Constraints

1

Spatial Constraints

In High-level Vision, spatial constraints restrict the relative position and orientation of parts of aggregates.

Example:

Relative positions of plate, saucer and table boundary as parts of a cover

Several ways to represent 2D spatial constraints:

- Bounding boxes
- Topological relations
- Grid regions
- Probability distributions

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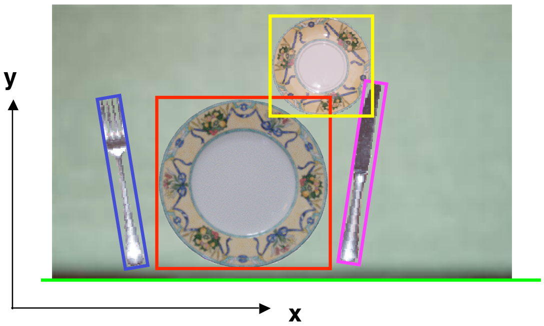
Bounding Boxes

A bounding box is an approximate 2D shape description



A bounding box is specified by

xmin, xmax, ymin, ymax

relativ to a reference coordinate system

- object-centric vs. global reference coordinate system
- position constraints in terms of relative distances between bounding-box boundaries
- orientation constraints in terms of angles between object axes

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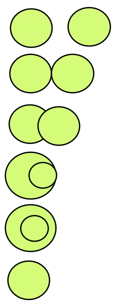
Topological Relations

<u>Elementary relations</u> (disjunct):



• disconnected	dc	
• externally connected	ec	
• partial overlap	po	
• tangential proper part	tpp	tppi
• non-tangential proper part	ntpp	ntppi
• equal	eq	

<u>Composed relations</u>:

- spatially_related
- connected
- overlapping
- inside

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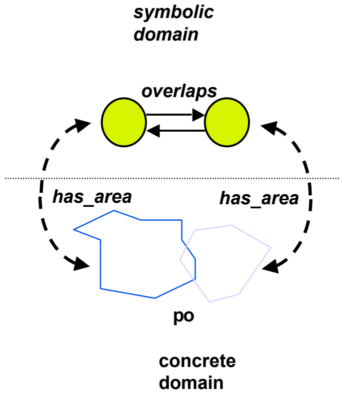
Integrating Topological relations into a Description Logic

Symbolic domain:
defined roles, TBox axioms_

Concrete domain:
RCC8 predicates
- dc, ec, po, tpp, ntpp, tppi, ntppi, eq
- disjunctions

Examples:
inside = ∃ *(has_area)(has_area)* . tpp-ntpp
contains = ∃ *(has_area)(has_area)* . tppi-ntppi
overlaps = ∃ *(has_area)(has_area)* . po

General format for role-forming predicate restriction:
<role name> = ∃ $(u_1, \dots, u_m)(v_1, \dots, v_n)$. P
P is (m+n)ary predicate of concrete domain



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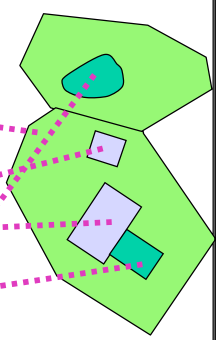
Example: Automatic classification using spatial reasoning

luxury_estate = *large_area* ∩
∃ *contains* . *house_with_swimming_pool*
large_area = *area* ∩
∃ *(has_area)* . large_size
house_with_swimming_pool = *house* ∩
∃ *touches* . *swimming_pool*
house = *area* ∩
∃ *(has_area)* . house_features
swimming_pool = *area* ∩
∃ *(has_area)* . swimming_pool_features
area = ∃ *(has_area)* . is_region

TBox



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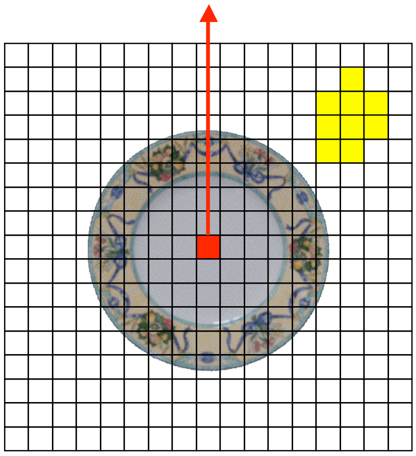
Spatial Relations as Grid-Point Sets

A grid region describes the possible locations (implicit OR) of a point r relativ to a reference point and a reference orientation of an object o.



Relative location is a relation
O x R
between an object o and some point r.

Example:
O = plate
r = center-of-gavity of saucer

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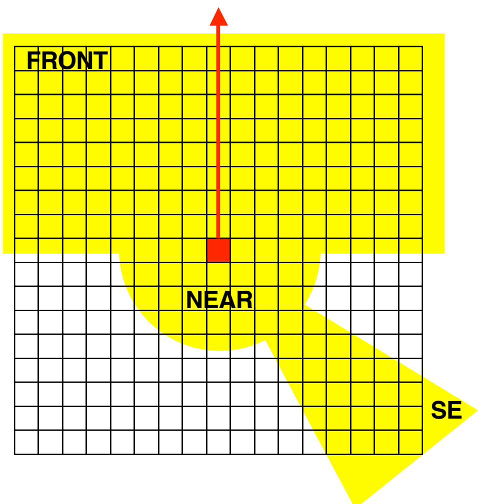
Qualitative Spatial Relations as Grid-Point Sets



