

# Level of Detail in Discrete Spatial Representation

John Stell

School of Computing, University of Leeds, U.K.

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# Overview

- ▶ Motivation: Qualitative Spatial Representation
- ▶ What is QSR?
- ▶ Limitations of basic QSR  
World has: movement, change, uncertainty,  
discrete space, granularity
- ▶ How QSR has been extended
- ▶ Granularity (level of detail) remains a key challenge
- ▶ Conclusions

## Motivation: Spatial Humanities

The digital humanities use computational representations of data as a lens through which to consider human experience.

The specifically spatial aspects of this process have become known as the 'spatial humanities' (Bodenhamer, Corrigan, & Harris, 2010).

## Motivation: Spatial Humanities

The development of spatial humanities has been driven partly by the availability of technology.

Spatial humanities makes extensive use of GIS.

for example . . .

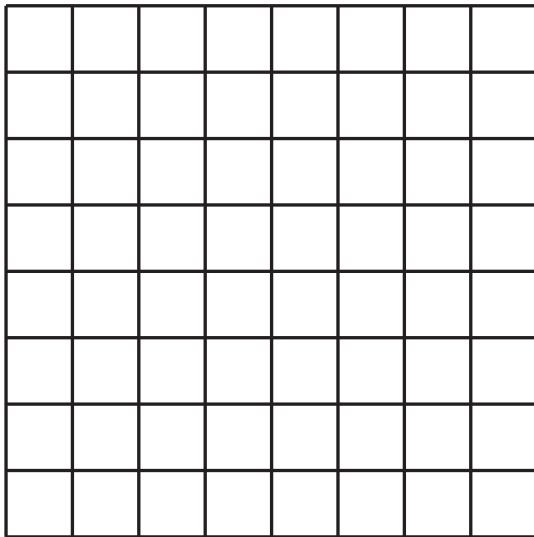
## Motivation: Spatial Humanities – Example

‘Mapping the Lakes’ an interdisciplinary project by Ian Gregory (Lancaster) and others, led to examining:

“the ways in which GIS can be used to explore the spatial relationships between two textual accounts of tours of the English Lake District” Thomas Gray, in 1769 and Samuel Taylor Coleridge in 1802.

Cooper and Gregory (2011)

## Motivation: Spatial Humanities – Coordinate Geometry



## Motivation: Spatial Humanities – problems

‘The use of GIS as a lens to understand the geographical dimensions of the humanities raises questions about the biases, assumptions, and the silences in the technology that impinge upon the exploration of the spatial turn’

Harris, Rouse, and Bergeron (2010)

## Motivation: Spatial Humanities – needs

The humanities need to expand the limited quantitative digital representation of space to encompass the intangible and socially constructed world and not simply the world that can be measured.



## Motivation: Spatial Humanities – part of a solution?

Qualitative Spatial Representation (QSR) provides a model in which qualitative spatial relationships such as ‘inside’, ‘overlapping’, ‘separate from’, ‘left of’, ‘alongside’, and many others, find computational representation as logical statements rather than as numerical relationships.

## Coordinate geometry is not experienced space

“no one has ever perceived a point, . . . whereas people have perceived individuals of finite extent.”

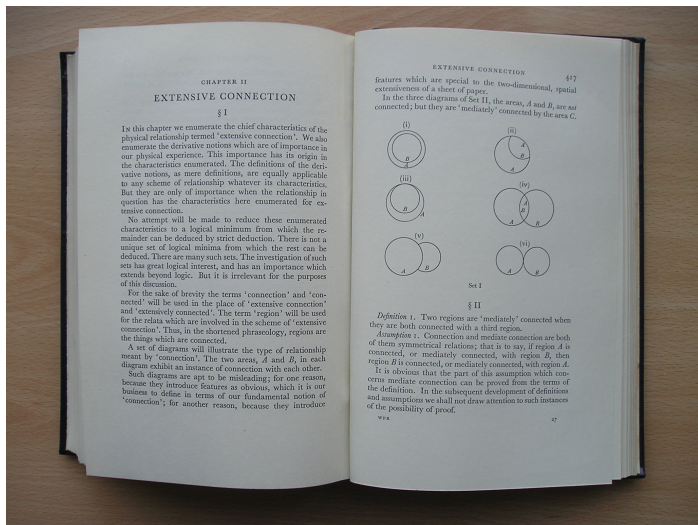
(Simons, 1987, p42)

## Discrete Space

*“To understand what we mean when we say that space is discrete, we must put our minds completely into the relational way of thinking, and really try to see the world around us as nothing but a network of evolving relationships. These relationships are not among things situated in space – they are among the events that make up the history of the world. The relationships define the space, not the other way round.”*

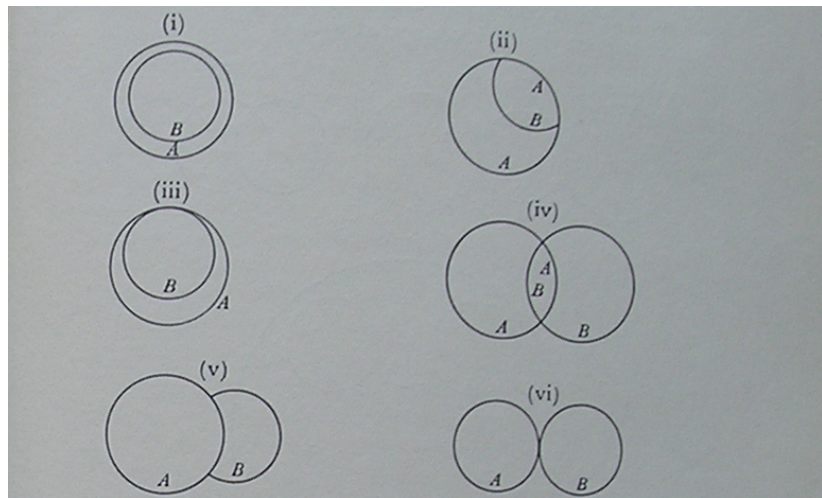
(Smolin 2000)

