Geospatial Information with Description Logics, OWL, and Rules

Presenter: Charalampos Nikolaou
Outline

- Geospatial information with description logics and OWL
- OWL reasoners with geospatial capabilities
- Geospatial information with SWRL rules
Geospatial information with DLs and OWL

Three main approaches:

1. Use a DL as it is

2. Define a spatial DL (concrete domain approach)

3. Hybrid: OWL + Spatial ABox
Use a DL as it is
Use a DL as it is

Use OWL-DL

- **Regions** are represented by **concepts**
- **Points** are represented by **individuals**
- RCC-8 relations among regions expressed by DL axioms

Translation of $PO(X, Y)$ as

\[
\begin{align*}
Z_1 & \equiv X \cap \neg Y \\
Z_2 & \equiv \neg X \cap Y \\
Z_3 & \equiv \forall R. X \cap \forall R. Y \\
\end{align*}
\]

TBox

\[
Z_1(z_1) \quad Z_2(z_2) \quad Z_3(z_3)
\]

ABox
Use a DL as it is

Use OWL-DL

Discussion

- Impractical when implemented in a reasoner
  [Stocker-Sirin, OWLED’09]
- Unnatural modeling?
- Can we generalize the approach?
  - For example, can we define the concept of a dream house as one that is located inside a forest?
- How do we express disjunctions of RCC-8 relations (indefinite information)?
Define a spatial DL
(concrete domain approach)
Concrete domains

- Reason about specific domains (real numbers, time intervals, spatial regions)
- Formalization of a concrete domain using a first-order theory
- From **roles** to **features**: associate an individual to a value from a concrete domain
- Notation: $\mathcal{DL}(\mathcal{D})$
Concrete domains

Examples:

- Reals with order ($\mathbb{R}$)
  - **Domain**: the set of real numbers $\mathbb{R}$
  - **Predicates**: $<$ interpreted by the “less-than” relation

- Allen’s Interval Calculus
  - **Domain**: the set of time intervals
  - **Predicates**: Allen’s basic interval relations (before, starts, etc.) and Boolean combinations of them

- RCC-8 Calculus
  - **Domain**: the set of non-empty, regular closed subsets of $\mathbb{R}^2$
  - **Predicates**: basic RCC-8 relations ($\text{EQ}$, $\text{PO}$, etc.) and Boolean combinations of them
Concrete domains

**TBox**
Concept equivalences/inclusions can include features and concrete domain predicates

**ABox**
Assertions can associate an individual to values from a concrete domain
Concrete domains

Two state of the art approaches

- $\mathcal{ALC}(\text{RCC8}) : \mathcal{ALC}$ with RCC-8 calculus as the concrete domain
  - extension of model-theoretic semantics of $\mathcal{ALC}$
  - $\omega$-admissibility property
  - tableau-based technique

[Lutz-Milicic, JAR’07]
Concrete domains

Two state of the art approaches

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  - $\omega$-admissibility property
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- $\text{DL-Lite}^{\mathcal{F},\mathcal{R}}(\text{RCC8})$ : DL-Lite with RCC-8 calculus as the concrete domain
  - extension of model-theoretic semantics of DL-Lite
  - FOL-rewritability for unions of conjunctive queries

[Lutz-Milicic, JAR’07]
["Ozcep-Moller, DL’12]
An Example

- **DreamHouse**
  One that is located inside a pine forest and borders a lake
An Example

- **DreamHouse**
  One that is located inside a pine forest and borders a lake

\[\text{DreamHouse} \equiv \text{House} \sqcap \exists(\text{loc}), (\text{hasLake loc}).\text{EC} \]
\[\qquad \sqcap \exists(\text{loc}), (\text{hasForest loc}).\text{NTPP} \lor \text{TPP}\]
\[\text{DreamHouse} \subseteq \forall\text{hasForest}.\text{PineForest} \sqcap \forall\text{hasLake}.\text{Lake}\]
An Example

- **DreamHouse**
  One that is located inside a pine forest and borders a lake

\[
\text{DreamHouse} \equiv \text{House} \sqcap \exists \! (\text{loc}. (\text{hasLake loc}).\text{EC}) \\
\sqcap \exists (\text{loc}, (\text{hasForest loc}).\text{NTPP} \lor \text{TPP})
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An Example

