The importance of Scale in Discerning Pattern and Meaning in Geographic Space

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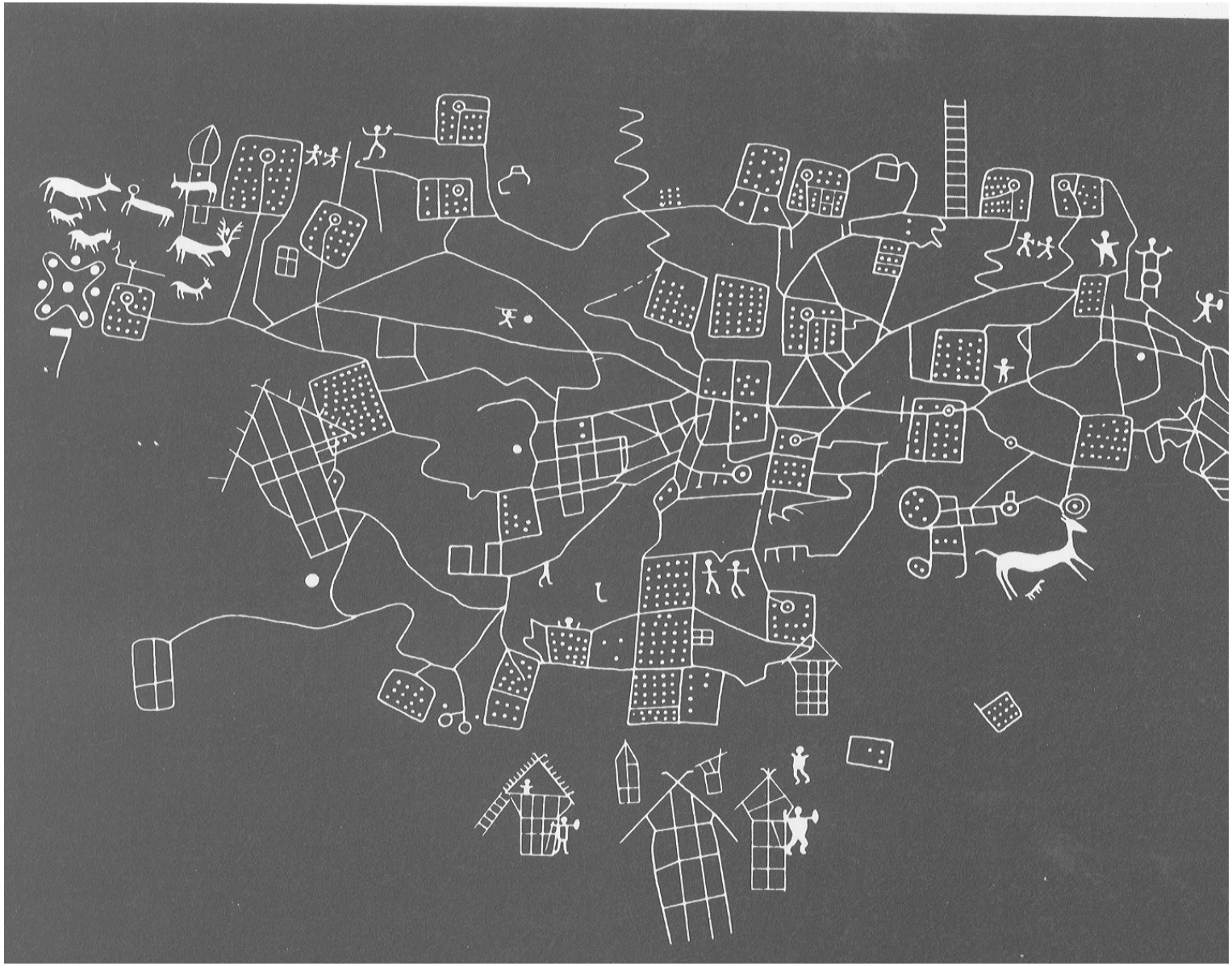
Gabriel thought maps should be banned. They gave the world an ordered reasonableness which it did not possess.

Boyd, W. *An Ice Cream War*.

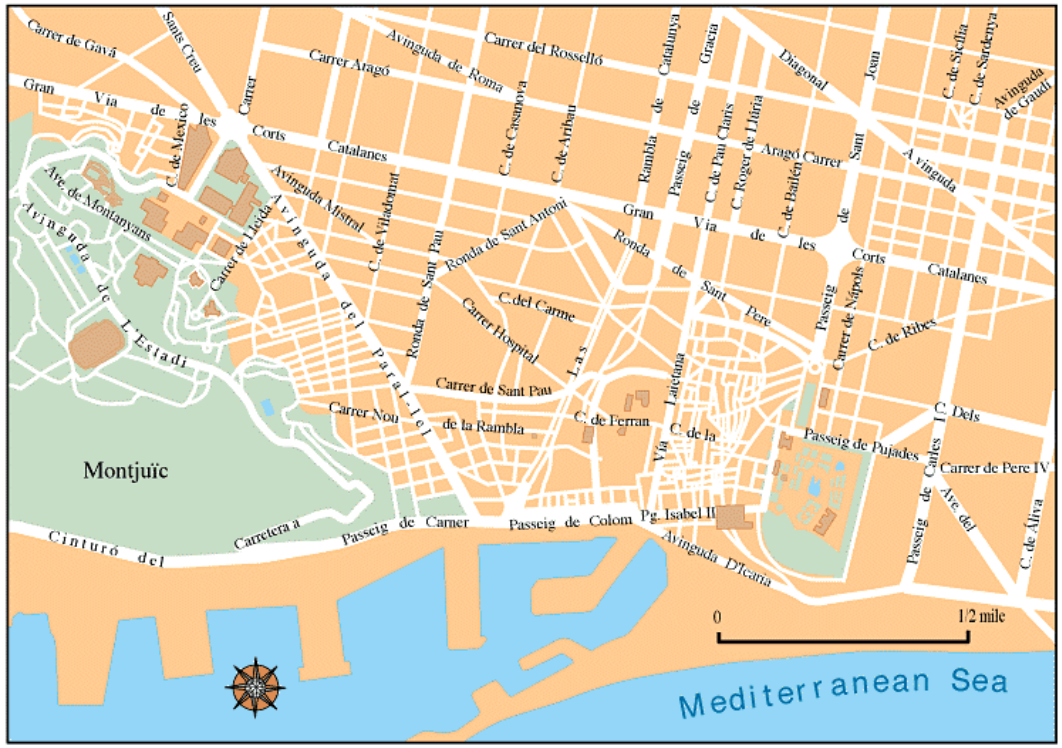
Overview

- Explore some ideas of pattern and meaning
- Examine the role of scale in visualising pattern (what happens when we view things at different scales)
- Present some of the types of analysis used to make explicit what is implicit when viewing map space
- Talk about idea of pattern space…
- Conclusions: compliment of cartography and EDA .. Ideas of geovisualisation



Bedolina Petroglyph, Valcamonica 2500 BC

(What is it that makes it reasonable to claim this as a map?)

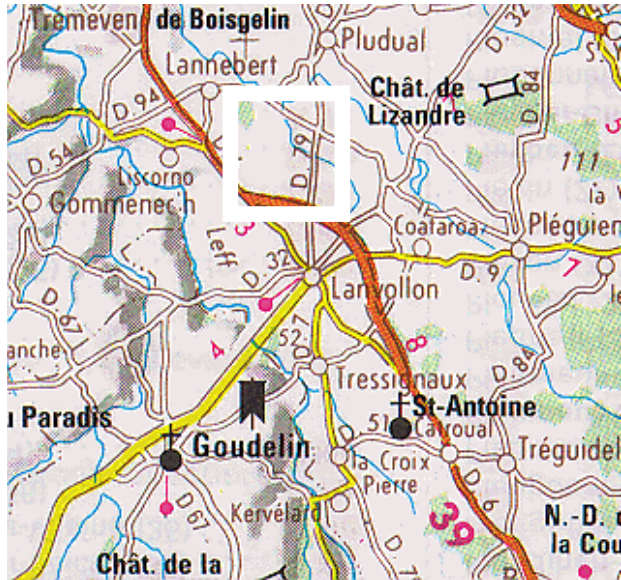


Interpretation: bringing to bear our own geographical knowledge and experiences

Scale Pattern and Geographic Meaning

- Issues of scale “intrinsic to nearly all geographical query” (McMaster and Shea 1992, p1).
- *‘To understand is to perceive pattern’* Isaiah Berlin
- Ideas of scale and pattern are central to the process of interpretation in the geosciences.
- My research: generalisation….

