Image Interpretation as Deduction

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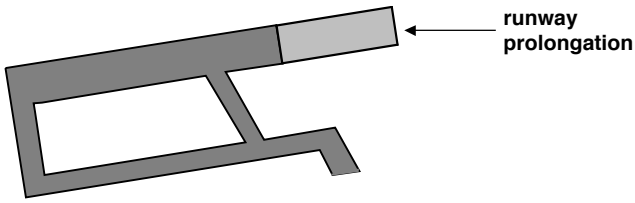
Aerial Image Analysis as Classification

Classification of changes using a description logic (Lange and Schroeder 95)



- **Using the LOOM-classifier to determine the change concept which describes given evidence**
- **Bottom-up analysis of images, no hypothesis generation, no predictive control**

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Concepts and Relations for Airfield Classification (1)

```
(defconcept road-object
      :is   (:and scene-object
                  (> has-length has-width)
                  (:the has-material (:one-of concrete asphalt)

(defconcept runway
      :is   (:and road-object
                  rectangle
                  (:the has-length (:through 2150 4000))
                  (>= has-width 45)
                  (:at-least 1 has-connecting-driveway)
                  (:all has-connecting-driveway (>= has-width 23))
                  (:satisfies
                    ((?x) ... driveway and taxiway constraints ...)))

(defrelation has-connecting-driveway
      :is   (:and has-neighbor
                  (:domain road-object)
                  (:range
                    (:and  road-object
                           (:at-least 2 has-neighbor road-object)))))

(defrelation has-neighbor
      :function  ((x) (compute-neighboring-objects x))
      :characteristics  (:symmetric :multiple-valued))
```

necessary and sufficient conditions for classifying ... a **road-object**

... a **runway**

procedural constraints

important geometrical relation **has-neighbor** *must be implemented procedurally*

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Concepts and Relations for Airfield Classification (2)

```
(defconcept basic-change
      :implies    (:and (:exactly 1 has-before)
                        (:exactly 1 has-after)
                        (<  (:compose has-before has-time)
                            (:compose has-after has-time))))

(defconcept elongation
      :is   (:and basic-change
                  (:relates  has-contained-object
                             has-before
                             has-after)
                  (<      (:compose has-before has-length)
                          (:compose has-after has-length))
                  (=      (:compose has-before has-width)
                          (:compose has-after has-width))

(defconcept runway-elongation
      :is
            (:and elongation
                  (:all has-before runway)
                  (:all has-after runway)))
```

primitive concept **basic-change**, *classification must be provided interactively*

defined concepts **elongation** *and* **runway-elongation**, *classification is provided by deduction*

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Image Interpretation as Deduction?

The classifier of a description logic carries out classifications automatically:

evidence => class (concept) membership

Problems:

- **partial evidence must be sufficient**
- **deduction of all possible partial interpretations**
- **no goal-oriented analysis**
- **no comparative evaluation of conflicting interpretations**

Support of hypothesize-and-test cycle is required !

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Hypothesizing Possible Concept Specializations

Extension of description logic reasoning service for hypothesis generation:

- **Which concept hypotheses can be specialized further consistent with existing evidence?**
- **Which additional evidence is required for specialization?**

1. partial evidence => consistent concepts
2. partial evidence + concepts => missing evidence

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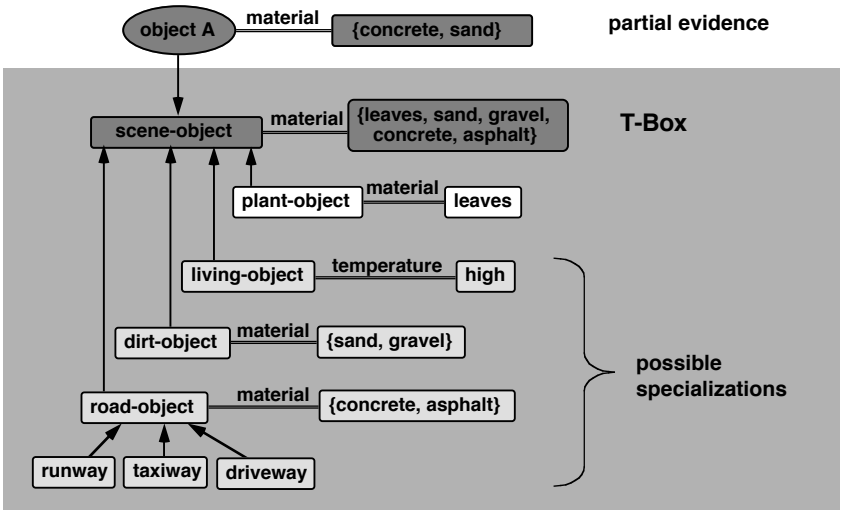
Example for Possible Concept Specializations



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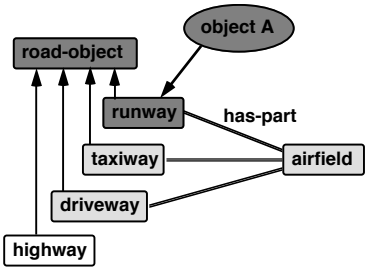
Hypothesizing Possible Aggregats (1)

For which concepts (aggregats) are roll fillers (parts) available?