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\[
\text{DreamHouse} \equiv \text{House} \sqcap \exists (loc), (\text{hasLake} \ loc).\text{EC} \\
\qquad \sqcap \exists (loc), (\text{hasForest} \ loc) \text{NTPP} \lor \text{TPP} \\
\text{DreamHouse} \sqsubseteq \forall \text{hasForest}.\text{PineForest} \sqcap \forall \text{hasLake}.\text{Lake}
\]
### An Example (classification)

- **ABox**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Expression</th>
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<tbody>
<tr>
<td>House(h)</td>
<td>loc(f, (v_f))</td>
</tr>
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<td>loc(h, (v_h))</td>
</tr>
<tr>
<td>hasLake(h, l)</td>
<td>loc(l, (v_l))</td>
</tr>
<tr>
<td></td>
<td>NTPP((v_h), (v_f))</td>
</tr>
<tr>
<td></td>
<td>EC((v_h), (v_l))</td>
</tr>
</tbody>
</table>
An Example (classification)

- **ABox**

  House(h) \hspace{1cm} \text{loc}(f, v_f) \hspace{1cm} \text{NTPP}(v_h, v_f)

  hasForest(h, f) \hspace{1cm} \text{loc}(h, v_h) \hspace{1cm} \text{EC}(v_h, v_l)

  hasLake(h, l) \hspace{1cm} \text{loc}(l, v_l)

- **Question**: Is individual $h$ a DreamHouse?
An Example (classification)

- **ABox**
  
  - House(h)
  - hasForest(h, f)
  - hasLake(h, l)
  - loc(f, v_f)
  - loc(h, v_h)
  - loc(l, v_l)
  - NTPP(v_h, v_f)
  - EC(v_h, v_l)

- **Question**: Is individual h a DreamHouse?
- **Answer**: Yes.
An Example (classification)

- **ABox**
  
<table>
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</tr>
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<td>hasLake(h, l)</td>
<td>loc(l, v_l)</td>
<td></td>
</tr>
</tbody>
</table>

- **Question**: Is individual \( h \) a DreamHouse?
- **Answer**: Yes.
- **Why?**
An Example (classification)

- **ABox**

  \[
  \begin{align*}
  \text{House}(h) & \quad \text{loc}(f, v_f) & \quad \text{NTPP}(v_h, v_f) \\
  \text{hasForest}(h, f) & \quad \text{loc}(h, v_h) & \quad \text{EC}(v_h, v_f) \\
  \text{hasLake}(h, l) & \quad \text{loc}(l, v_l) & \quad \text{NTTP}(v_h, v_l)
  \end{align*}
  \]

  DreamHouse \equiv \text{House} \sqcap \exists(\text{loc}), (\text{hasLake}\ \text{loc}).\text{EC} \\
  \quad \sqcap \exists(\text{loc}), (\text{hasForest}\ \text{loc}).\text{NTTP} \vee \text{TPP}

  DreamHouse \subseteq \forall\text{hasForest}.\text{PineForest} \sqcap \forall\text{hasLake}.\text{Lake}
An Example (classification)

- **ABox**

  \[
  \text{House}(h) \quad \text{loc}(f, v_f) \quad \text{NTPP}(v_h, v_f) \\
  \text{hasForest}(h, f) \quad \text{loc}(h, v_h) \quad \text{EC}(v_h, v_1) \\
  \text{hasLake}(h, l) \quad \text{loc}(l, v_1)
  \]

\[
\text{DreamHouse} \equiv \text{House} \sqcap \exists (\text{loc}), (\text{hasLake} \text{ loc}).\text{EC} \\
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\text{DreamHouse} \sqsubseteq \forall \text{hasForest}.\text{PineForest} \sqcap \forall \text{hasLake}.\text{Lake}
\]
An Example (classification)

- **ABox**

  - $\text{House}(h)$
  - $\text{loc}(f, v_f)$
  - $\text{NTPP}(v_h, v_f)$
  - $\text{hasForest}(h, f)$
  - $\text{loc}(h, v_h)$
  - $\text{EC}(v_h, v_l)$
  - $\text{hasLake}(h, l)$
  - $\text{loc}(l, v_l)$