# Origins of Mereotopology



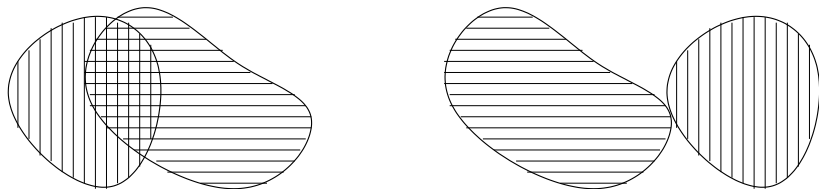
Whitehead. Process and Reality (1929)

# Origins of Mereotopology



Whitehead. *Process and Reality* (1929)

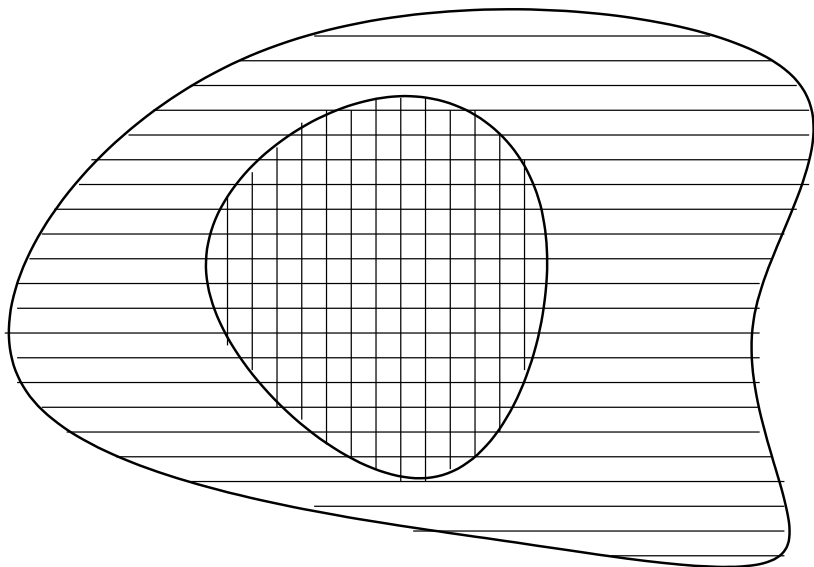
# The idea of connection



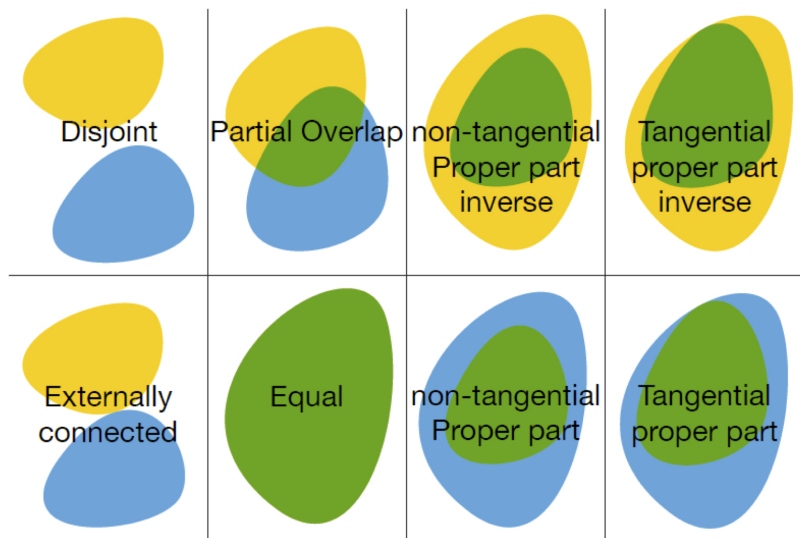
Think: overlapping or touching at boundary

From Connection we can define Part, and other relations –

## Part defined from Connection



# The RCC-8 Relations



Yellow relates to Blue



# Properties of Connection

A **Boolean Connection Algebra** is a Boolean algebra  $A$  with connection relation  $C$ , where  $A$  has more than two regions, and

Every region is connected to itself

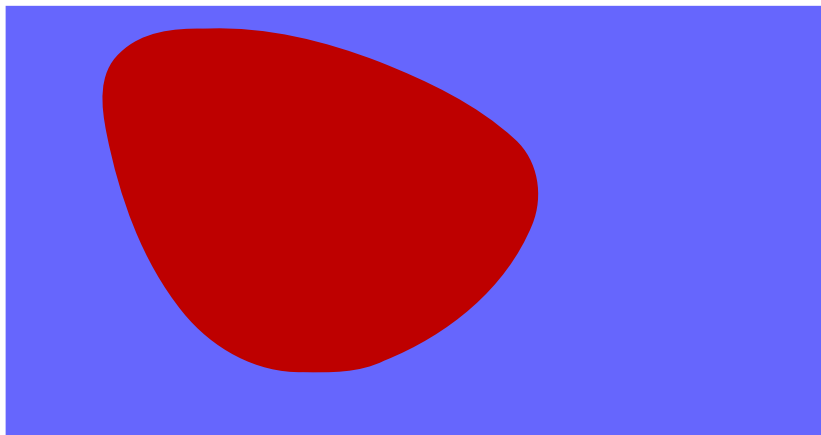
Connection is symmetric

Every region is connected to its outside

A region is connected to a union of two others iff it's connected to at least one of them