Generalisation

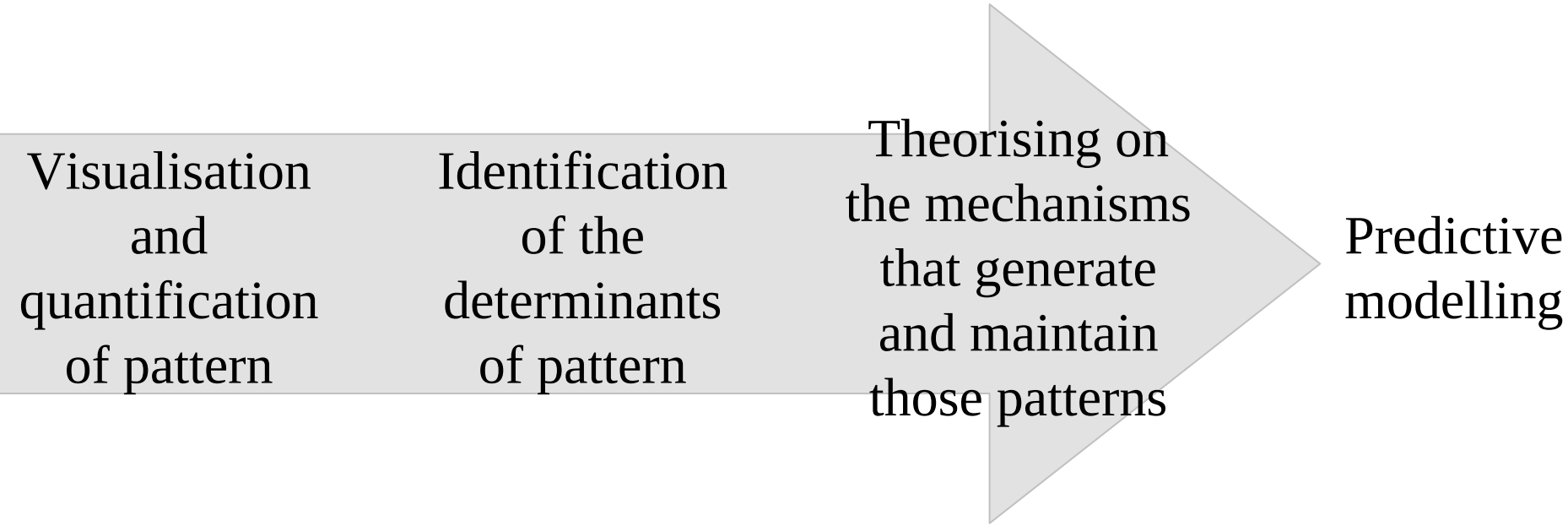


Why compare output at different scales?

- "All geographical processes are imbued with scale" (Taylor 2004)
- So…choice of scale is critical to analysis
- comparing output at different scales, describing .. common practices in the geosciences.
- We wish to know the operational scales of geographic phenomena…
- how relationships between variables change as the scale of measurement increases or decreases;
- want to know the degree to which information on spatial relationships at one scale can be used to make inferences about relationships at other scales
- scale of observation very much "scopes" the problem – providing a starting point from which we "interface" with phenomena that may occur over widely varying spatial, temporal and organisational scales.

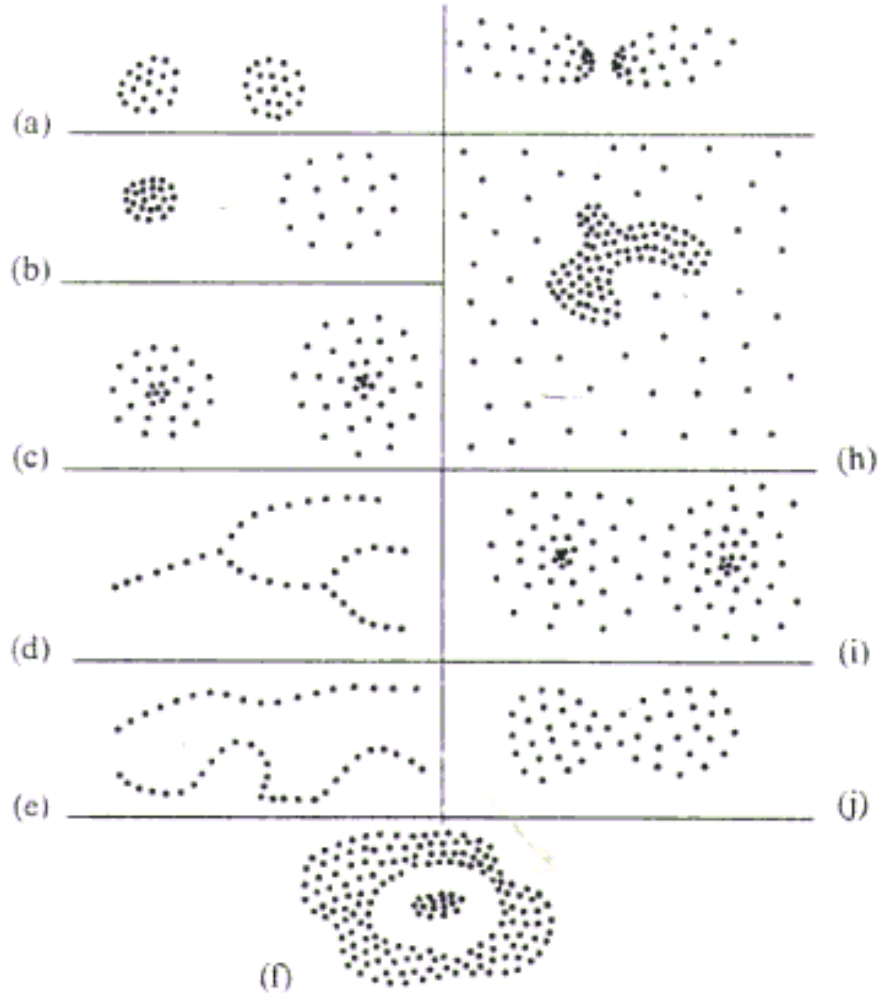
Visualisation of Pattern

- Because we are naturally spatial thinkers (Kaiser, 1993), our efforts to develop theories and models often revolve around visual forms and metaphors
- ….visualisation of pattern is a cornerstone to the development of theories: A pathway from pattern to prediction….