$\text{DreamHouse} \equiv \text{House} \sqcap \exists (\text{loc}), (\text{hasLake loc}).\text{EC}$

$\sqcap \exists (\text{loc}), (\text{hasForest loc}).\text{NTPP} \lor \text{TPP}$

$\text{DreamHouse} \sqsubseteq \forall \text{hasForest. PineForest} \sqcap \forall \text{hasLake. Lake}$
An Example (classification)

- **ABox**

  \[
  \begin{align*}
  &\text{House}(h) & \text{loc}(f, v_f) & \text{NTPP}(v_h, v_f) \\
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  \text{DreamHouse} \sqsubseteq \forall\text{hasForest}.\text{PineForest} \sqcap \forall\text{hasLake}.\text{Lake}
  \]
Hybrid: OWL + Spatial ABox
Hybrid: OWL + Spatial ABox

General architecture

[Diagram showing the General architecture with DL, TBox, ABox, and DL Reasoning]

KB
Hybrid: OWL + Spatial ABox

General architecture

- DL
  - TBox
  - ABox

- DL Reasoning

- KB
Hybrid: OWL + Spatial ABox

General architecture

![Diagram showing the general architecture of a knowledge base (KB) with DL (Description Logic) and Spatial ABox reasoning](image-url)
Hybrid: OWL + Spatial ABox

1. Grutter et al.

2. Reasoner RacerPro (DL/OWL + Spatial ABox)

3. Reasoner PelletSpatial (DL/OWL + Spatial ABox)
Hybrid: OWL + Spatial ABox

Domain Knowledge (TBox)

- Introduction of roles (e.g., `partiallyOverlaps`) for RCC relations (e.g., `PO`)
- `spatiallyRelated`: top role for topological relations
- Role inclusion axioms for RCC relations
  \[
  \text{partiallyOverlaps} \sqsubseteq \text{spatiallyRelated}
  \]

Assertions (ABox)

- Assertion of the “connectsWith” relation, \( \text{connectsWith}(a, b) \), between two regions (individuals)

[Grütter et al., ISWC’08]
Hybrid: OWL + Spatial ABox

RCCBox

- Definition of RCC relations based on the “connectsWith” relation
  \[ P(x, y) \equiv \forall z (C'(z, x) \rightarrow C(z, y)) \quad \text{DC}(x, y) \equiv \neg C(x, y) \]

- Axioms for composition tables of RCC

Predicate \( C(x, y) \) corresponds to role connectsWith\((x, y)\) in ABox

[Grütter et al., ISWC’08]
Hybrid: OWL + Spatial ABox

Application

1. Input: a set of geometries (polygons in $\mathbb{Z}^2$)

2. Compute assertions of the form $\text{connectsWith}(a, b)$

3. Update ABox with new spatial relations according to definitions in RCCBox
   1. Should $\text{DC}(a, b)$ be inferred in RCCBox, then
   2. the role assertion $\text{disconnectedWith}(a, b)$ is inserted in ABox

4. Check spatial consistency of ABox using path consistency on the RCC network constructed from the spatial role assertions of the ABox

[Grüttet et al., ISWC’08]
The reasoner RacerPro

- **Description Logic**: $SHIQ$
- **Spatial Extension**: the ABox is associated to a spatial representation layer (RCC substrate)
- **RCC substrate**: offers representation and querying facilities for RCC networks

**Features**

- Representation of indefinite information: disjunctions of RCC relations can be used between two individuals
- Consistency checking of RCC networks
- Querying of **asserted** and **entailed** RCC relations using the query language nRQL

RacerPro: ABox Reasoning

- Spatial regions: \( a, b, \) and \( c \)

- Region \( a \) contains \( b \)
  
  \[(rcc\text{-related} \ a \ b \ (:ntppi \ :tppi))\]

- Region \( a \) is disjoint with \( c \)
  
  \[(rcc\text{-related} \ a \ c \ (:dc))\]
RacerPro: ABox Reasoning

- Spatial regions: a, b, and c

- Region a contains b
  
  \( (rcc\text{-}related \ a \ b \ (((ntppi :tppi))) \) 

