Spatial Representation and Reasoning

KRR, AI MSc 2020 – 2021

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Spatial Representation and Reasoning

- Representing time and space in information systems in general
- Qualitative representation and inference

Spatial Representation and Reasoning

Representing time and space in information systems in general

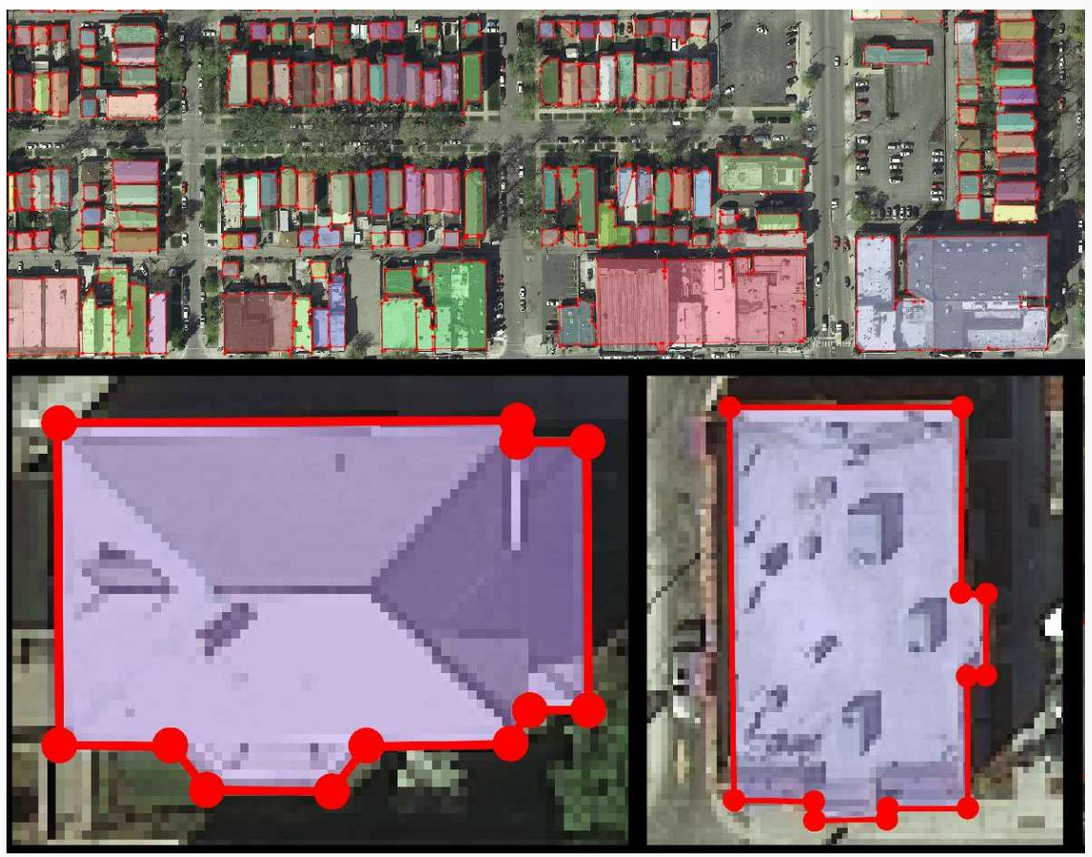
Space and Time

- Time: a 1D point or segment
- Computational issues:
  - Rigorously specified numerical or string representations: Unix time, ISO 8601
  - Timezones, leap seconds, faulty assumptions (y2k)
- Semantics issues:
  - Distinction between a range and an underspecified point within a range
  - Deciding inclusion, ordering

```
ex:stasinos ex:born
 “1973”^^xsd:date .
ex:stasinos ex:born [
 rdf:type Period;
 starts “19730815”^^xsd:date;
 ends “19730915”^^xsd:date ].
```