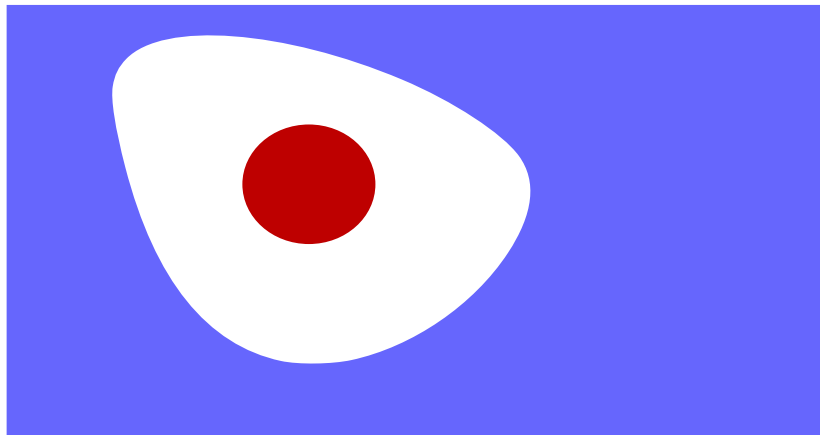
For every (non-universe) region you can find an unconnected region

## Properties of Connection



A region is connected to its outside

# Properties of Connection



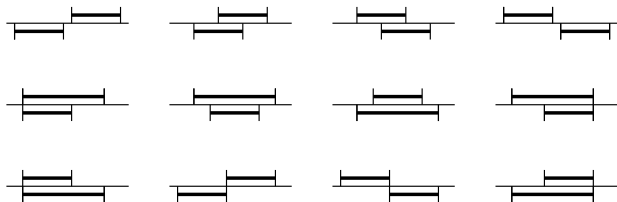
Only the universe is connected to everything equivalent to:  
every (non-universal) region has a non-tangential proper part

# Limitations of Basic RCC

- ▶ Regions don't move
- ▶ Regions don't change topological properties
- ▶ Regions are crisp, not uncertain
- ▶ Regions are in a dense space (can always be sub-divided)
- ▶ Regions exist at a single level of detail

# Other qualitative description calculi

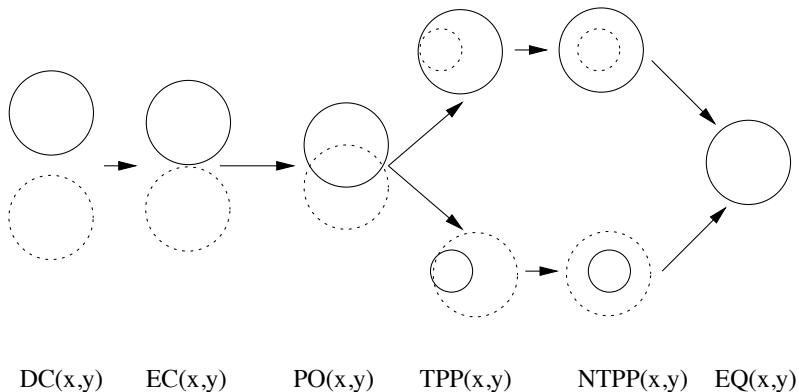
- ▶ Allen's time intervals



- ▶ Qualitative directions (left, right, up, down, etc)

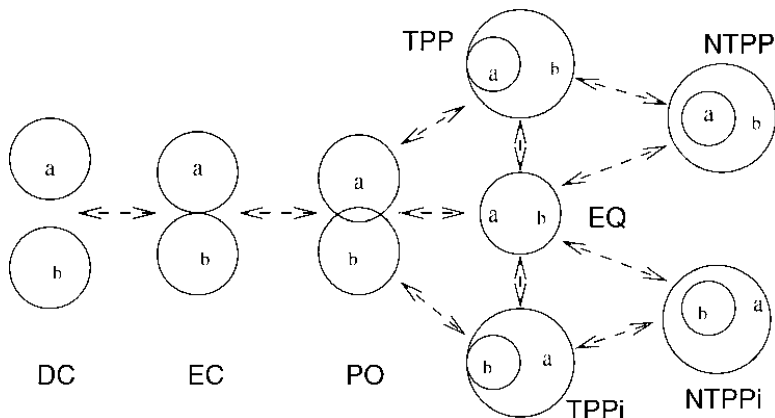
These introduce some features which are not purely topological

# Moving Regions



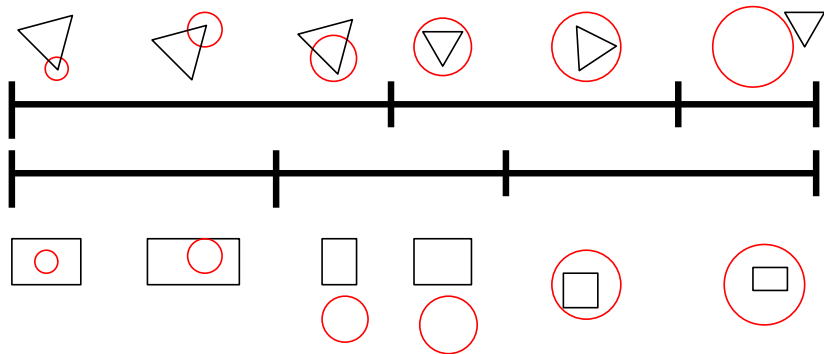
Some Possible RCC8 Transitions  
(not the complete conceptual neighbourhood diagram)