- Region a is disjoint with c
  
  \( (rcc\text{-}related \ a \ c \ (:dc)) \)

(?) Which regions are disjoint?
RacerPro: ABox Reasoning

- Spatial regions: $a$, $b$, and $c$

- Region $a$ contains $b$
  \[(\text{rcc-related } a \ b \ ((:\text{ntppi} \ :\text{tppi})))\]

- Region $a$ is disjoint with $c$
  \[(\text{rcc-related } a \ c \ (:\text{dc}))\]

\[(\text{retrieve } (?x \ ?y) \ (\text{and } (?x \ ?y \ :\text{dc})))\]
RacerPro: ABox Reasoning

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  \]

\(?\text{(retrieve } (?x \ ?y) \ (\text{and} \ (?x \ ?y \ :\text{dc}))\)\)

\((a, c) \ \text{and} \ (c, b)\)
Dream House (definition)

- **DreamHouse**
  One that is located inside a pine forest and borders a lake

\[
\text{DreamHouse} \equiv \text{House} \sqcap \exists (loc), (\text{hasLake} \; loc).\text{EC} \\
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(implies DreamHouse

(and

(all hasForest PineForest)

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**Dream House (ABox reasoning)**

- **ABox**
  - Fire(f)
  - PineForest(n)
  - Lake(l)
  - House(h)
  - hasForest(h, n)
  - hasLake(h, l)
  - NTPP(h, n)
  - NTPP(n, f)
  - EC(h, l)
Dream House (ABox reasoning)

- **ABox**

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- **Question**: What are the houses that are threatened?
### Dream House (ABox reasoning)

- **ABox**
  
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- **Question**: What are the houses that are threatened?
- **Answer**: House $h$. 
## Dream House (ABox reasoning)

- **ABox**

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- **Question**: What are the houses that are threatened?
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- **Why?**
Dream House (ABox reasoning)

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h

l

n

f
Dream House (ABox reasoning)

- Fire(f)
- PineForest(n)
- Lake(l)
- House(h)
- hasForest(h, n)
- hasLake(h, l)
- NTPP(h, n)
- NTPP(n, f)
- EC(h, l)

Diagram:
- Node h connected to node n with NTPP
- Node f connected to node l with NTPP
Dream House (ABox reasoning)

- Fire(f)
- PineForest(n)
- Lake(l)
- House(h)
- hasForest(h, n)
- hasLake(h, l)
- NTPP(h, n)
- NTPP(n, f)
- EC(h, l)
- EC
- NTPP
- h
- l
- n
- f
Dream House (ABox reasoning)

Fire(f)  House(h)  NTPP(h, n)
PineForest(n)  hasForest(h, n)  NTPP(n, f)
Lake(l)  hasLake(h, l)  EC(h, l)
**Dream House (ABox reasoning)**

- Fire(f)
- PineForest(n)
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- House(h)
- hasForest(h, n)
- hasLake(h, l)
- NTPP(h, n)
- NTPP(n, f)
- EC(h, l)

![Diagram of relations between entities]

**Composition of edge**

\((v_h, v_n) \text{ and } (v_n, v_f)\)
Dream House (ABox reasoning)

\[
\begin{align*}
\text{Fire}(f) & \quad \text{House}(h) & \quad \text{NTPP}(h, n) \\
\text{PineForest}(n) & \quad \text{hasForest}(h, n) & \quad \text{NTPP}(n, f) \\
\text{Lake}(l) & \quad \text{hasLake}(h, l) & \quad \text{EC}(h, l)
\end{align*}
\]
Dream House (ABox reasoning)

Fire(f)  House(h)  NTPP(h, n)
PineForest(n) hasForest(h, n) NTPP(n, f)
Lake(l)  hasLake(h, l)  EC(h, l)

Diagram:
- h (House) connected to l (Lake) via EC
- h (House) connected to n (PineForest) via NTPP
- l (Lake) connected to n (PineForest) via NTPP
Dream House (ABox reasoning)