Grid-point sets constitute qualitative location concepts

Constraint propagation is possible via set relationships

Example:
(SE plate saucer) ^
(FRONT plate saucer)
=> inconsistent

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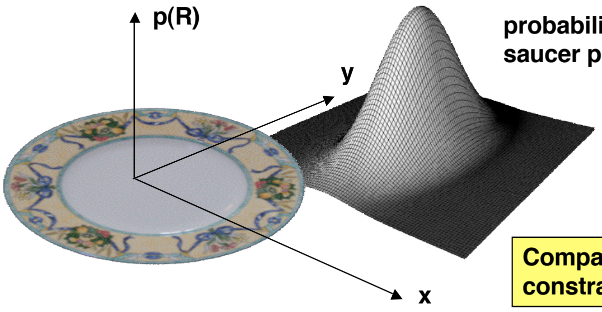
Probability Distributions

Constraints on the coordinates (x, y) of a point relative to a reference coordinate system can be expressed in terms of a probability distribution (density).



Compare with inequality constraints!

Probabilistic reasoning will be treated later.

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Temporal Constraints

In High-level Vision, temporal constraints restrict order and temporal spacing between occurrences.

Example:

```
(equivalent  place-cover
        (and  agent-activity
                (exactly  1  pc-tp1  (and  transport  (some  tp-obj  plate))
                (exactly  1  pc-tp2  (and  transport  (some tp-obj  saucer))
                (exactly  1  pc-tp3  (and  transport  (some tp-obj  cup))
                (<=  pc-tp2 o tp-end  pc-tp3 o tp-end)
                (=  pc-beg  (minim  pc-tp1 o tp-beg  pc-tp2 o tp-beg  pc-tp3 o tp-beg))
                (=  pc-end  (maxim  pc-tp1 o tp-end  pc-tp2 o tp-end  pc-tp3 o tp-end))
                (<=  (-  pc-end  pc-beg)  max-duration))))
```

There are several ways to express temporal constraints:

- Allens interval algebra
- Convex time-point algebra (= 1D bounding boxes)
- Modal Logics

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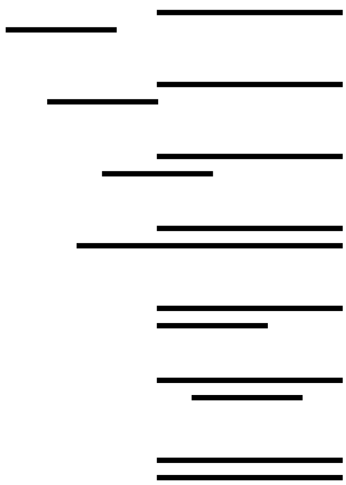
Interval Relations in Allen´s Algebra



BEFORE (I1, I2)	< >
MEETS (I1, I2)	m mi
OVERLAPS (I1, I2)	o oi
FINISHES (I1, I2)	f fi
STARTS (I1, I2)	s si
DURING (I1, I2)	d di
EQUAL (I1, I2)	=

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Convex Time-point Algebra

Qualitative relations between time points which can be described by the inequality

$$T1 + c12 \le T2$$

(T1, T2: time points; c12: constant)

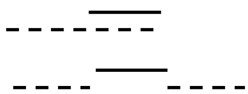
"Convex relation":

All intervals satisfying a convex relation can be generated by continuous displacements of the begin and end points of an interval

In Allen´s Algebra:

convex relation e.g. d v m

non-convex relation e.g. b v bi



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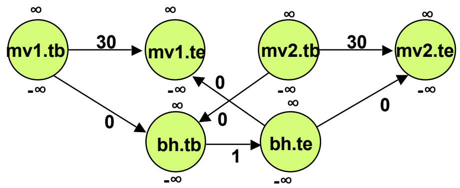
Constraint Propagation for Occurrence Recognition (1)

Example:

Verify occurrence "two moving objects, one behind the other"

1. **Initialize constraint net of occurrence model**



2. **Compute primitive events for scene**

ID:	move1
instance:	move
parts:	mv-ob = obj1
	mv-tr = trj1
times:	mv-tb = 13
	mv-te = 47

ID:	behind1
instance:	behind
parts:	bh-ob1 = obj1
	bh-obj2 = obj2
times:	bh-tb = 20
	bh-te = 33

(and many more)

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Constraint Propagation for Occurrence Recognition (2)

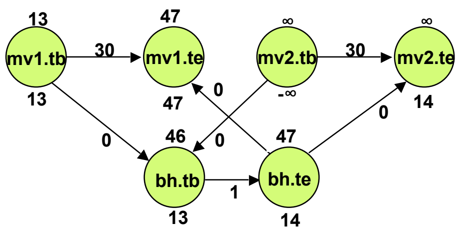
3. **Instantiate parts in occurrence model**

propagate minima and maxima of time points through constraint net:

- minima in edge direction $t_{2min}' = \max \{t_{2min}, t_{1min} + c_{12}\}$
- maxima against edge direction $t_{1max}' = \min \{t_{1max}, t_{2max} - c_{12}\}$

Example: move1 in scene instantiates mv1 of model

ID:	move1
instance:	move
parts:	mv-ob = obj1
	mv-tr = trj1
times:	mv-tb = 13
	mv-te = 47



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Constraint Propagation for Occurrence Recognition (3)

4. **Consistency and completeness test**

   A (partially) instantiated model is inconsistent, if for any node T one has: Tmin > Tmax

   => search for alternative instantiations or terminate with failure

   An occurrence has been recognized if the occurrence model is instantiated with sufficient completeness and the instantiation is consistent.