Visualisation and quantification of pattern
Identification of the determinants of pattern
Theorising on the mechanisms that generate and maintain those patterns
Predictive modelling

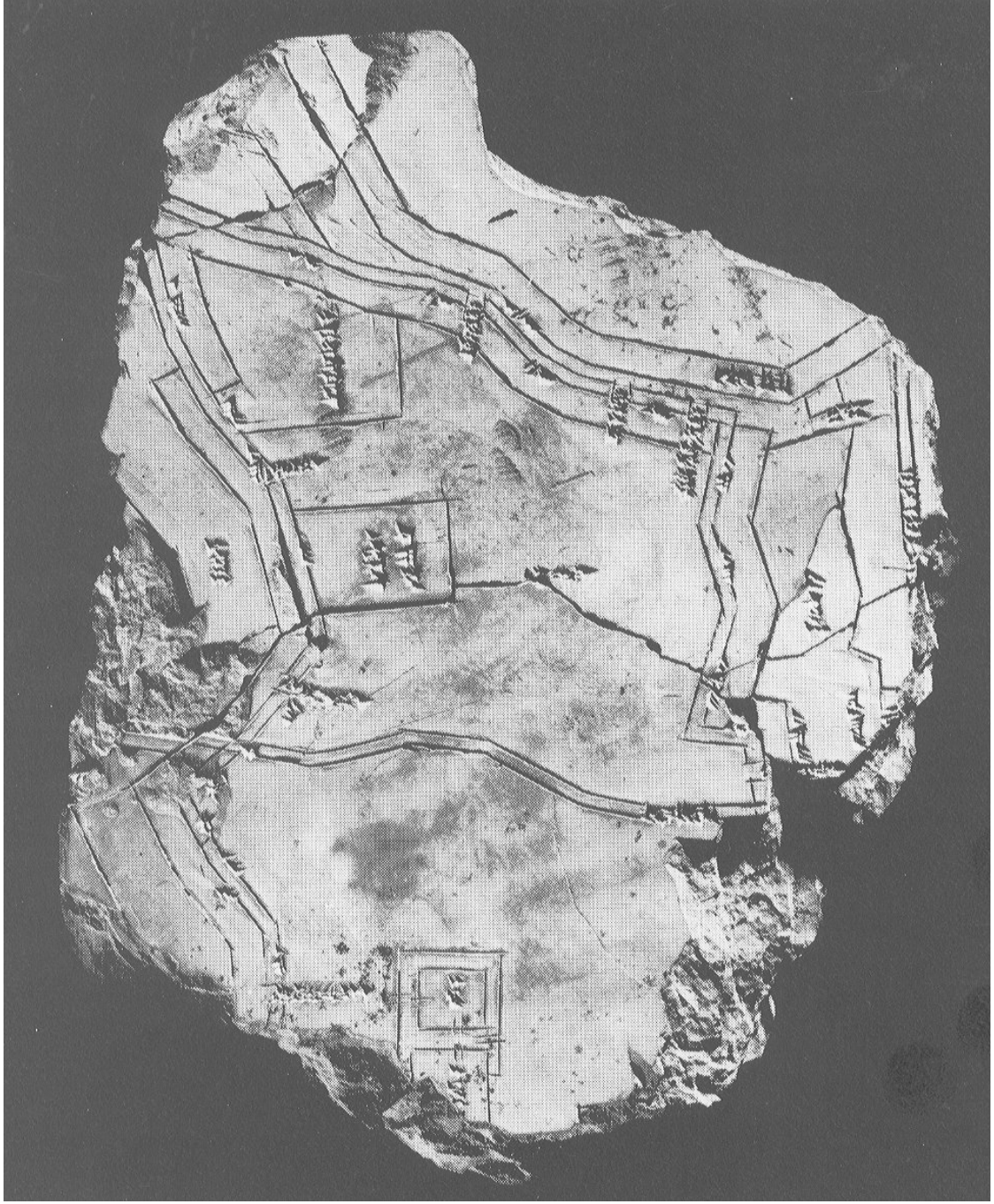
Pattern, structure and meaning

- Patterns convey some underlying process - real or imagined (Zahn 1971).
- The meaning we give to these patterns comes from experiences and understanding of geographic processes.



Patterns and Process

- Patterns evident at any given scale – reflect specific causes and consequences –
- those patterns a manifestation of a collective set of processes, behaviours and responses … operating at a range of scales.
- Understanding of pattern in terms of the processes that produce them is the essence of science – their observation leads us to theorise about the causal processes, and to develop predictive models.
- “The essence of modeling is, in fact, to facilitate the acquisition of this understanding, by abstracting and incorporating just enough detail to produce observed patterns” (Levin 1992, p1946).



Clay tablet from Nuzi
2300 BC

Pattern and Granularity

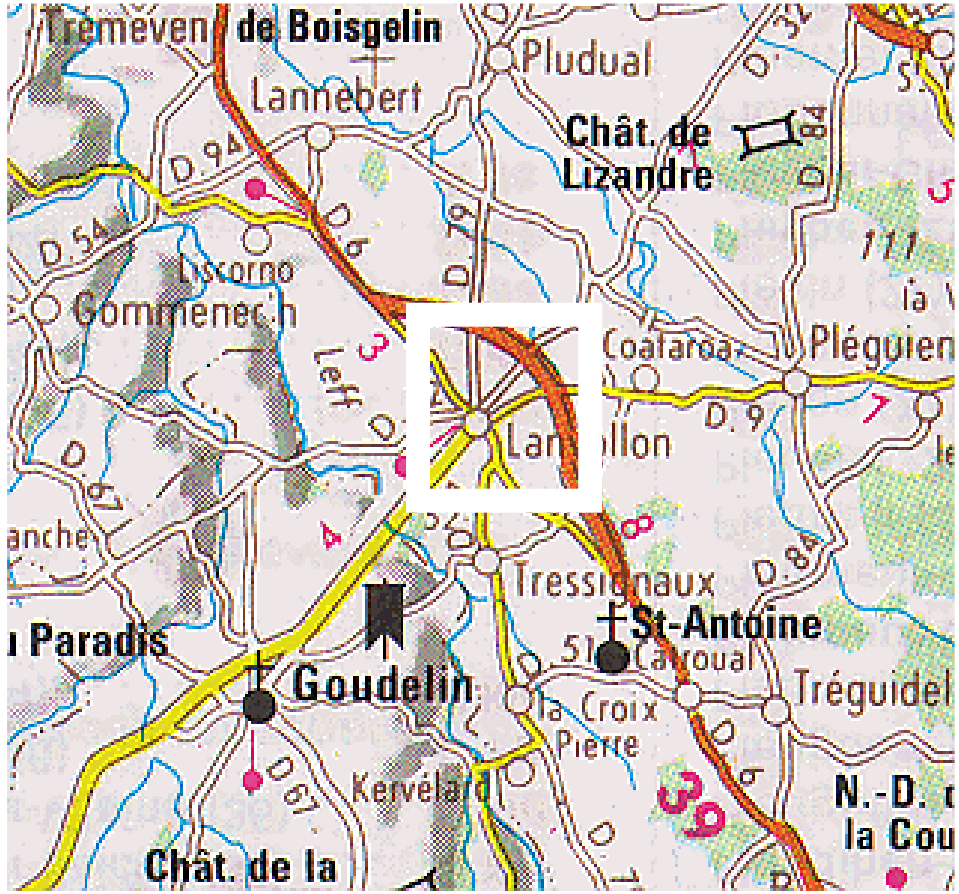
- study how pattern and variability change with the scale of description
- address problems of “cross linkage” – supporting cross scale analysis in situations where relationships vary across scale (Wilbanks 2001).
- by viewing phenomena at coarser scales, we move from the unpredictable to behaviours that are regular enough to allow generalisations to be made
- leading some to argue for a theory of scaling (Schneider 2001).

- no single natural scale at which a geographical problem should be studied… chosen scale often just a start point – one that imposes a necessary and perceptual bias – “a filter through which the system is viewed” (Levin 1992, p1943).
- Often it is important to observe phenomena at a range of scales in order to address problems of sensitivity of scale effects (Meyer et al., 1992), to avoid excessive focus at any one scale (and by inference a particular set of patterns and processes)
- At fine scale of observation we discern many of the attributes that define individual phenomena (their form often revealing their function).
- At broader scale we gain a more synoptic view – regional context in which the phenomenon finds itself.
- .. qualities such as patterns of distribution and association, of containment, connectivity, and contiguity between phenomena.

- Example: river engineer (in designing flood defences) would require detailed plans of the topography either side of a river. At a more general level they would require information on human habitation patterns and at a broader scale, they would also need to know a great deal about the river regime, such as the size of the catchment, the drainage capacity of the soil and the land cover within the catchment.
- Very “granular” or synoptic models necessarily treat subcomponents of the model in a rather homogenous way. E.g. general circulation models – which model processes at the global scale.
- … need to move from the general to the specific, to understand the causal links between processes operating at fundamentally different scales (Wilbanks 2001).