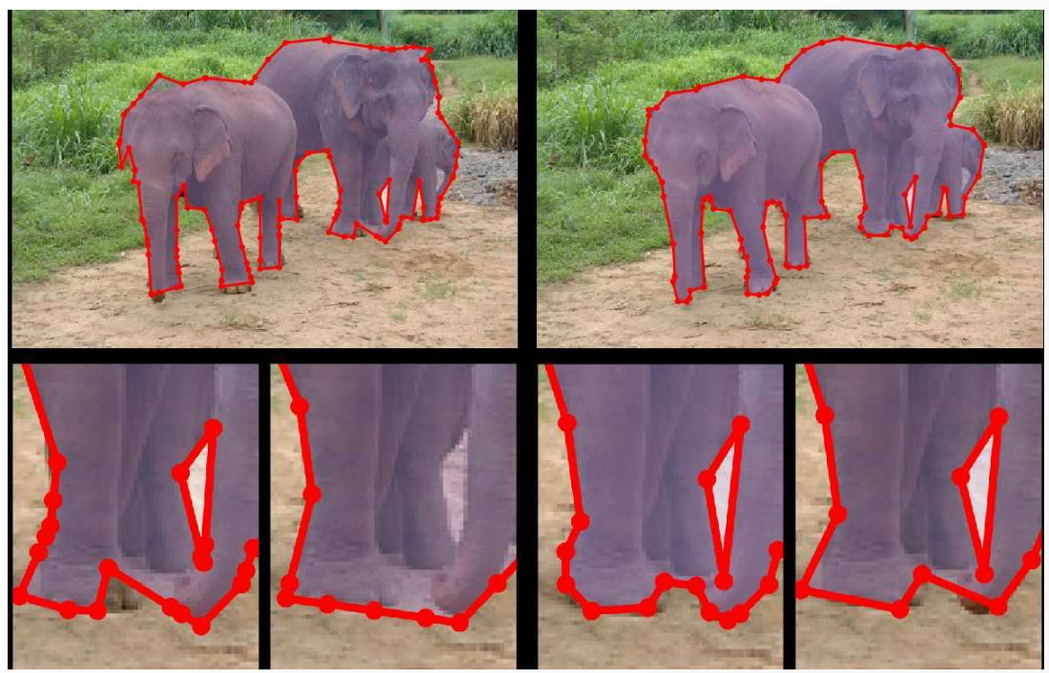
Space and Time

- Space: a 2D point or region
- Computational issues:
  - Rigorously specified numerical or string representations
  - Origin, unit, projection
- Semantics issues:
  - Distinction between a range and an underspecified point within a range
  - Deciding inclusion, ordering



Space and Time

- Space: a 2D point or region
- Computational issues:
  - Rigorously specified numerical or string representations
  - Approximating original shape
- Semantics issues:
  - Distinction between a range and an underspecified point within a range
  - Deciding inclusion, ordering
  - Leaving aside occlusions for now