## Moving Regions



RCC8 conceptual neighbourhood diagram, Cohn and Renz (2008)

## Moving Regions

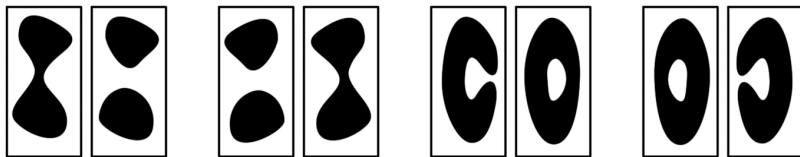


Event detection from video. Cohn, Hogg, et al.

Zoom out from numerical detail



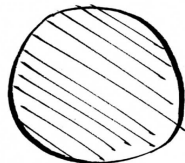
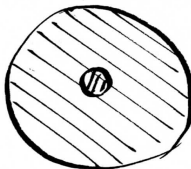
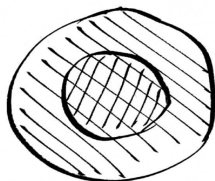
## Changing Regions



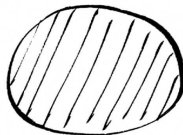
Splitting and Merging

In addition regions can appear / disappear

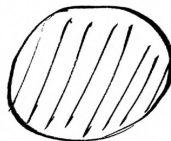
## Changing Regions



PO



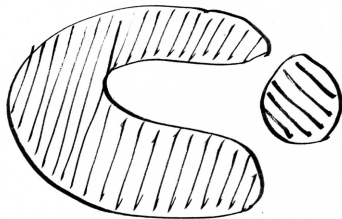
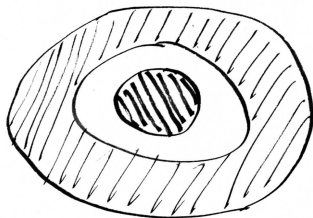
PO



DR

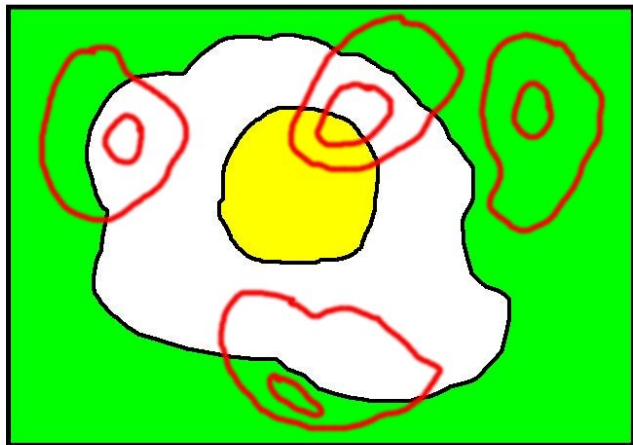
Part vanishes, PO to DR transition avoiding EC

## Changing Regions



RCC8 detects no change, but are these qualitatively different?

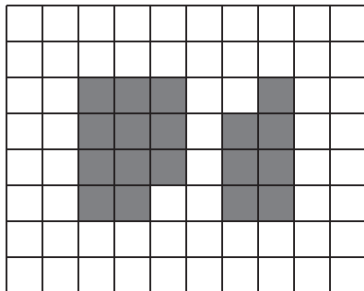
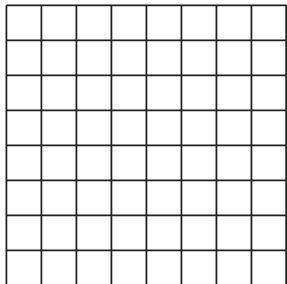
## Fuzzy Regions



Egg-Yolk Regions.

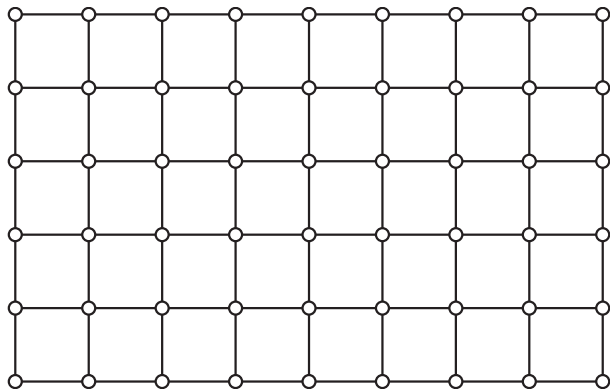
Yolk – definitely in region. White – possibly in region.

