

PROCESSES AND EVENTS IN GEOGRAPHICAL SPACE

Session II: Handling Processes and Events in GIScience

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A “Brief History of Time”

(Worboys & Duckham 2004, Worboys 2005)

- ▶ **Stage 0:** Static GIS
- ▶ **Stage 1:** Snapshots
- ▶ **Stage 2:** Object changes
- ▶ **Stage 3:** Events, processes, and actions

Stage Zero: Static GIS

Geographical information is presented without any time-reference. The time is implicitly some generalised “present” — but this could be

- ▶ When the data were collected (but this could span a long period)
- ▶ When the data were entered into the system (ditto)
- ▶ When the system was published/released (could be much later)
- ▶ When the user accesses the data (unpredictable)

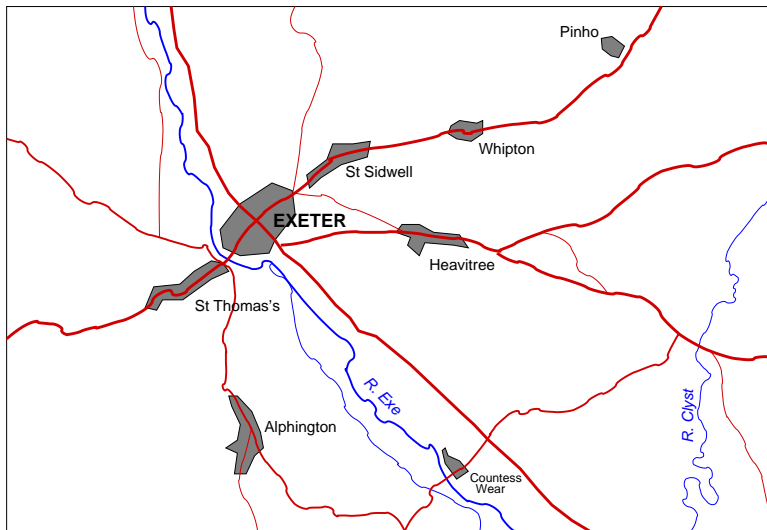
Only really useful for representing things which *don't change*, or *only change slowly*.

Stage One: Snapshots

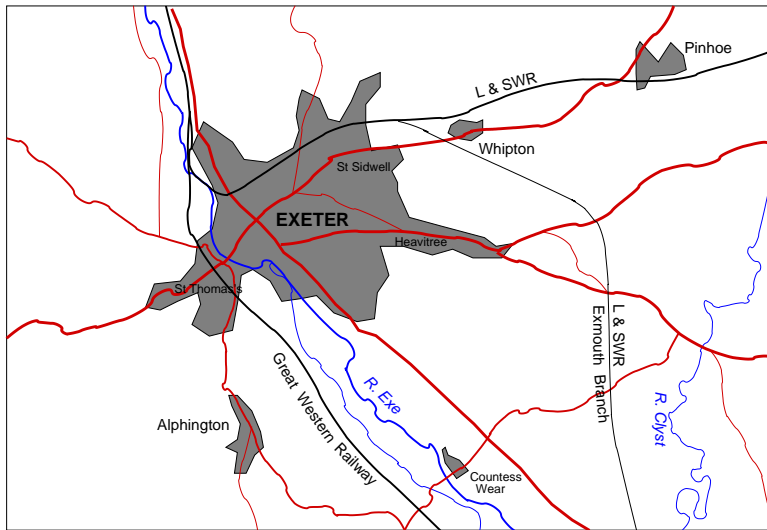
The passage of time is represented by means of a *sequence of snapshots*, each indexed by a different time.

See examples on the next four slides, showing the development of Exeter (Devon,UK) over the last 200 years.