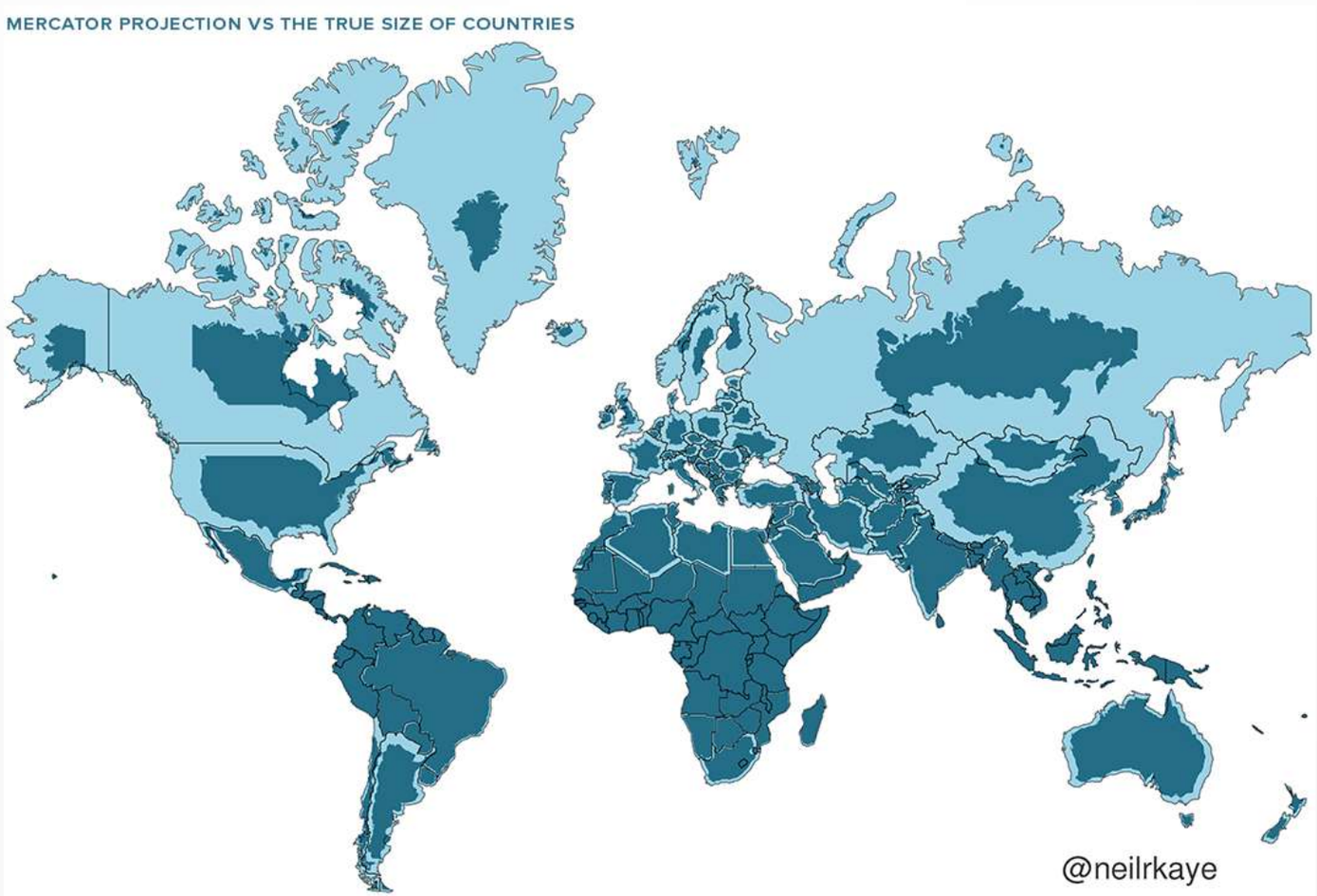


Semantics and interoperability

- Origin: Is 17:10 in Athens before or after 16:15 in Melbourne?