Different characteristic patterns

(a) 1:25 000

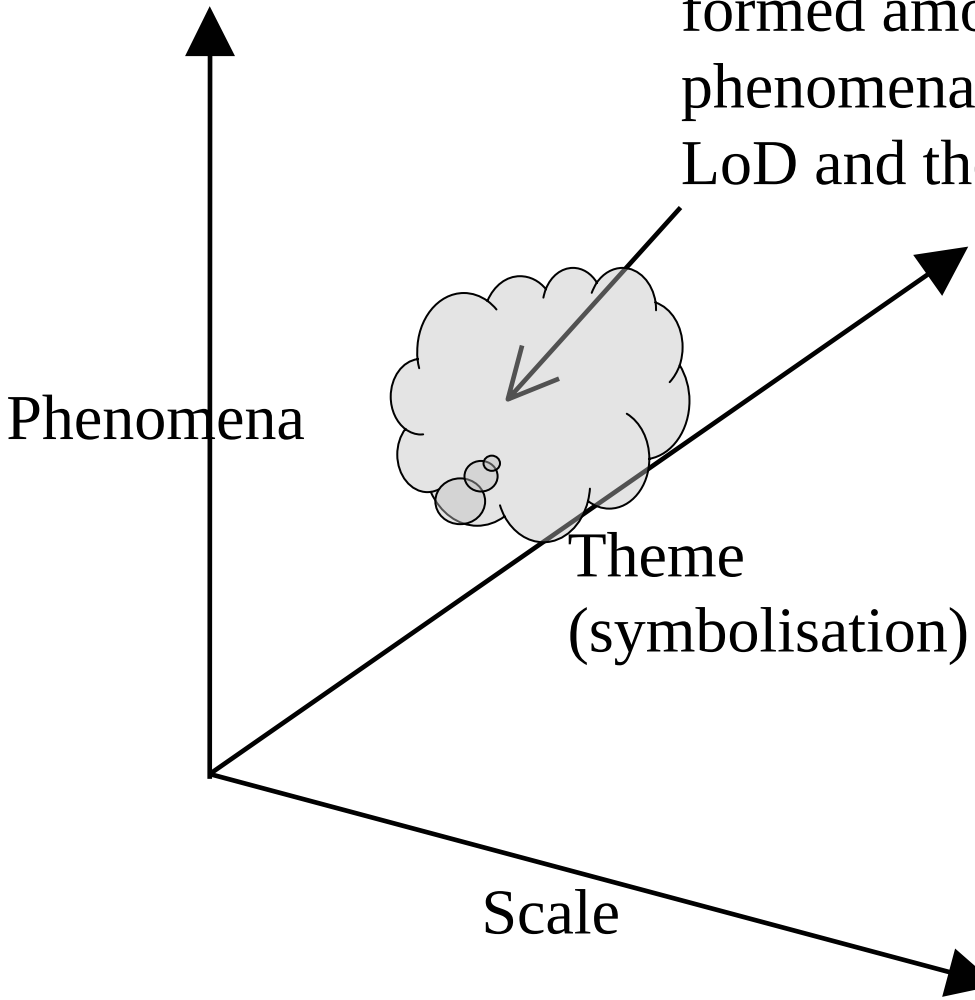


(b) 1: 250 000

scale and symbology will strongly influence what association is seen between morphology and drainage, between the old town of a city and its surrounding suburbs, or the interconnectivity and travel time between major cities.

Interdependence of scale, theme, and pattern:

A particular subset of all patterns formed among a particular set of phenomena, at a particular scale / LoD and theme.



- ….enabling us to interpret the world around us through the process of abstraction….
- Changing scale and theme enables us to see new sets of patterns among geographic phenomenon

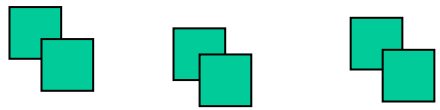
Qualities of pattern

- complexes of primitive objects, and relations between those primitives. Comprising:
- *intrinsic properties:* shape, extent, orientation, distribution/ density, topology configuration (the collection of objects that comprise the pattern).
- *extrinsic relations:* properties between different patterns such as relative proximity/ orientation, topology/ connectedness
- .. variously conveying qualities of similarity, distinctness, regularity or chaos.

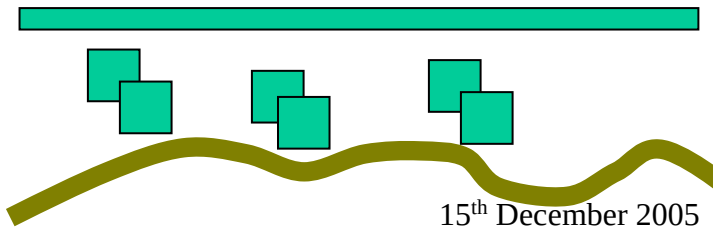
Characteristics of pattern

- High dimensionality - Scale and thematic dependent
- Generalisation - emphasis to specific elements of the pattern
- Patterns within objects

- Patterns within class

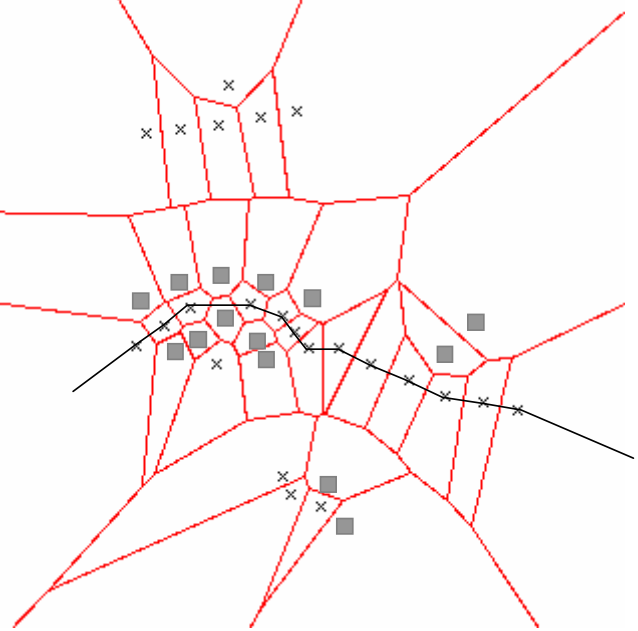


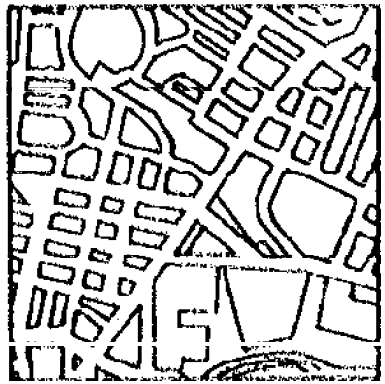
- Patterns between
- (many) classes

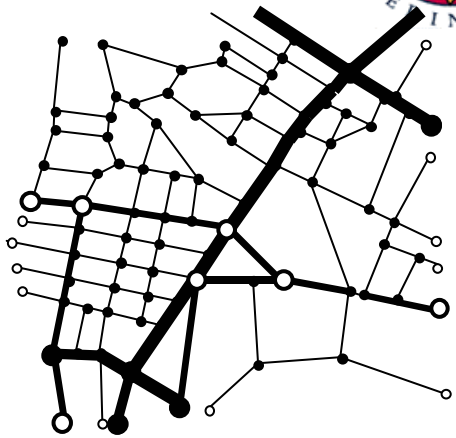


Techniques for detecting pattern

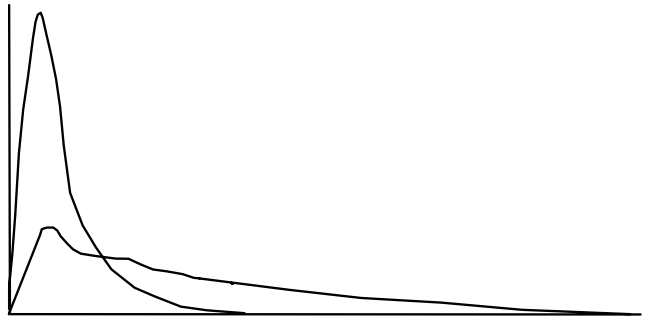
- Metric
- Topological …
- Among surfaces, objects, and networks