# Discrete Regions



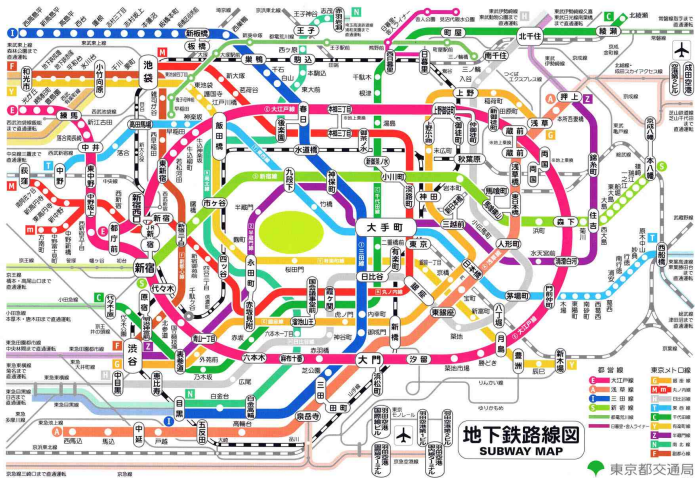
Pixel as atomic region

## Discrete Regions



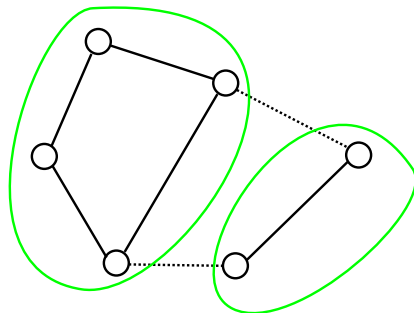
Graph, edges represent adjacency. Galton (1999) and later

## Discrete Regions



## Abstract Graph without structure of pixel grids

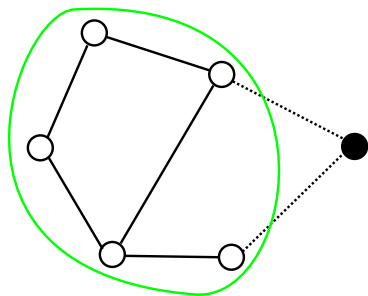
## Discrete Regions



Two regions (subgraphs) are connected if they are at most one edge apart.



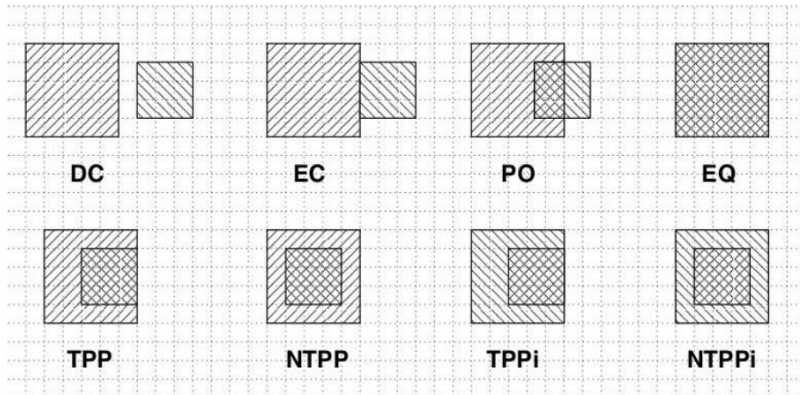
## Discrete Regions



Cannot define part from connection.

Everything connected to the black node is connected to the green region.

# Discrete Regions



RCC8 still makes sense. Landini, Galton, Randell (2013)

# Moving Discrete Regions



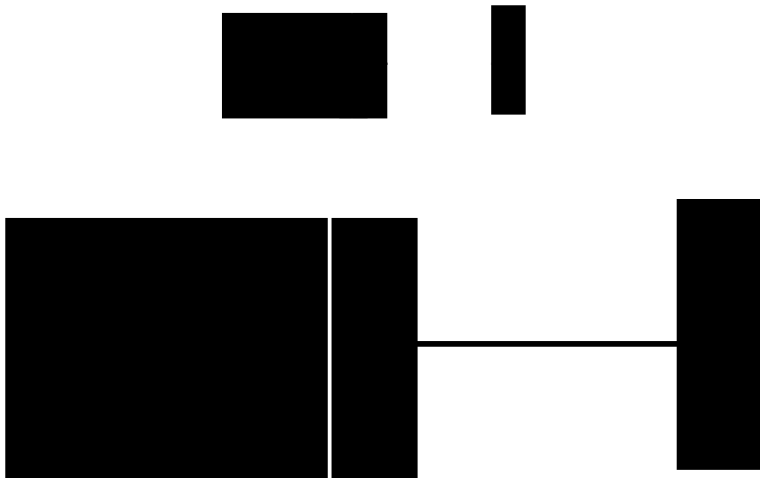
EC



EQ

External Connection to Equal transition without intermediate overlap

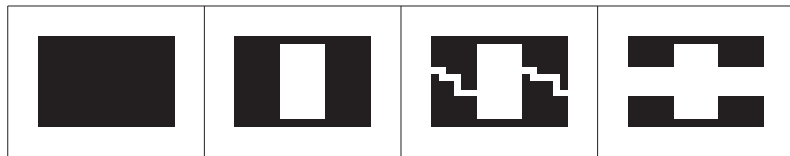
## Granular Regions



With granularity comes change

# Changing Granular Discrete Regions

Upper level (less detailed view)

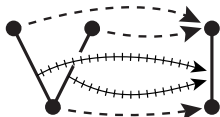


Lower level (more detailed view)

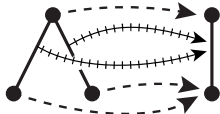
Compare Qualitative Descriptions at the Two Levels

# Changing Granular Discrete Regions

Upper  
Meet

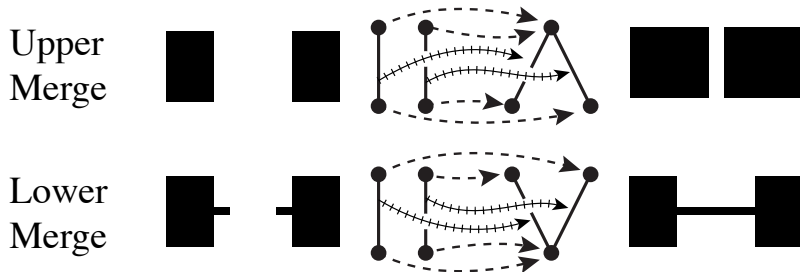


Lower  
Meet



Count components – not relations between regions  
Stell, IJCAI (2013)