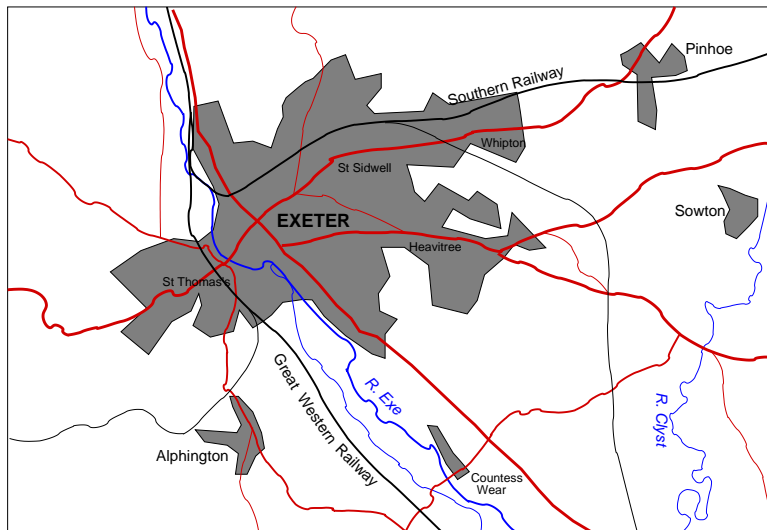
Exeter 1809

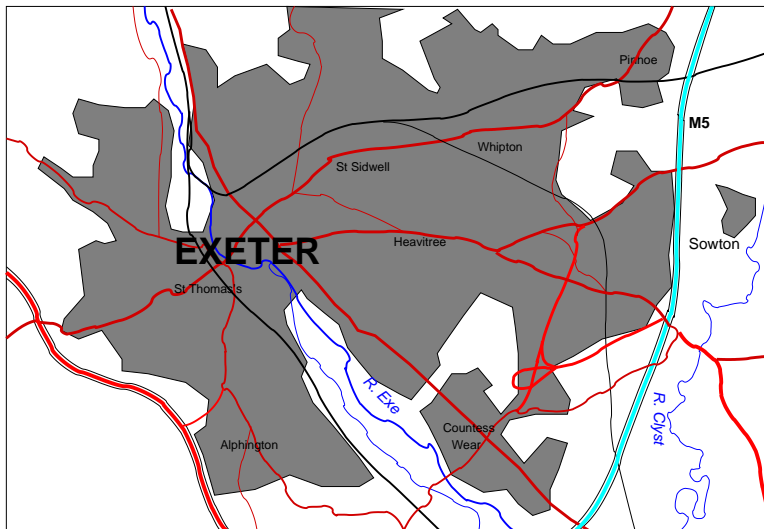


Exeter 1898



Exeter 1946





What can be inferred from the snapshots?

Given these four snapshots, we can infer that

- ▶ The branch-line past Alphington was built between 1898 and 1946, and was closed between 1946 and 2006.
- ▶ The M5 motorway was built between 1946 and 2006.

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But we *cannot* answer the question

- ▶ Was the branch-line closed before or after the motorway was built?

Refining the snapshot model

If we have more snapshots we can answer more of these kinds of question.

If we have one snapshot for each year, then any change can be pinned down to within a year, so we can infer the relative ordering of any changes that are more than a year apart.

But the storage implications of this are considerable.

A better plan is to have a single baseline snapshot, and then store only the changes that take place.

This leads directly on to . . .

Stage Two: Object change

At Stage 2, the focus is on the life-histories of individual objects and features in the area of interest, rather than on snapshots.

We now store explicitly information such as:

- ▶ The branch line past Alphington was opened in 1903 and closed in 1958.
- ▶ The M5 motorway was extended as far as Exeter in 1977

and from these we can infer the answer to our question

- ▶ Was the branch-line closed before or after the motorway was built?

The branch-line was closed *before* the motorway was built.

We distinguish between

- ▶ *Changes which do not affect an object's identity.*
These include change of location, change of size, shape or orientation, some changes of name, change of government, many physical changes.
- ▶ *Changes which do affect an object's identity.*
These include the creation or destruction of an object, merging, splitting, reincarnation, etc. — so called “Identity-based change” (Hornsby & Egenhofer).

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Throughout these changes the geographical identities of both the USA and Hawaii were preserved. What changed was the political status of the latter.

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Czechoslovakia was created in 1918 on declaration of independence from the former Austro-Hungarian Empire.

In 1993, Czechoslovakia ceased to exist, its territory being partitioned between two new entities, the Czech and Slovak republics.

The creation in 1918 and partition in 1993 were changes that occurred with respect to Czechoslovakia, both of which affected its identity (bringing it into existence, and destroying it).

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Compare the reunification of Germany: this may perhaps be described as the BRD retaining its identity while absorbing within itself the former DDR, which thereby ceased to exist as a geographical entity. [I invite correction from any Germans present in the tutorial!]

Identity of natural features

With changes in geopolitical entities, there are often explicit agreements about identity.