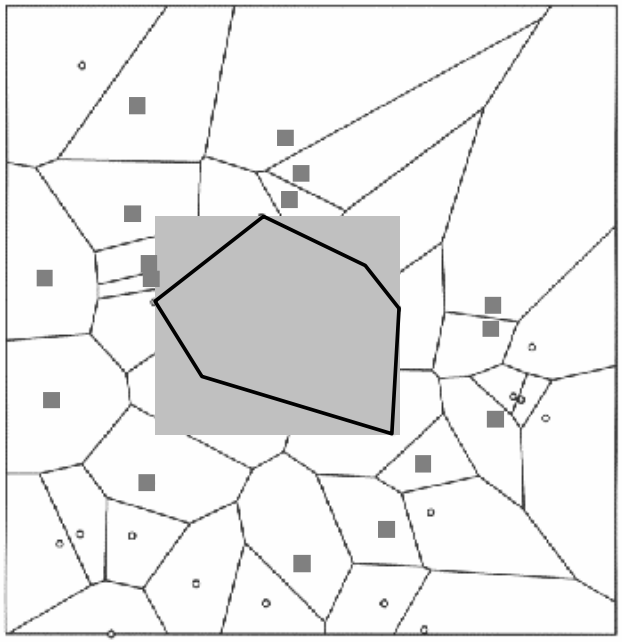


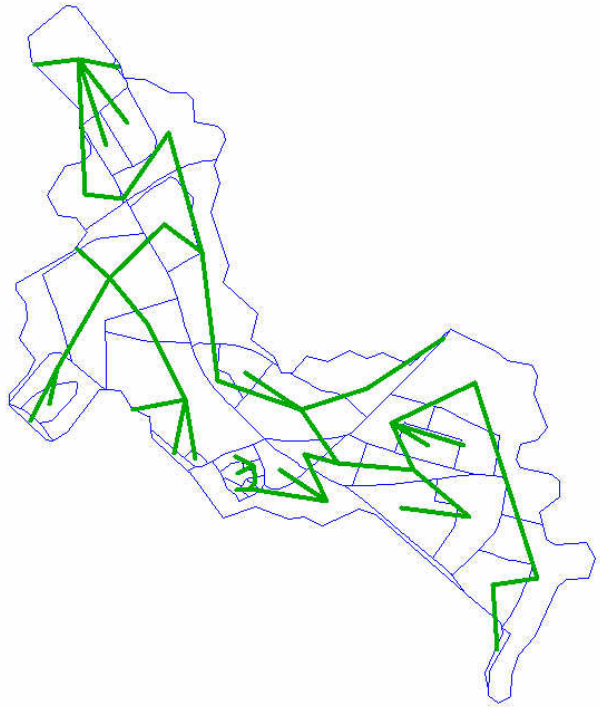


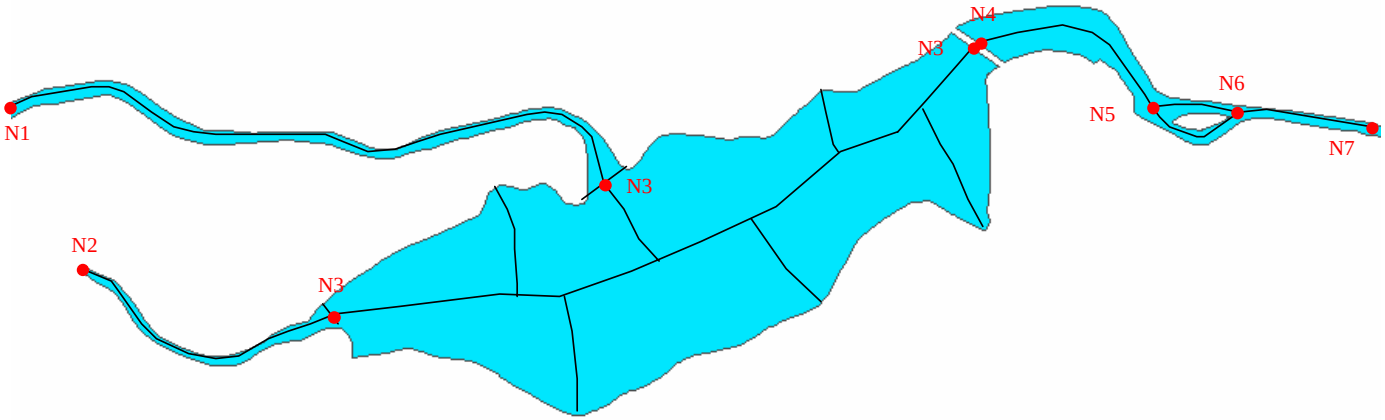



splitting








N1
N2
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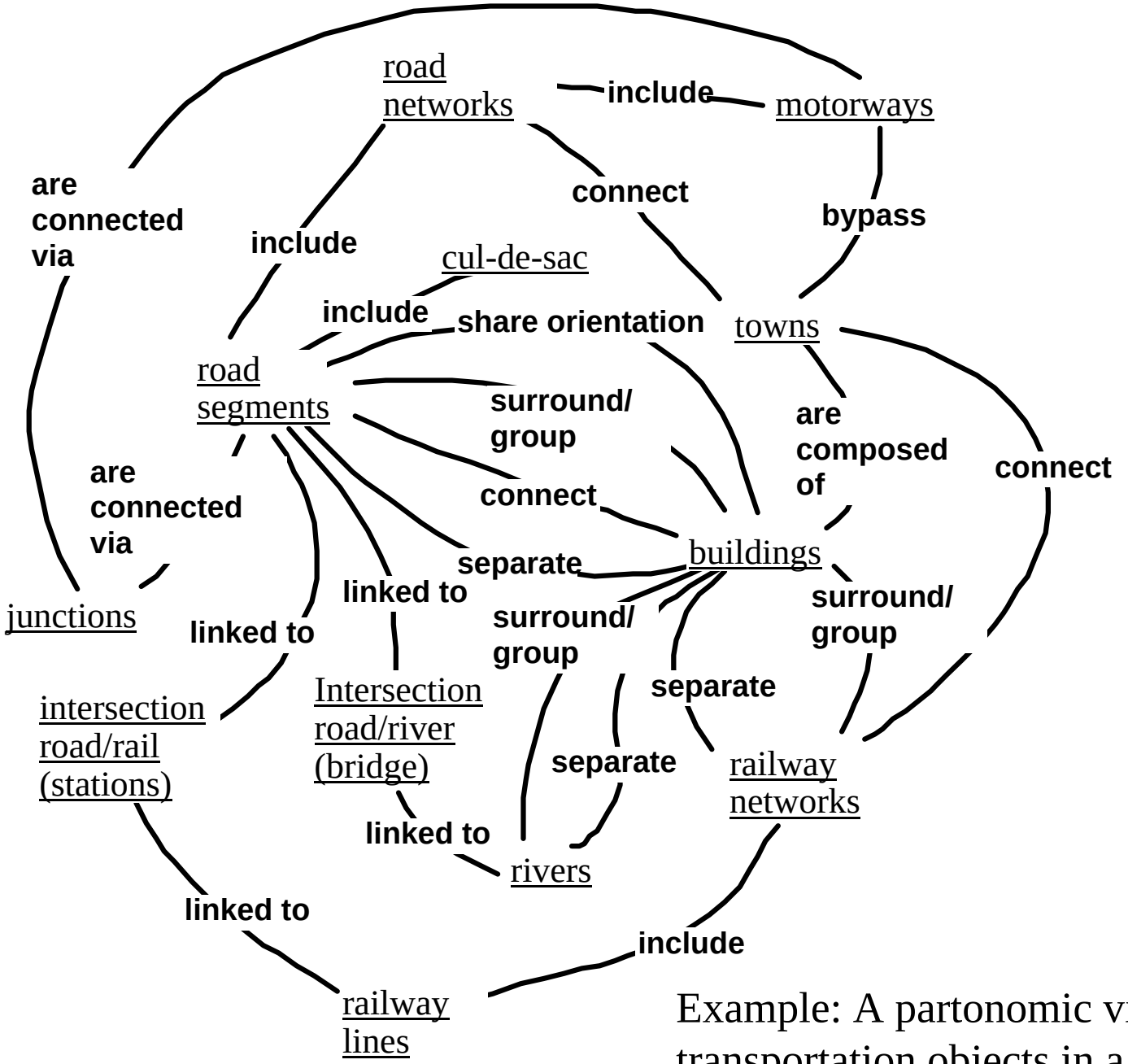
What patterns to measure?