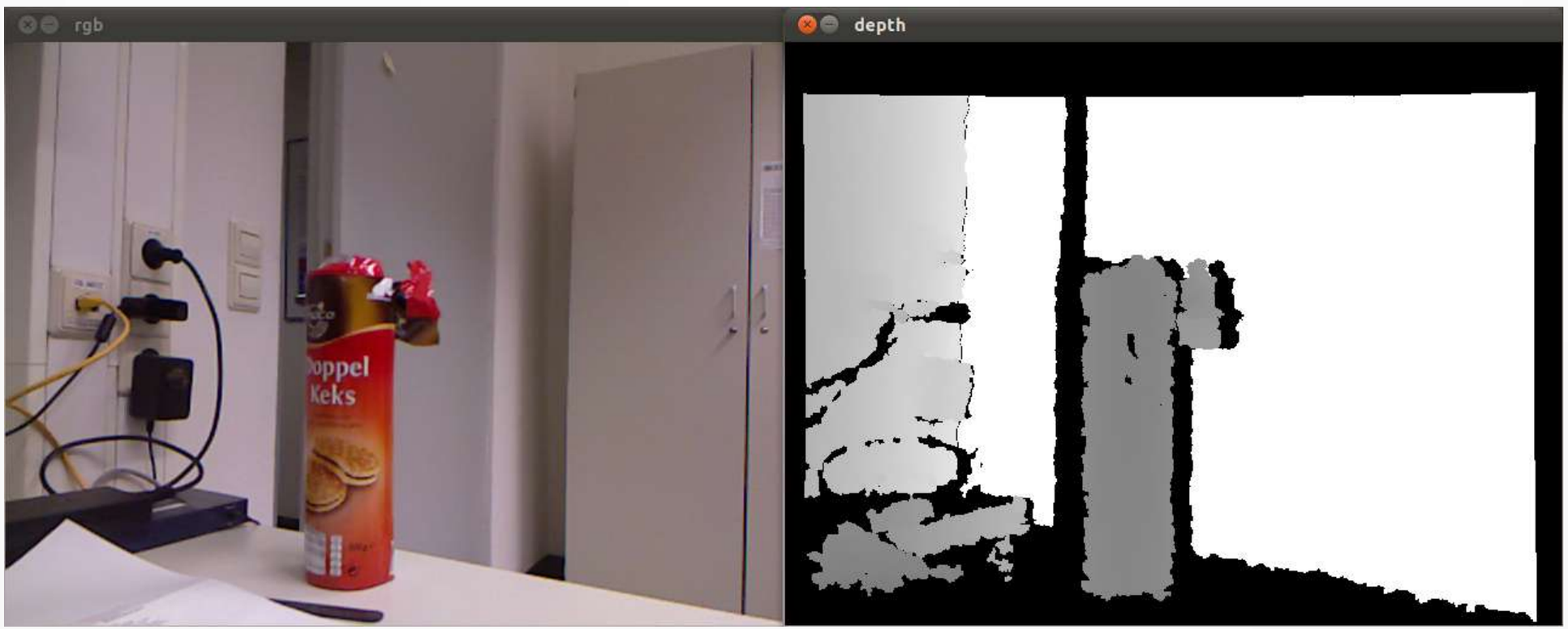
Semantics and interoperability

GIS: Projecting a 3D surface on a 2D representation



Semantics and interoperability

Co-registering a 2D image with distance pointcloud



Semantics and interoperability

- Origin: Is 17:10 in Athens before or after 16:15 in Melbourne?
- Scale: Is 5 (m) more than 2 (km)?
- GIS: Projecting a 3D surface on a 2D representation
- Co-registering a 2D image with distance pointcloud

Semantics and interoperability

- These problems are addressed by:
  - Developing specifications
  - Making either implicit or explicit reference to such specifications when exchanging data
- A specification for spatiotemporal references is part of ROS
- A specification for timestamps is part of UNIX and the network stack
- GIS databases annotate data with the projection used
- GPS is specified as using WGS 84

Spatial Representation and Reasoning

Qualitative representations and inference

Spatiotemporal relations

- Qualitative relations can be computed from detailed information:
  - “21 January 2021” is contained within “2021”
  - The shape of “Ag. Paraskevi” is contained in the shape of “Greece”
  - The shape of “Lake Ohrid” overlaps with the shape of “Greece”
  - The shape of “Evros River” is the boundary of the shape of “Greece”
- Often, useful queries are expressed in terms of such relations rather than specific coordinates
  - All KR lectures during 2021
  - The number of municipalities in Attica with a population over 100k

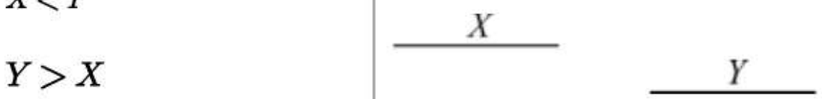
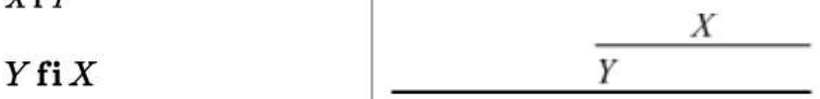
Spatiotemporal relations

- Qualitative relations can be computed from detailed information
- Often, useful queries can be answered combining detailed, quantitative information with qualitative information
  - “Aztecs flourished in central Mexico”
  - “The Inca empire dominated western South America”
  - Machu Picchu, Peru, Mexico coords.
  - Was Machu Picchu built by the Aztecs?