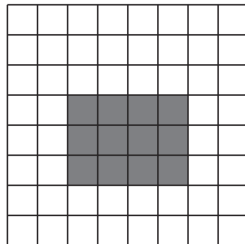
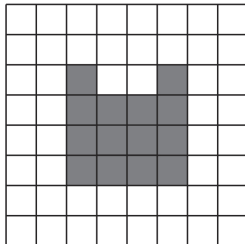
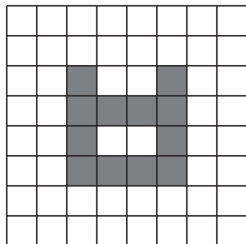
# Changing Granular Discrete Regions



In total there are 15 types of granular change

# Changing Granular Discrete Regions

Mathematical morphology provides formal granularity



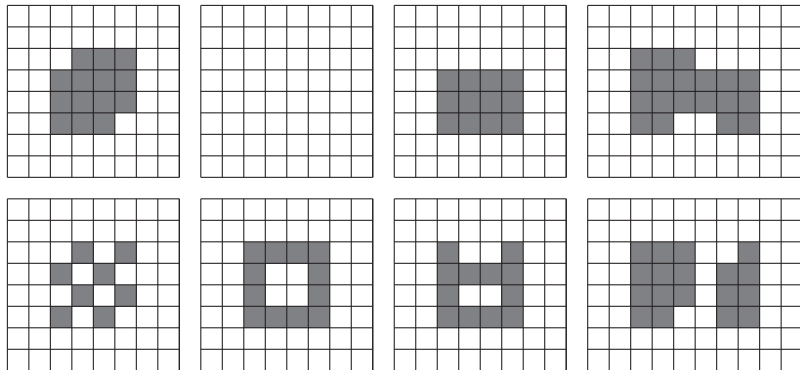
Closing: fill in holes and gaps where probe won't fit outside

Opening: remove small parts where probe won't fit inside





# Changing Granular Discrete Regions



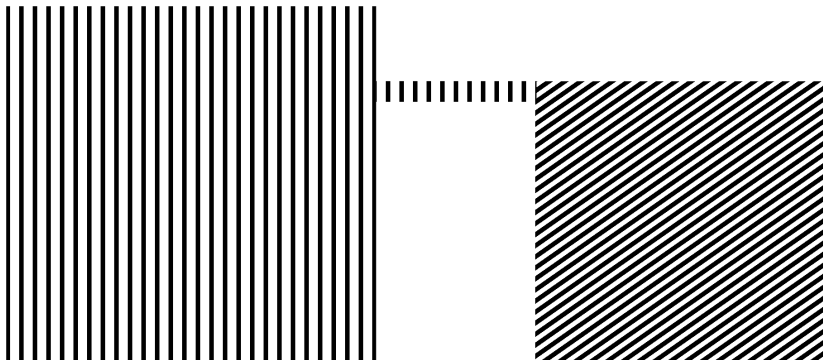
Change in Level of detail via closing then opening



# Spatial Relations at Two Levels of Detail

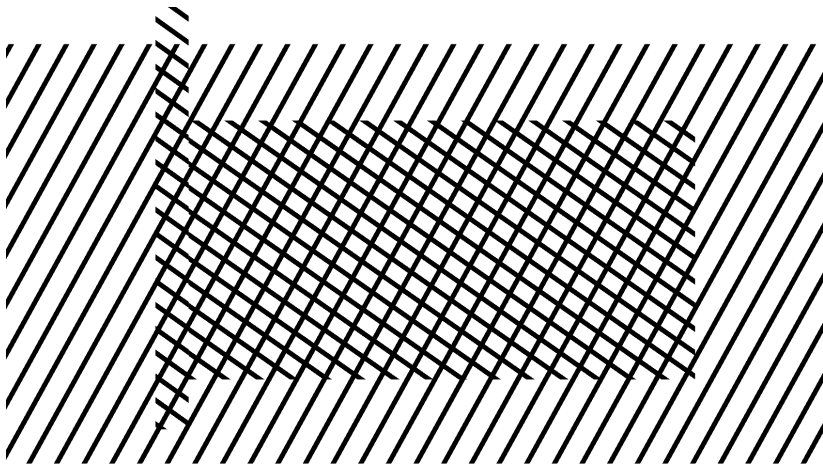
Closing / opening works for number of components of one region

But how about relationships between two regions?