- patterns of association, regularity, similarity, enclosure, differentiation, connectivity, shape, attribution, land use, elevation

- Objects are infinitely decomposable, infinitely describable….
- Apparently an infinite number of measurable properties (both within class, between class)

Recognising Phenomena from Partonomic Structures

- The hierarchical relationships among these various patterns constitutes a partonomy (Tversky 1990) – a partonomy, like a taxonomy, is a hierarchy but based on a "part-of" relation rather than a "kind-of" relation (taxonomy).
- A set of partonomic relationships gives rise to distinctive spatial configurations that enables the categorization of pattern and the identification of phenomena, as a first step in their interpretation.
- combination of various patterns enables the creation of 'higher order' phenomenon
- Example of: town conveyed by the densities, metric and topological characteristics and associations among railways, rivers, buildings, streets, airports, historic and cultural landmarks)



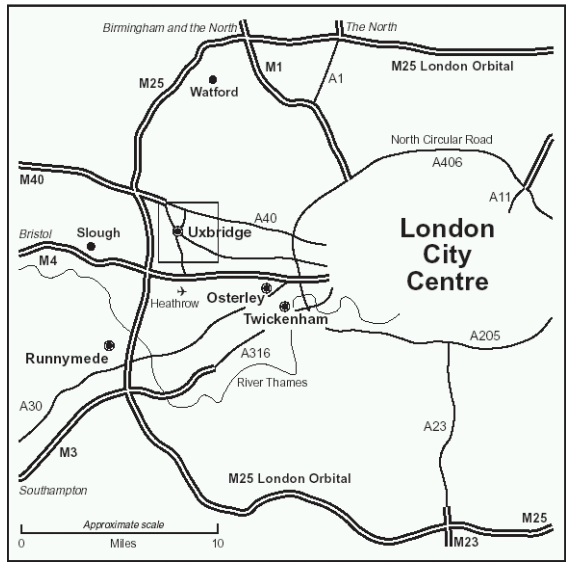
Example: A partonomic view for a subset of transportation objects in a city.

Taking advantage of partonomic relationships

Partonomic organisation promotes an understanding of function and interaction with other patterns.

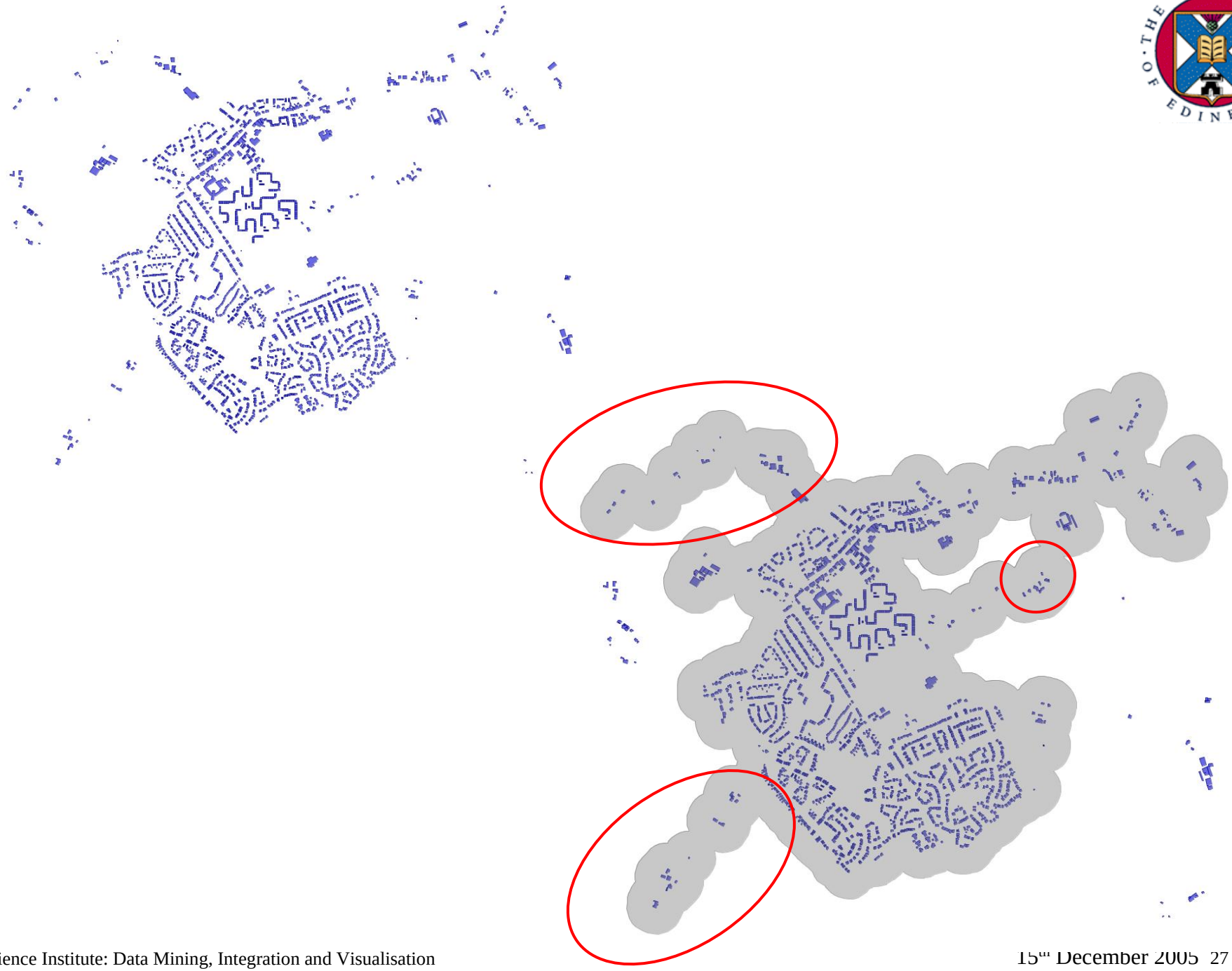
Example: partonomic organisation of a city boundary and its role as a hub to a collection of roads enables us to recognise and accept highly abstracted forms of such a relationship.

Example: Lanvollon as a simple circle, the roads as spokes radiating outwards from its centre



London and its major arteries: where do all the roads go?

Existence of such partonomic organisations is what ‘survives’ Muller’s conceptual cusps.