Spatiotemporal relations

- Bottomline:
  - There is a need for representing both qualitative and quantitative information
  - There is a need for querying in either representation
- We need to draw inferences from either, and from combing both, to answer queries expressed either qualitatively or quantitavely

Allen

Relation	Illustration	Interpretation
$X < Y$ $Y > X$		X precedes Y Y is preceded by X
$X \mathbf{m} Y$ $Y \mathbf{mi} X$		X meets Y Y is met by X (*i* stands for ***i****nverse*)
$X \mathbf{o} Y$ $Y \mathbf{oi} X$		X overlaps with Y Y is overlapped by X
$X \mathbf{s} Y$ $Y \mathbf{si} X$		X starts Y Y is started by X
$X \mathbf{d} Y$ $Y \mathbf{di} X$		X during Y Y contains X
$X \mathbf{f} Y$ $Y \mathbf{fi} X$		X finishes Y Y is finished by X
$X = Y$		X is equal to Y

Allen

- study {d,f} afternoon
- afternoon {m,<} sleep

  →
- study {m,<} sleep

Relation	Illustration	Interpretation
$X < Y$ $Y > X$		X precedes Y Y is preceded by X
$X \mathbf{m} Y$ $Y \mathbf{mi} X$		X meets Y Y is met by X (*i* stands for ***i****nverse*)
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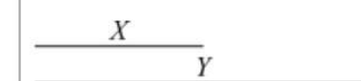
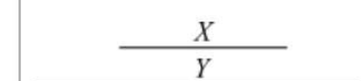
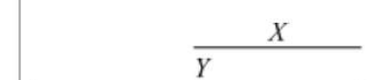
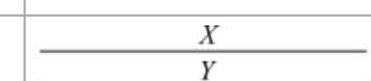
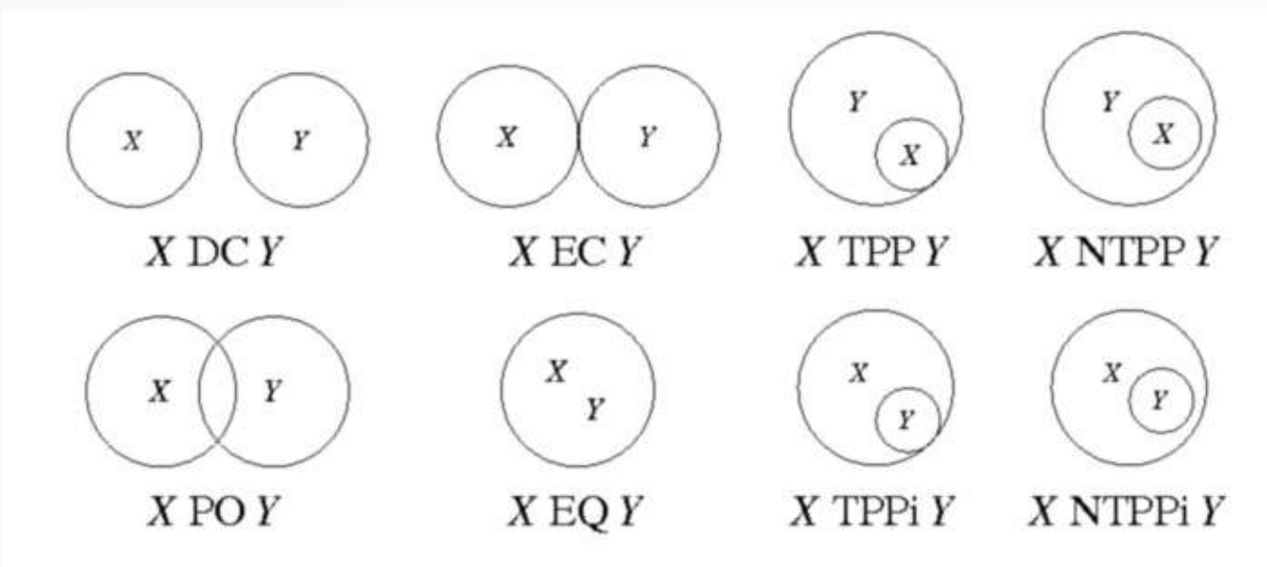
$X \mathbf{s} Y$ $Y \mathbf{si} X$		X starts Y Y is started by X
$X \mathbf{d} Y$ $Y \mathbf{di} X$		X during Y Y contains X
$X \mathbf{f} Y$ $Y \mathbf{fi} X$		X finishes Y Y is finished by X
$X = Y$		X is equal to Y