With natural entities, it may be much less clearcut:

A lake divides into two water-bodies as the water-table lowers.

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There is nothing in *nature* to decide between these; we are free to choose — and we are forced to do so if we want to record the change explicitly in a Stage 2 GIS.

Stage Three: Events, processes, and actions

Not everything that happens is easily described using episodes in the life-histories of objects.

At Stage 3, events, processes and actions are accorded first-class status as fully-fledged members of the ontology.

This allows us to handle phenomena such as

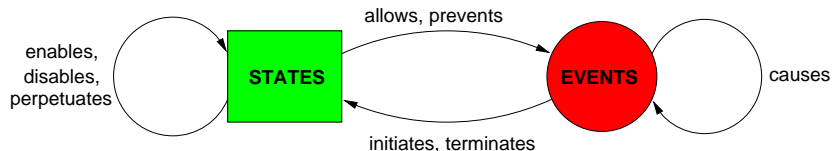
migrations, wildfires, hurricanes, epidemics, traffic congestion, battles, coastal erosion, . . .

viewing them as objects of study in their own right and not just as a collection of episodes from the life-histories of individual objects.

In particular, we can describe the network of *causal relations* amongst events, processes, and states, forming the basis for *explanation* and *prediction*.

Causal relations amongst events, processes, and states

Galton & Worboys (in GeoS 2005) attempted to establish a “standard terminology” for these. See the notes for an explanation of the different terms in the diagram:



Example: An **accident** *causes* the road to **become obstructed**, which *initiates* the **obstructed state** of the road, which *perpetuates* the **low traffic flow** that is *initiated* by the **reduction in flow** caused by the road **becoming obstructed**.

3+1 or 4?

- ▶ **3+1-dimensionalism:** The world is a three-dimensional *space* whose three-dimensional contents come into existence, move about, change, and pass away as *time* passes.
- ▶ **4-dimensionalism:** The world is a four-dimensional *space-time* whose four-dimensional contents are fixed once and for all.

You may hear passionate arguments on both sides!

The argument from relativity

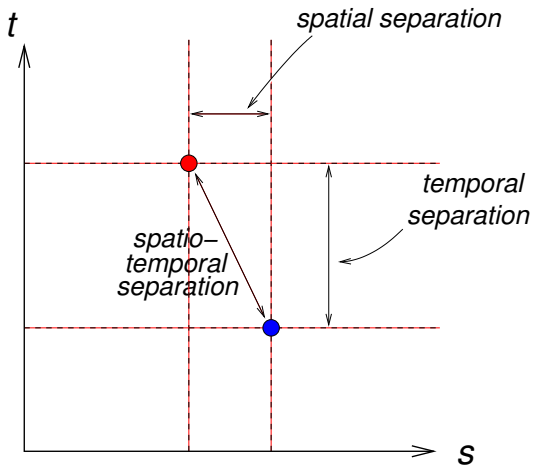
The Special Theory of Relativity tells us that *the spatial and temporal separations between two events are not absolute but depend on the state of the observer.*

Instead, *the spatio-temporal separation between two events is absolute and does not depend on the state of the observer.*

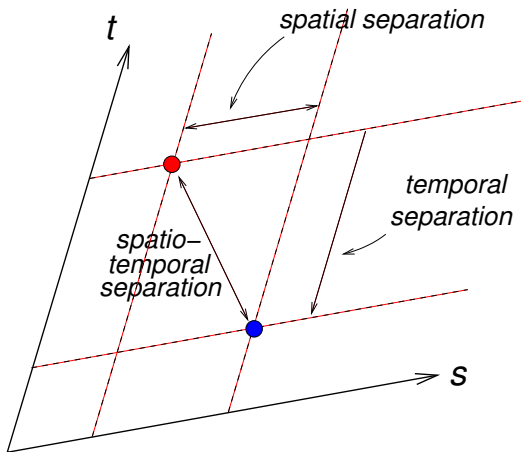
Different observers will resolve the spatio-temporal separation into spatial and temporal components in different ways.

Hence, the only viable observer-independent picture of the universe is as a four-dimensional “block”.