Classifying patterns…

- Patterns can be organised into partonomic hierarchies reflecting relations between parts and subparts.
- The taxonomic hierarchy reflects ‘kind – of’ relations.
- Change in scale – change in partonomic views.
- Cartography concerned with the minimum partonomic form of any given pattern in order to convey a particular set of relationships between a set of geographic phenomenon across scales

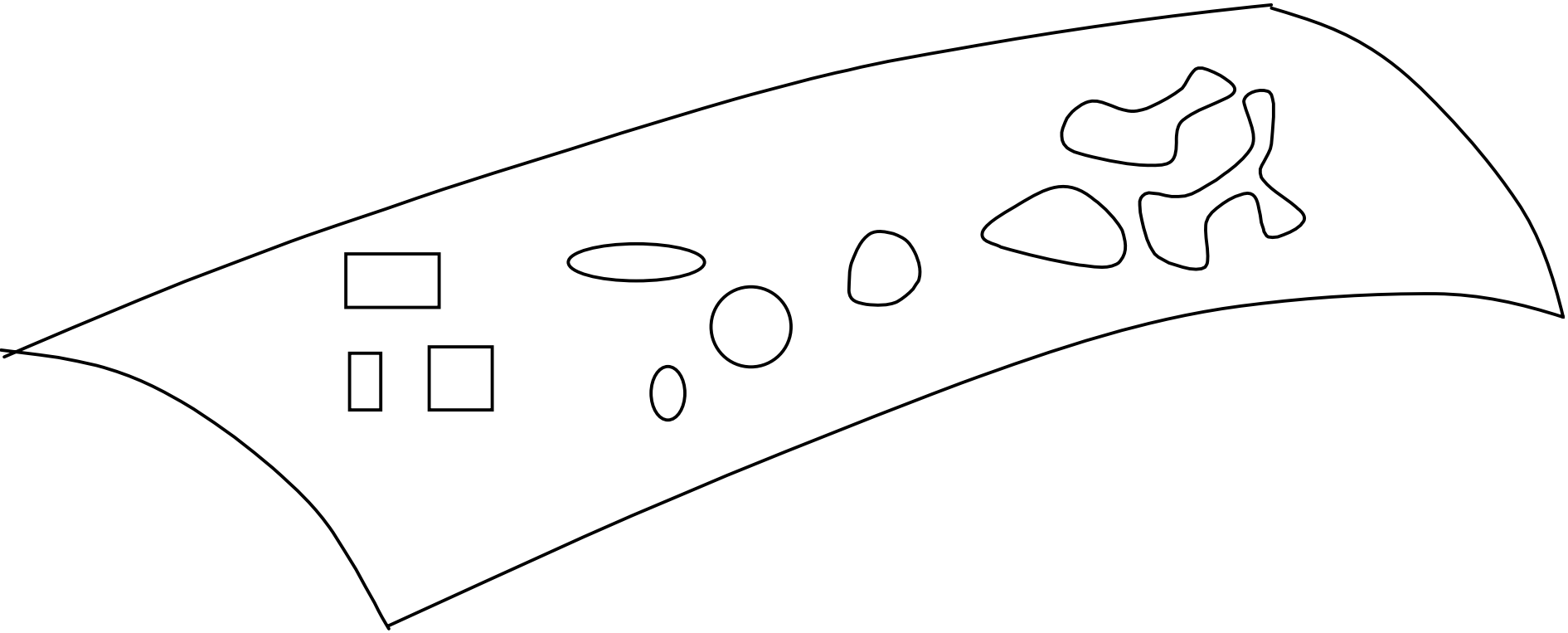
Patterns as object

- **patterns as objects:** bounded in space, organised hierarchically - recognisable by a set of distinctive qualities.
- The ‘high level’ structures and patterns > can be ‘decomposed’ / defined in terms of individual map objects

Categorisation of Pattern – the idea of Pattern Space

- Interpretative process > successful identification and categorisation of various patterns.
- Each pattern defined in a multidimensional feature space in
- ...each dimension captures some quality of pattern (qualitative / quantitative, intrinsic/ extrinsic).
- Any given pattern can be placed in this multi-dimensional space – the metric proximity of any set of patterns denoting similarity/ dissimilarity of shape.
- Patterns, as objects, can be treated as points that reside in the pattern space
  – creating ‘clouds’ of points according to similarity, creating neighbourhoods of similar patterns.

Pattern Space



Pattern Space: patterns embedded in a multi dimensional measurement space

First and second order isomorphisms

- First order isomorphism is concerned with changes in the intrinsic qualities of a pattern.
- Second order isomorphism calls for the representation of the *morphing of patterns* (modelling the changes from one pattern to another)
- …….rather than the representation of its geometry per se.

First and second order isomorphisms

- Generalisation of a pattern creates second order changes between the pattern and surrounding patterns
- In pattern space the point representing the location of any given pattern ‘moves’ through pattern space as the level of detail changes.

Some Research Questions

- How many dimensions of pattern description are there (qualitative/ quantitative)?
- Is there a set of pattern primitives to give a structural description for any given pattern?
- How do we model decomposition of pattern?
- No framework in which we can model the manifestations of an object over changing scales & themes
- Need a science of morphology dealing with underlying principles of form description
- a framework for modelling transitions in patterns
- Shape grammars (Gips 75; Stiny 75) and space syntax (Hillier and Hanson)

Conclusion (1 of 3): The Link

- inextricable link between scale, pattern and meaning (Hutchinson 1953)
- Meaning and interpretation can only be gained by viewing phenomena at a range of scales and in varying contexts (themes).
- …operational scales at which processes operate – reflecting a linkage between scale and the persistence of a pattern through changing levels of detail.
- ? dominant patterns among phenomena: defined in terms of how much they persist over large changes in scale.

Conclusion (2 of 3): Generalisation

Generalisation is about:

- Generalisation as a process by which we render a subset of relationships through the manipulation of individual objects and their relationships
- modelling geographic space – the scale at which we view the world profoundly affecting our ability to understand it.
- modeling the way in which information is transferred across scales.
- Generalisation as a set of transformations (from one pattern to another) in which certain partonomic qualities are preserved and others are disregarded

Conclusion (3 of 3): Data Modelling

Databases

- Database centric view – the Map as a “looking glass” by which we interactively search and retrieve information
- increasing emphasis now being given to data modeling and ways of reclassifying and aggregating geographic phenomena
- ….Reclassifying and aggregating has relevance to data mining and pattern analysis techniques
- Decision Making
- High levels of automation: shifting the balance and process of decision making between the human and the machine

- End

Conclusion (3 of 3)

Analytical Techniques

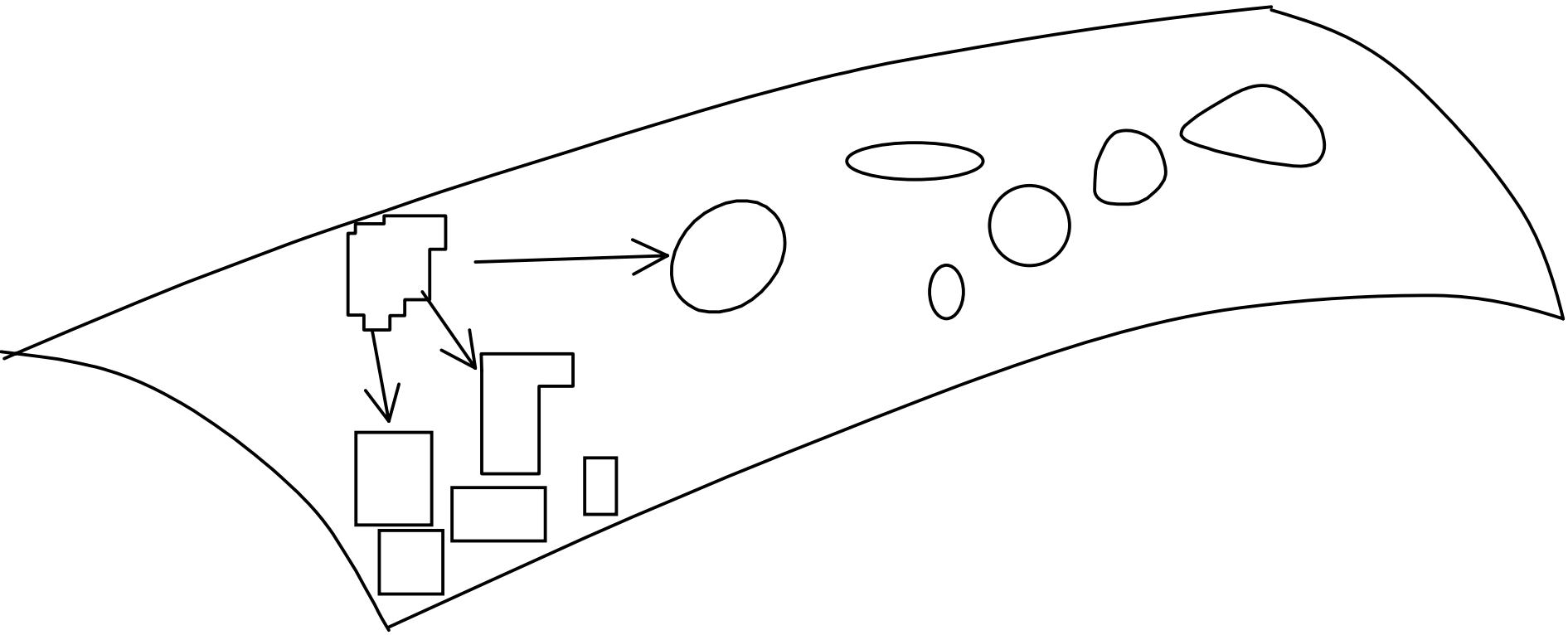
- No limit to cartometric analytical techniques:
- For 1) discrete (individual buildings, coastline), 2) continuous surfaces (numerical description of the topography of a piece of land), 3) networks…
- Object description (density, isolation, extent, hausdorf, MBR, compactness, contiguity, orientation)
- Patterns of distribution, surface classification and trends (cluster analysis, trend surface analysis)
- Structural form (skeletonisation)
- Object Neighbourhoods (Space exhaustive tesselations of space, topological models, manifolds)
- Patterns of networks (graph theory)
- ….Shape grammars (Gips 75; Stiny 75) and space syntax