RCC8

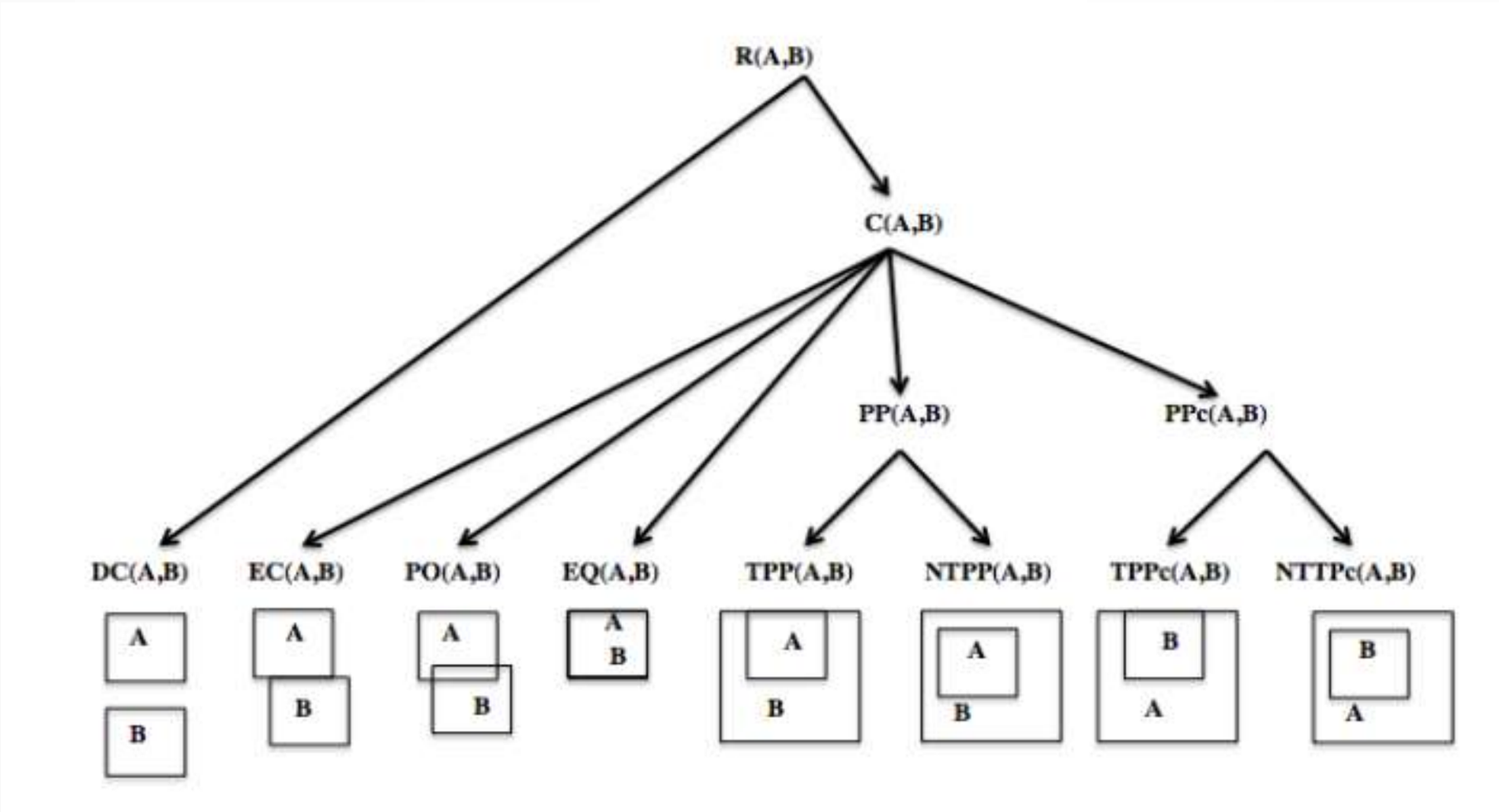
- Disconnected (DC)
- Externally connected (EC)
- Partially overlapping (PO)
- Equal (EQ)

