>}, \text{<owl:disjointWith}>\)
Step 2: Construction of the DAG

DAG of the evidential network

- Animal
- Male
- Man
- NodeUnion
- NodeInter1
- NodeDisjoint
- NodeInter2
- Female
- Human
- Woman
Step 3: Evidence Attribution

OWL Ontology → Belief Extension to OWL → Evidential Ontology → Extraction of Belief Information

Structural Translation Rules

Conditional Belief Tables Attribution

Directed Evidential Network (DEVN)

Inference and Reasoning Tasks
Step 3: Evidence Attribution

Assigning Masses

\[
m(A) = \begin{pmatrix} \bar{a} \\ \theta_A \end{pmatrix} \begin{pmatrix} 0.4 \\ 0.5 \\ 0.1 \end{pmatrix}
\]

\[
m[A](Ml) = \begin{pmatrix} a \\ \bar{a} \\ \theta_{ml} \end{pmatrix} \begin{pmatrix} 0.5 \\ 0 \\ 0.6 \\ 0.5 \\ 0.4 \end{pmatrix}
\]

\[
m(A)(H) = \begin{pmatrix} h \\ \bar{h} \end{pmatrix} \begin{pmatrix} 0.1 \\ 0 \\ 0.5 \\ 0.9 \\ 0.5 \end{pmatrix}
\]

\[
m[A](F) = \begin{pmatrix} \bar{f} \\ \theta_f \end{pmatrix} \begin{pmatrix} 0.8 \\ 0 \\ 0.6 \\ 0.2 \\ 0.4 \end{pmatrix}
\]

\[
m[F](W) = \begin{pmatrix} w \\ \bar{w} \end{pmatrix} \begin{pmatrix} 0.75 \\ 0 \\ 0 \\ 0.25 \\ 0.5 \end{pmatrix}
\]

\[
m[MI](M) = \begin{pmatrix} m \\ \bar{m} \end{pmatrix} \begin{pmatrix} 0.75 \\ 0.25 \\ 0.5 \\ 0 \\ 0.5 \end{pmatrix}
\]
Step 4: Inference in the network

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2. Structural Translation Rules
3. DAG of the network
4. Conditional Belief Tables Attribution
5. Directed Evidential Network (DEVN)
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Conclusion:

- Evidential extension to OWL is a new area of research.

Future Work:
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- Masses attributed automatically by a learning process.
Thanks For Attending