Fire(f)  House(h)  NTPP(h, n)
PineForest(n)  hasForest(h, n)  NTPP(n, f)
Lake(l)  hasLake(h, l)  EC(h, l)
The reasoner PelletSpatial

- **Description Logic**: OWL 2 ($\text{SROIQ}(D)$)

- **Spatial Extension**: Separate ABox for spatial data

- **Spatial ABox**: Topological relations are managed as a **basic** RCC-8 network (a single relation between two nodes)

**Features**

- Representation of definite information only

- Consistency checking of basic RCC-8 networks (path consistency)

- Querying of **asserted** and **entailed** basic RCC-8 relations using a subset of SPARQL (BGPs and operator AND)

Available from [http://clarkparsia.com/pellet/spatial](http://clarkparsia.com/pellet/spatial)
SWRL Rules
Geospatial information with SWRL rules

Extension of OWL for the representation of qualitative and quantitative spatial information (SOWL)

- RCC-8
- Directional relations (e.g., East, North-West), and
- Distance relations (e.g., “3Km away from Vienna”)
Geospatial information with SWRL rules

Modeling

- Point
  - X
  - Y
- Line
- Polyline
- MBR
  - Ymax
  - Ymin
  - Xmax
  - Xmin
- Footprint
- Location
  - WestOf
  - DistanceReg1-Reg2
  - Reg1
  - Reg2

Legend:
- subclass
- property
- class
- datatype
- instance

Batsakis et al., RuleML’11
Geospatial information with SWRL rules

Spatial assertions

- RCC-8 relations between two regions
- Directional relations between two regions
- Distance relations between two regions
- Geometry of regions (in subclasses of Footprint)

[Batsakis et al., RuleML’11]
Geospatial information with SWRL rules

Implementation of the previous framework using OWL

1. OWL 2 property axioms for expressing inverse, symmetry, and transitivity for spatial relations

[Batsakis et al., RuleML’11]
Geospatial information with SWRL rules

Implementation of the previous framework using OWL

1. OWL 2 property axioms for expressing inverse, symmetry, and transitivity for spatial relations

2. SWRL rules to
   - encode composition of spatial relations
   - compute the intersection of two sets of spatial relations
   - check spatial consistency (using Pellet)

[Batsakis et al., RuleML’11]
Geospatial information with SWRL rules

Implementation of the previous framework using OWL

1. OWL 2 property axioms for expressing inverse, symmetry, and transitivity for spatial relations

2. SWRL rules to
   - encode composition of spatial relations
     \[
     DC(X, Z) \leftarrow NTPP(X, Y) \land EC(Y, Z)
     \]
     \[
     DC_{EC}(X, Z) \leftarrow EC(X, Y) \land TPPi(Y, Z)
     \]
   - compute the intersection of two sets of spatial relations
   - check spatial consistency (using Pellet)

[Batsakis et al., RuleML’11]
Geospatial information with SWRL rules

Implementation of the previous framework using OWL

1. OWL 2 property axioms for expressing inverse, symmetry, and transitivity for spatial relations

2. SWRL rules to
   - encode composition of spatial relations
     
     $$DC(X, Z) \leftarrow NTPP(X, Y) \land EC(Y, Z)$$

     $$DC \lor EC(X, Z) \leftarrow EC(X, Y) \land TPPi(Y, Z)$$

     denotes disjunction of relations $DC$ and $EC$

   - compute the intersection of two sets of spatial relations
   - check spatial consistency (using Pellet)

[Batsakis et al., RuleML’11]
Geospatial information with SWRL rules

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\[
\begin{align*}
\text{DC}(X, Z) & \leftarrow \text{NTPP}(X, Y) \land \text{EC}(Y, Z) \\
\text{DC\_EC}(X, Z) & \leftarrow \text{EC}(X, Y) \land \text{TPPi}(Y, Z)
\end{align*}
\]


[Batsakis et al., RuleML’11]
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     \[ DC(X, Z) \leftarrow NTPP(X, Y) \land EC(Y, Z) \]
     \[ DC_{EC}(X, Z) \leftarrow EC(X, Y) \land TPPi(Y, Z) \]
   - compute the intersection of two sets of spatial relations
     \[ NTPP(X, Y) \leftarrow NTPP_{PO}(X, Y) \land DC_{EC} \land NTPP(X, Y) \]
   - check spatial consistency (using Pellet)
     \[ R_s(x, y) \leftarrow R_i(x, y) \cap (R_j(x, k) \circ R_k(k, y)) \]

\[ \text{denotes disjunction of relations DC and EC} \]