RCC8: Region Connection Calculus



- Tangential proper part (TPP) and inverse
- Non-tangential proper part (NTPP) and inverse

RCC8


R(A,B)
C(A,B)
PP(A,B)
PPc(A,B)
DC(A,B)
EC(A,B)
PO(A,B)
EQ(A,B)
TPP(A,B)
NTPP(A,B)
TPPc(A,B)
NTTPc(A,B)
A
B

Axioms: Symmetry, inverse

- X DC Y → Y DC X
- X EC Y → Y EC X
- X PO Y → Y PO X
- X EQ Y → Y EQ X
- X TPP Y → Y TPPi X
- X NTPP Y → Y NTPPi X

Axioms: Transitivity

- X EQ Y, Y EQ Z → X EQ Z
- X NTPP Y, Y NTPP Z → X NTPP Z
- X NTPPi Y, Y NTPPi Z → X NTPPi Z

Composition

- X NTPP Y, Y DC Z → X DC Z
- X TPP Y, Y TPP Z → X { NTPP , TPP } Z

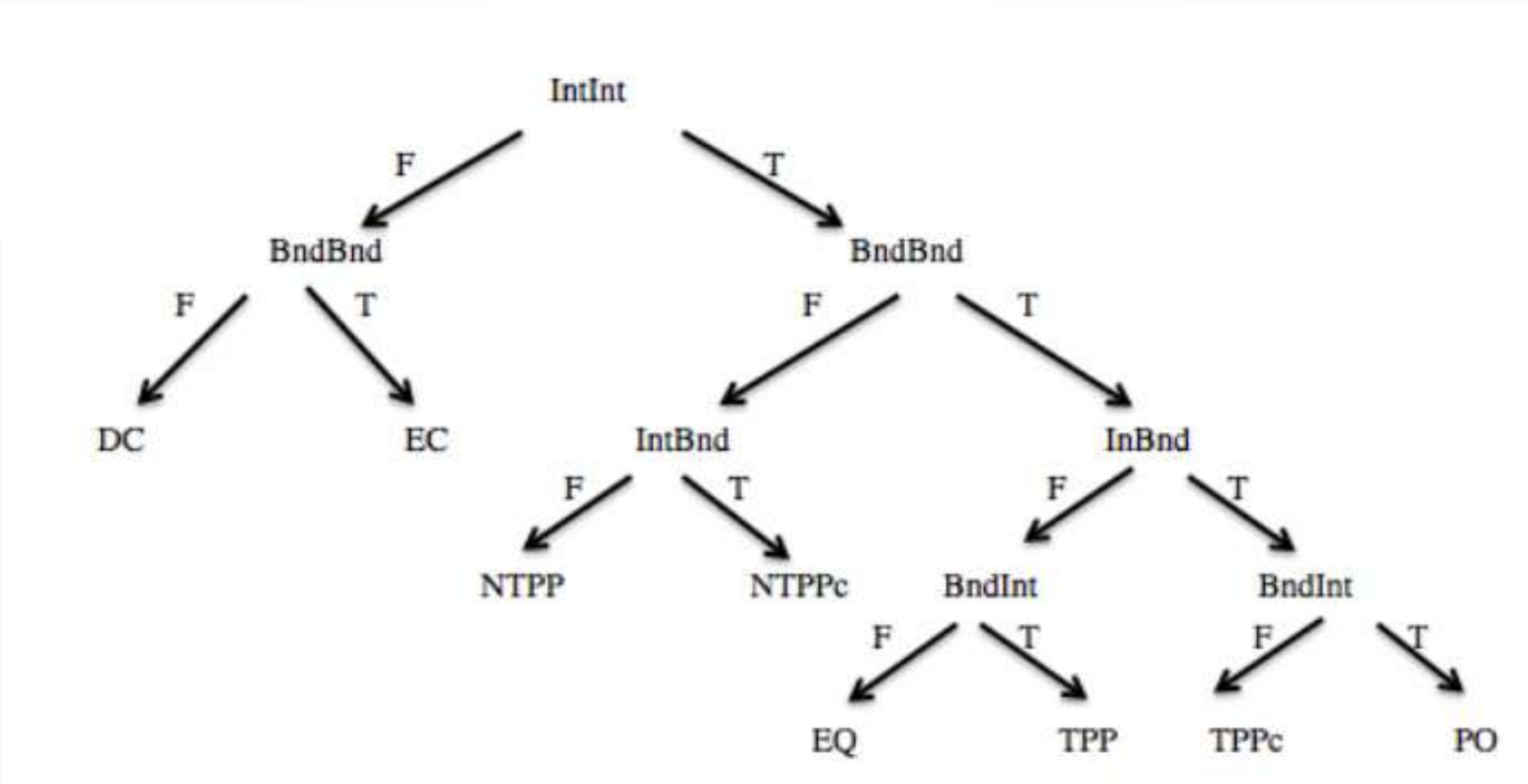
Composition

- X NTPP Z → Exists Y : X NTPP Y, Y NTPP Z
- X TPP Z → Exists Y : X TPP Y, Y TPP Z
- X TPP Z → Not Exists Y : X NTPP Y, Y NTPP Z

Composition table

;	DC	EC	PO	TPP	TPP˘	NTPP	NTPP˘
DC	DC, EC, PO TPP, TPP˘, 1' NTPP, NTPP˘	DC, EC, PO TPP NTPP	DC, EC, PO TPP NTPP	DC, EC, PO TPP NTPP	DC	DC, EC, PO TPP NTPP	DC