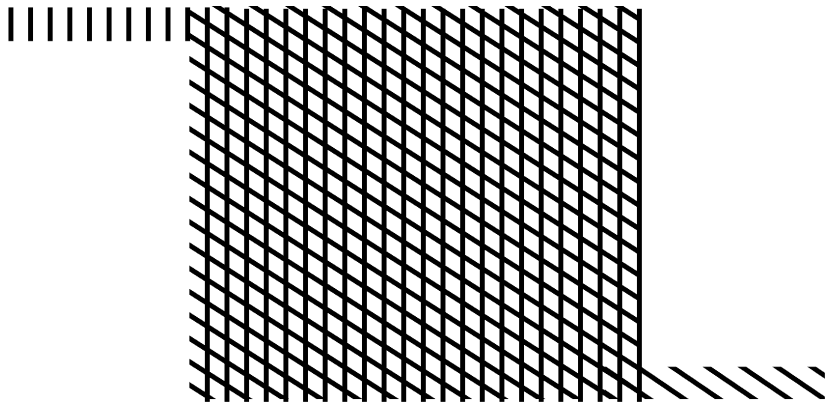
Seems clear: EC to DR

## Spatial Relations at Two Levels of Detail



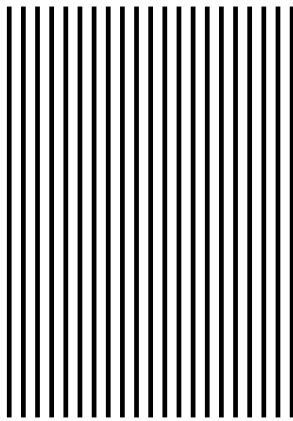
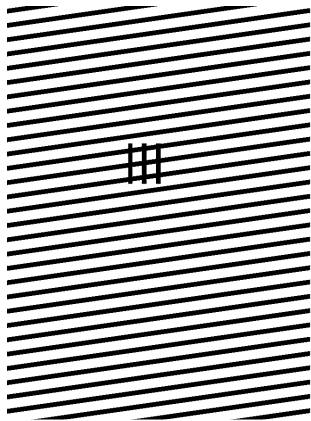
Seems clear: PO to NTPP

## Spatial Relations at Two Levels of Detail



Seems clear: PO to EQ

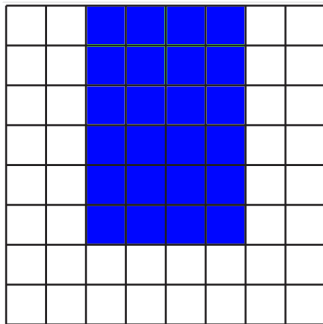
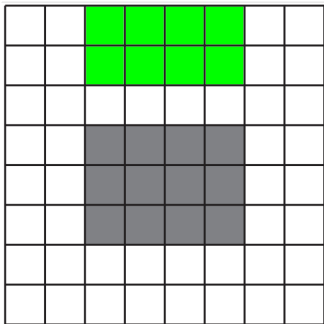
## Spatial Relations at Two Levels of Detail



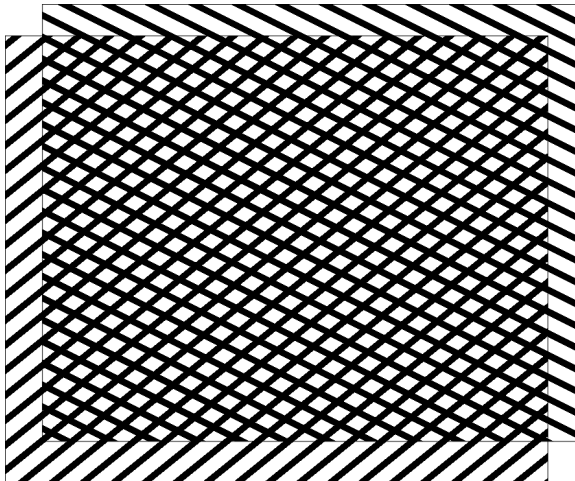
Seems clear: PO to DR

## Spatial Relations at Two Levels of Detail

Are the regions on the left connected at the coarse level?

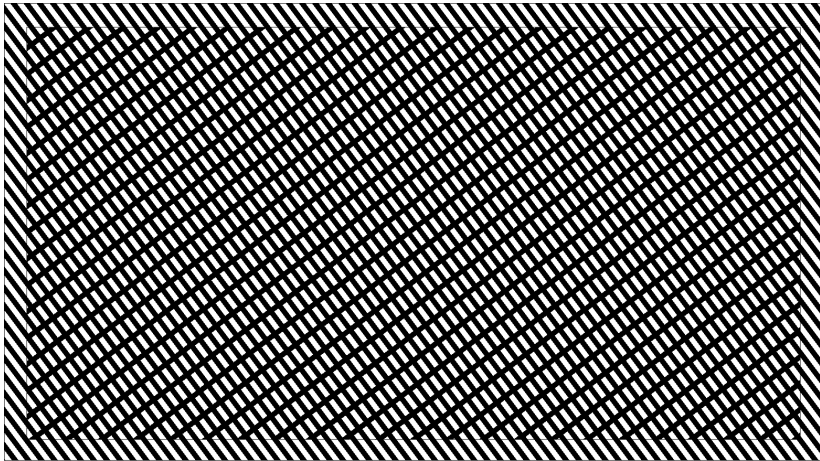


## Spatial Relations at Two Levels of Detail



PO or EQ?

## Spatial Relations at Two Levels of Detail



NTPP or EQ or TPP?



## Spatial Relations at Two Levels of Detail



# Spatial Relations at Two Levels of Detail

Try Dis-Connection instead of Connection?