[Batsakis et al., RuleML’11]
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Implementation of the previous framework using OWL

1. OWL 2 property axioms for expressing inverse, symmetry, and transitivity for spatial relations

2. SWRL rules to
   - encode composition of spatial relations
     \[ \text{DC}(X, Z) \leftarrow \text{NTPP}(X, Y) \land \text{EC}(Y, Z) \]
     \[ \text{DC}\_\text{EC}(X, Z) \leftarrow \text{EC}(X, Y) \land \text{TPPi}(Y, Z) \]
   - compute the intersection of two sets of spatial relations
     \[ \text{NTPP}(X, Y) \leftarrow \text{NTPP\_PO}(X, Y) \land \text{DC}\_\text{EC}\_\text{NTPP}(X, Y) \]
   - check spatial consistency (using Pellet)
     \[ R_s(x, y) \leftarrow R_i(x, y) \cap (R_j(x, k) \circ R_k(k, y)) \]

\[ \text{Batsakis et al., RuleML'11} \]

[Current relation between regions x and y]
Geospatial information with SWRL rules

Implementation of the previous framework using OWL

1. OWL 2 property axioms for expressing inverse, symmetry, and transitivity for spatial relations

2. SWRL rules to
   - encode composition of spatial relations
     - \[ \text{DC}(X, Z) \leftarrow \text{NTPP}(X, Y) \land \text{EC}(Y, Z) \]
     - \[ \text{DC} \_ \text{EC}(X, Z) \leftarrow \text{EC}(X, Y) \land \text{TPPi}(Y, Z) \]
   - compute the intersection of two sets of spatial relations
     - \[ \text{NTPP}(X, Y) \leftarrow \text{NTPP} \_ \text{PO}(X, Y) \land \text{DC} \_ \text{EC} \_ \text{NTPP}(X, Y) \]
   - check spatial consistency (using Pellet)
     - \[ R_s(x, y) \leftarrow R_i(x, y) \land (R_j(x, k) \circ R_k(k, y)) \]

\[ \text{Composition of } R_i \text{ with } R_k \]

Current relation between regions \( x \) and \( y \)

\[ \text{[Batsakis et al., RuleML'11]} \]
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     \]
   - compute the intersection of two sets of spatial relations
     
     \[
     \text{NTPP}(X, Y) \leftarrow \text{NTPP \_ PO}(X, Y) \land \text{DC \_ EC \_ NTPP}(X, Y)
     \]
   - check spatial consistency (using Pellet)
     
     \[
     R_s(x, y) \leftarrow R_i(x, y) \cap (R_j(x, k) \circ R_k(k, y))
     \]

Batsakis et al., RuleML’11
Geospatial information with SWRL rules

- Implementation of SOWL is available at http://www.intelligence.tuc.gr/prototypes.php

[Batsakis et al., RuleML’11]
Conclusions

□ We talked about
  □ Geospatial information with description logics and OWL
  □ OWL reasoners with geospatial capabilities
  □ Geospatial information with SWRL rules

□ **Next topic**: conclusions, questions, discussion
Bibliography

[Katz et al., OWLED’05]
Yarden Katz, Bernardo Cuenca Grau: Representing Qualitative Spatial Information in OWL-DL. OWLED 2005

[Lutz-Milicic, JAR‘07]

[Özçep-Möller, DL‘12]
Özgür L. Özçep, Ralf Möller: Combining DL-Lite with Spatial Calculi for Feasible Geo-thematic Query Answering. Description Logics 2012

[Grütter et al., ISWC‘08]
Bibliography

[Wessel-Möller, JAPLL’09]

[Stocker-Sirin, OWLED‘09]
Markus Stocker, Evren Sirin: *PelletSpatial*: A Hybrid RCC-8 and RDF/OWL Reasoning and Query Engine. OWLED 2009

[Batsakis-Petrakis, RuleML’11]