EC	DC, EC, PO TPP˘ NTPP˘	DC, EC, PO TPP, TPP˘ 1'	DC, EC, PO TPP NTPP	EC, PO TPP NTPP	DC, EC	PO TPP NTPP	DC
PO	DC, EC, PO TPP˘ NTPP˘	DC, EC, PO TPP˘ NTPP˘	DC, EC, PO TPP, TPP˘, 1' NTPP, NTPP˘	PO TPP NTPP	DC, EC, PO TPP˘ NTPP˘	PO TPP NTPP	DC, EC, PO TPP˘ NTPP˘
TPP	DC	DC, EC	DC, EC, PO TPP NTPP	TPP NTPP	DC, EC, PO TPP, TPP˘ 1'	NTPP	DC, EC, PO TPP˘ NTPP˘
TPP˘	DC, EC, PO TPP˘ NTPP˘	EC, PO TPP˘ NTPP˘	PO TPP˘ NTPP˘	PO TPP, TPP˘	TPP˘ NTPP˘	PO TPP NTPP	NTPP˘
NTPP	DC	DC	DC, EC, PO TPP NTPP	NTPP	DC, EC, PO TPP NTPP	NTPP	DC, EC, PO TPP, TPP˘, 1' NTPP, NTPP˘
NTPP˘	DC, EC, PO TPP˘ NTPP˘	PO TPP˘ NTPP˘	PO TPP˘ NTPP˘	PO TPP˘ NTPP˘	NTPP˘	PO TPP, TPP˘, 1' NTPP, NTPP˘	NTPP˘

Inferring from quantitative data



Two houses

- Two houses are connected via a road
  - h1 EC r
  - r EC h2
- House1 is located on Property1, touching the boundary
  - h1 TPP p1
- House2 is located on Property2, without touching the boundary
  - h2 NTPP p2
- What can you infer about the road?