- **Provide concepts which are consistent with existing role fillers**
- **Which roles provide decisive evidence?**
- **Criteria for ranking hypotheses**



Existing instance runway ***is evidence for*** airfield ***and its further parts*** taxiway ***and*** driveway***.***

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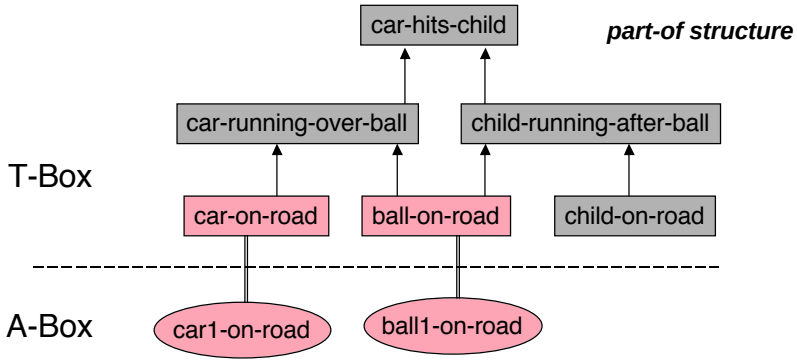
Hypothesizing Possible Aggregats (2)

For which concepts (aggregats) are roll fillers (parts) available?

Generating temporal and spatial expectations:



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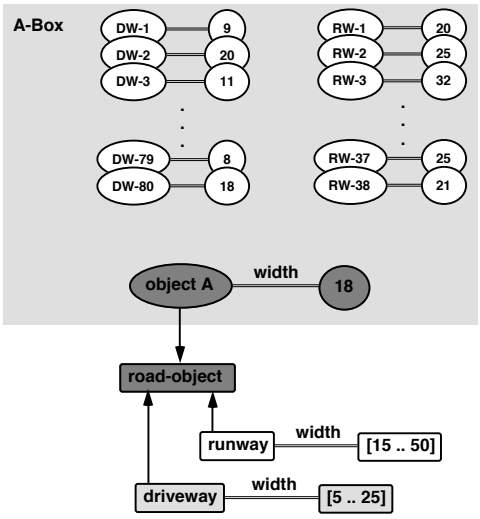
Exploiting A-Box Statistics

What are the most probable concepts (aggregates) for given parts (role fillers)?

- **using experiences for predictions**
- **ranking hypotheses**



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Logics of Image Interpretation

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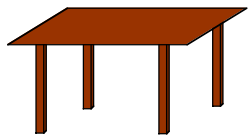
Describing Image Interpretation in Logical Terms



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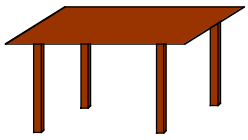
deduction

"from the evidence I conclude that this is a table"



!

model construction

"my conceptual model of a table explains the evidence"

Reiter & Mackworth 87, Matsuyama 90, Schröder 99

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Image Interpretation as (Logical) Model Construction

An interpretation I = [D, φ, π] of a logical language maps
- constant symbols of the language into elements of a real-world domain D
- predicate symbols of the language into predicate functions over D

A model of some clauses is an interpretation where all predicates are true.

Image interpretation as model construction:

- establish mapping φ by assigning segmentation results to constant symbols
- establish mapping π by assigning computational procedures to predicate symbols
- find clauses for which predicates are true

Deciding whether a model exists is undecidable in FOPC!
There may be infinitely many models!

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Finite Model Construction (Reiter & Mackworth 87)

- an image consists of regions and chains (edges)
- the image elements constitute all constant symbols of an interpretation (domain closure assumption)
- different constant symbols denote different image elements and vice versa (unique name assumption)

⇒ Problem can be expressed in Propositional Calculus and solved as a constraint satisfaction problem (CSP)

For MAPSEE, scene interpretation amounts to finding a mapping π for predicates *road, river, shore, land, water.*

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Logics of SIGMA
(Matsuyama & Hwang 90)

Image interpretation is set of hypotheses which

- extend generic knowledge
- allow to deduce the observations

⇒ partial model construction

The number of existing objects must be limited for the interpretation procedure to terminate. (e.g. no interpretations involving invisble objects).

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