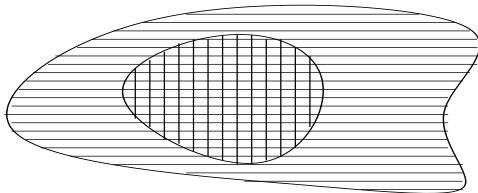
Leonard and Goodman, *Calculus of Individuals*

“discreteness” (separation or apartness)

$$x \sqsubset y$$

part defined in terms of separation:

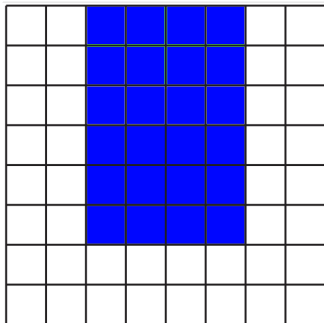
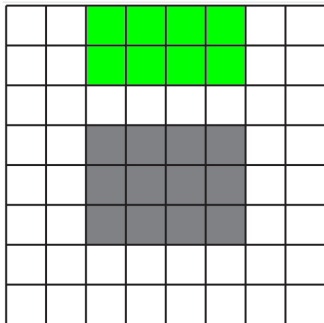
$x$  is a part of  $y$  if everything that is separate from  $y$  is also separate from  $x$



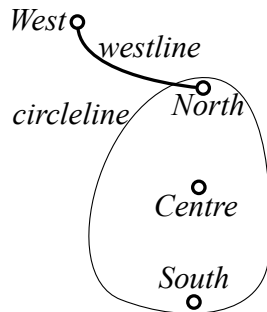
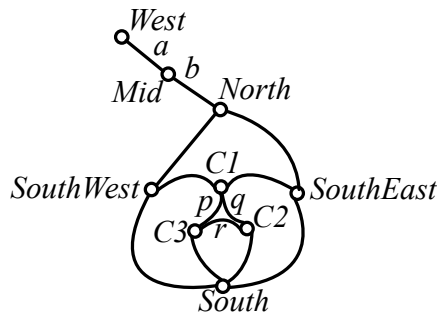
# Spatial Relations at Two Levels of Detail



Cannot be separated vs Are connected

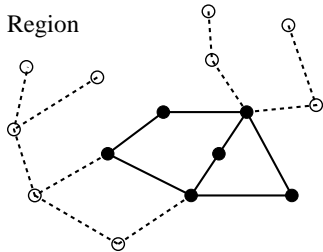


# Granularity for graphs

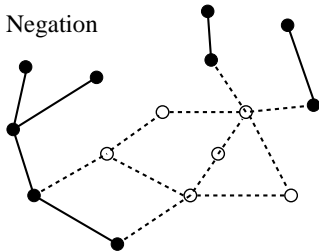


# Spatial Relations for graphs

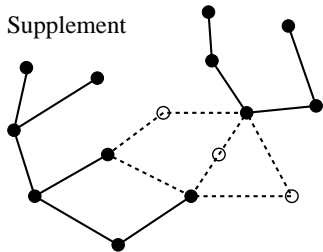
Region



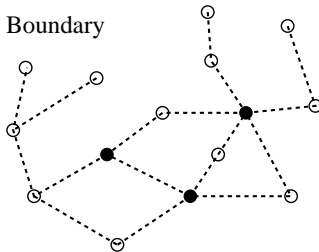
Negation



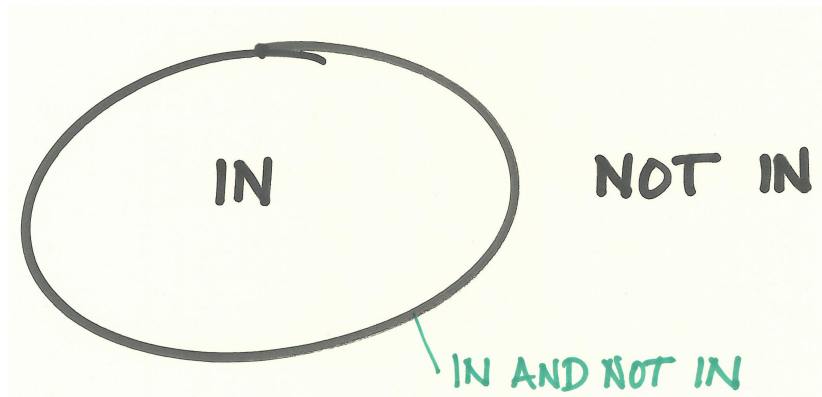
Supplement



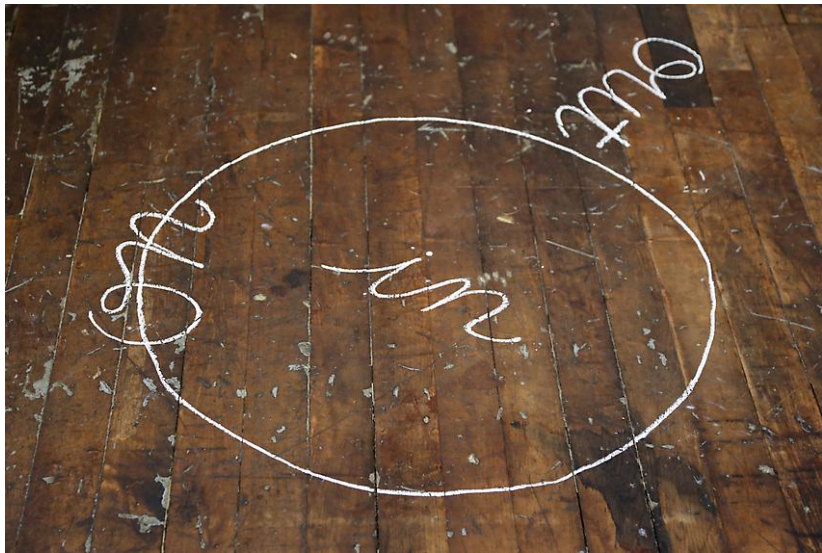
Boundary



## Spatial Relations for graphs



## Spatial Relations for graphs



# Conclusions

- ▶ Coordinate space of GIS does not fit human experience
- ▶ One alternative is QSR
- ▶ Use of both points and QSR is needed
- ▶ Interdisciplinary collaboration needed to build theories and systems that can more fully represent the world