Minkowski diagrams



Minkowski diagrams



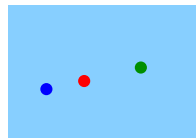
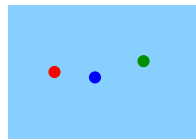
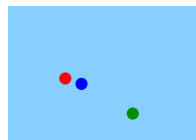
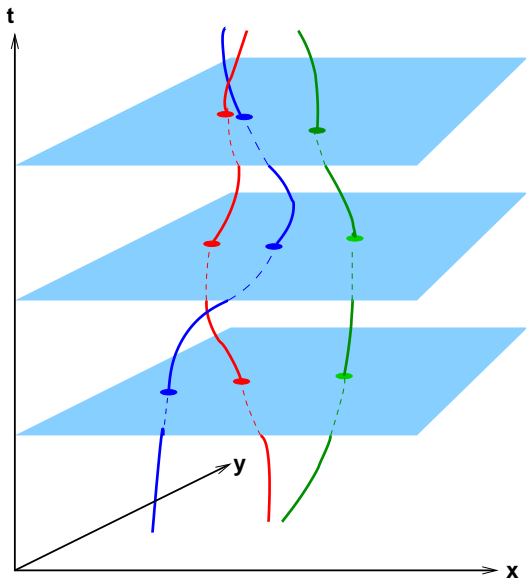
The relativistic effects illustrated in the Minkowski diagrams only become apparent when the relative motions are appreciable fractions of the speed of light.

Hence, for earth-bound geographers they are irrelevant.

None the less, the Minkowski diagram has inspired a potentially useful way of visualising change in the geographical world.

This is illustrated by Hägerstrand's *time geography* diagrams.

Time Geography diagrams (Hägerstrand, 1967)



The four-dimensionalist view of time, motion, and change

- ▶ The collection of spatio-temporal positions (\mathbf{x}, t) occupied by an object is its *lifeline*.
- ▶ “Motion” means that the lifeline contains points (\mathbf{x}_1, t_1) and (\mathbf{x}_2, t_2) for which $t_1 \neq t_2$ and $\mathbf{x}_1 \neq \mathbf{x}_2$.
- ▶ An object doesn’t “move along” its lifeline or “move through space-time”.
- ▶ On a fully-fledged 4-D view, the object *is* the contents of its lifeline.
- ▶ What we see at any one time is a “temporal slice” of the object, not the whole thing.
- ▶ Objects are not distinguishable from events: they are both just the contents of selected chunks of space-time.

N.B.: Most everyday language is adapted to the three-dimensional view. To espouse four-dimensionalism, you must abandon or radically reinterpret it.

Back to three-dimensionality: Continuants and Occurrents

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OCCURRENTS

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- ▶ At different times, the same continuant may have different properties; this is *change*.

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- ▶ It is said to *occur* (not exist).
- ▶ At different times, different parts of the occurrent are present.
- ▶ An occurrent is not said to undergo change.

Continuants and Occurrents

Continuants include most things we would normally call “objects”: *people, tables, chairs, buildings, roads, mountains, clouds, planets, ...*

The prototypical occurrents are events: *the assassination of Julius Caesar, the Second World War, a person’s life, an earthquake, a volcanic eruption.*

Not everyone agrees about states and processes:

- ▶ BFO: states are continuants (SNAP), processes are occurrents (SPAN)
- ▶ DOLCE: states and processes are both occurrents
- ▶ APG (idiosyncratic?): states and processes are both continuants (or “continuant-like”).

Fields and Objects

The distinction between field-based and object-based (or entity-based) approaches to modelling geographical information is well known.

- ▶ A **field** is a function mapping spatial locations to values, providing a *coverage* (e.g., an elevation field). The field-based approach is typically associated with **raster graphics**, in which colour values are assigned to pixels.
- ▶ An **object** is a discrete entity to which is assigned a spatial location. The object-based approach is typically associated with **vector graphics**, in which each entity is represented by its *geometry*, which may be a point, line, polyline, polygon, or (in 3D) solid.

What are the temporal analogues of fields and objects?

Temporal fields and objects

- ▶ A **temporal field** is a function from times to values. This is known as a *fluent* in Artificial Intelligence. Example: A record of how temperature/rainfall/wind speed/... at a particular location varies over time. Temporal fields record *states*.
- ▶ A **temporal object** is a discrete entity to which is assigned a temporal location: an *event*. An object-based approach to temporal information would be a database of events.

Fields are more “primitive” than objects; temporal fields appear earlier than temporal objects in Worboys’ sequence of stages.

The field-based approach puts space or time before what they contain; with the object-based approach it is the other way round.

Neither approach is superior to the other: each is needed in appropriate circumstances.