A Need for a Science of Morphology?

- No science of morphology dealing with underlying principles of form description
- Disparate collection of techniques: no criteria for selecting among that collection
- No framework in which we can model the manifestations of an object over changing scales & themes

Labelling the dimension of pattern space

- How do we categorise / decompose pattern?
- Computationally tractable > the number of dimensions must be low
- Yet sufficient ‘fidelity’ that we can distinguish and ‘place’ any given pattern, and model second order isomorphism during generalisation.
- Pattern decomposition (borrow from Hummel and Biederman’s 36 simple 3D forms – called geometric ions)



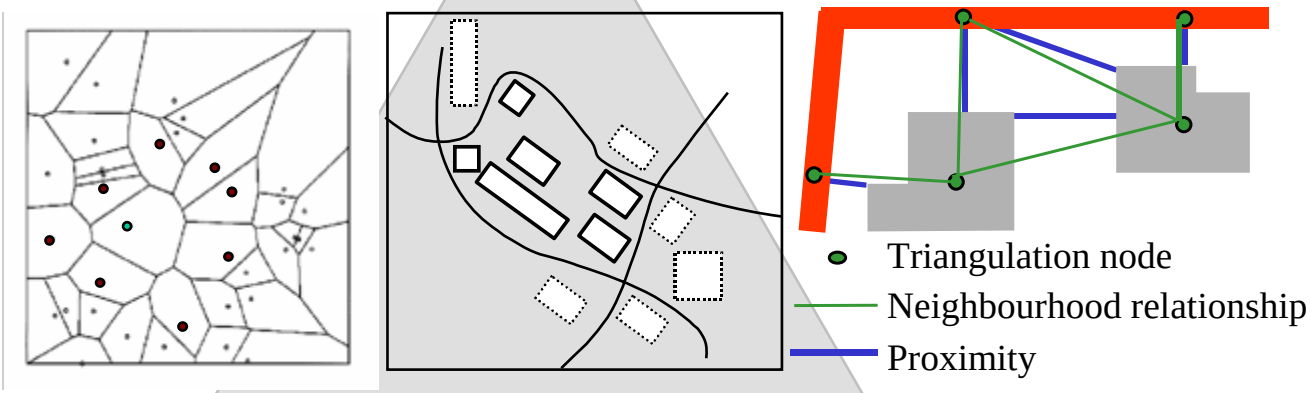
Three new derived forms – the degree of difference from the original form represented as the distance from the original object in a multi dimensional pattern space.

Linkages between taxonomies and partonomies

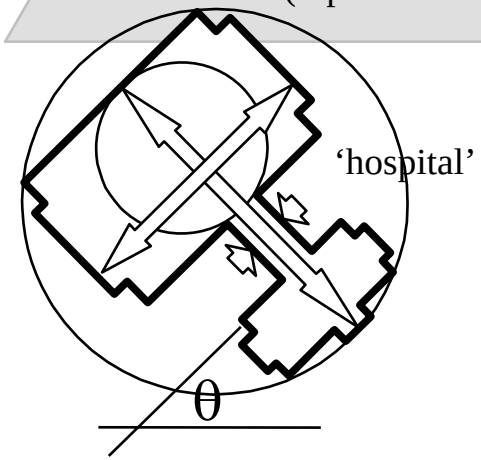
- the structure *within* a pattern contributes to the structural relationships *between* patterns
- Example: relative orientation and proximity between buildings and roads, or between varying river sinuosity and elevation.

…for a discrete object….

‘local interaction’ /relative description
Relationship between object and other objects in immediate vicinity (relative alignment, relative size, proximity model)



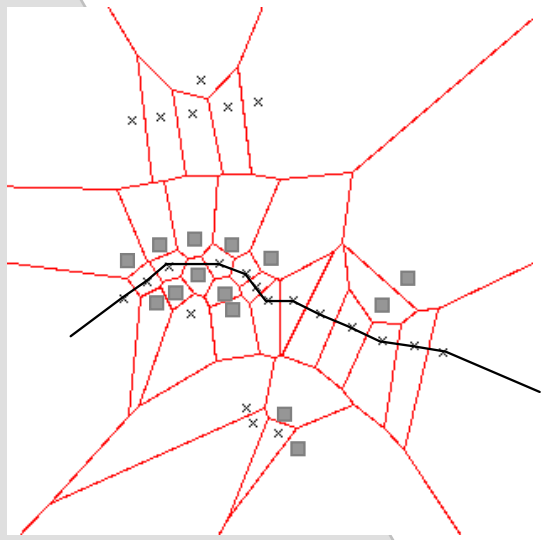
‘internal’ description (for each discrete component part:)
shape metrics (compactness, area, type...)
associated behaviours (aspatial attributes)



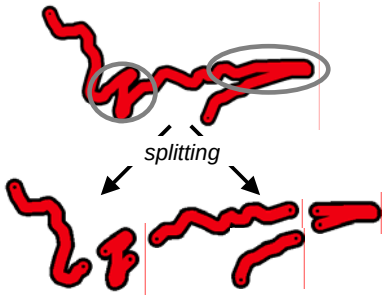
‘collective’ description
pattern of distribution of all objects of that class

…for a linear/ network object….

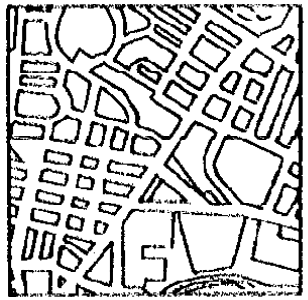
'local interaction' /relative description
Relationship between object and other objects in immediate vicinity (relative alignment, relative size, proximity model)

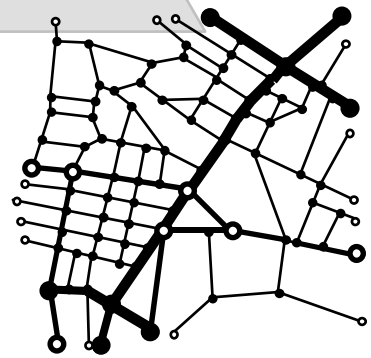


'internal' description (for each discrete component part:)
shape metrics (contiguity, convolution, type...)
associated behaviours (aspatial attributes)



'collective' description
graph theoretic representation of all road class





Taxonomic View

- Partonomic views reveal the relationship between objects, … a taxonomic view can be used to categorise pattern.
- Example: city boundary is a member of the taxonomic category ‘anthropogenic forms’ and it is therefore likely to be comprised of a set of connected lines forming a region.