THE UNIVERSITY OF MELBOURNE

Image Adapted from cliparts.co

GEOM20007

SPATIAL VISUALISATION

GEOVISUALISATION 1

REVISION

- Cartographic interaction
- Interaction types
- WIMP/GUI/Widgets
  - Linear work flows are too rigid for exploration

PUTTING IT TOGETHER

Data graphics

- Visual variables (Bertin)
- Design principles (Tufte)

Cartography

- Cartographic visual variables (MacEachren, Slocum et al.)
- Cartography design principles (Slocum et al.)

Visual Design (information)

Coming up: <u>interaction design</u>

OVERVIEW

- What is geovisualisation?
  - Tukey's EDA
  - Visual Thinking

- Techniques and tools for exploring data

GEOVISUALISATION

Builds from visual communication to visual thinking to present a coherent view of a phenomena

Theory, methods, and tools for visual exploration, analysis, synthesis, and presentation of geospatial data - any data having a geospatial reference
(MacEachren and Kraak, 2001)

EXPLORATORY DATA ANALYSIS (EDA)

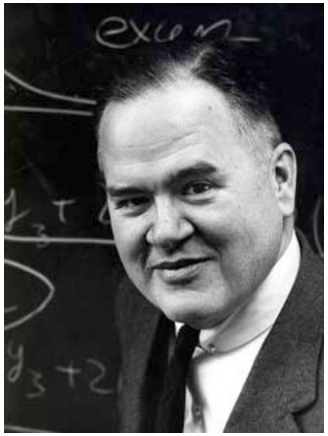


Image: http://quotesgram.com/john-tukey-quotes/

Tukey (1977) described three components EDA

1. Graphical presentation
2. Provision of flexibility in viewpoint and in facilities
3. Intensive search for parsimony and simplicity

EXPLORATORY DATA ANALYSIS (EDA)

1. Graphical presentation

Data graphic techniques

- Tables
- Graphs (e.g., histogram, scatterplot)
- Numerical summaries (e.g., mean, std. dev., correlation)

Cartographic techniques

- Thematic maps (e.g., dot, choropleth, prop'al symbols)

Draws on various disciplines

- Human physiology (e.g. sensory system), psychology (e.g. mental workload), ergonomics (e.g. context of use), **graphic/cartographic design principles**

(ISO, 1998)

EXPLORATORY DATA ANALYSIS

2. Provision of flexibility in viewpoint and in facilities

Interaction design

- Dialogues
- Dialogue principles (e.g., suitability, error tolerance)
- Mapping to interaction primitives

3. Intensive search for parsimony and simplicity

The Design Process

- Context of use, user requirements
- Produce designs (e.g. graphic-carto-dialogue principles)
- Early designs (e.g. wireframe), later designs (e.g. prototypes)
- Evaluation
- Iterative design process

VISUAL COMMUNICATION AND THINKING

(Dibiase, 1990)

1. Visual communication
   - Display space << Data space
   - Visualisation pipeline is critical

2. Visual thinking
   - <u>Traditionally</u> private
   - Visual-information-seeking mantra
     - Overview first, zoom and filter, then details-on-demand

(Shneiderman, 1996)

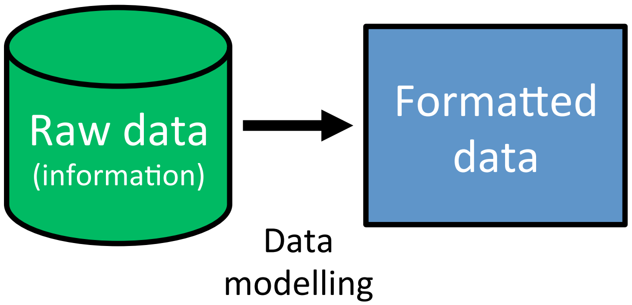
More information: http://www.infovis-wiki.net/index.php/Visual_Information-Seeking_Mantra

EXPLORATION IN GEOVISUALISATION

Common methods

1. Manipulating data
2. Varying symbolisation
3. User viewpoint
4. Highlighting and linking data
5. Multiple views
6. Dynamic re-expression
7. Animation

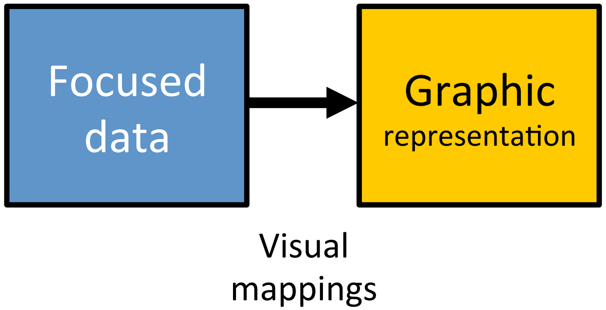
1. Manipulating data



Common techniques for manipulation

- Sorting/arranging (e.g., ordering columns)
- Standardising (e.g., proportion, density, rate)
- Transforming (e.g., matrix operations, changing scales)
- Classification (e.g., equal int., quantiles, optimal)

2. Varying the symbolisation



- Change the type of visualisation (e.g., choropleth to prop. symbol)
- Change the mark used (e.g., graphic primitive or visual variable)
  - Interactive colour schemes
    - ColorBrewer and Landserf Schemes (giCentre Utilities)

2. Varying the symbolisation (quant/qual), e.g., statistical bins

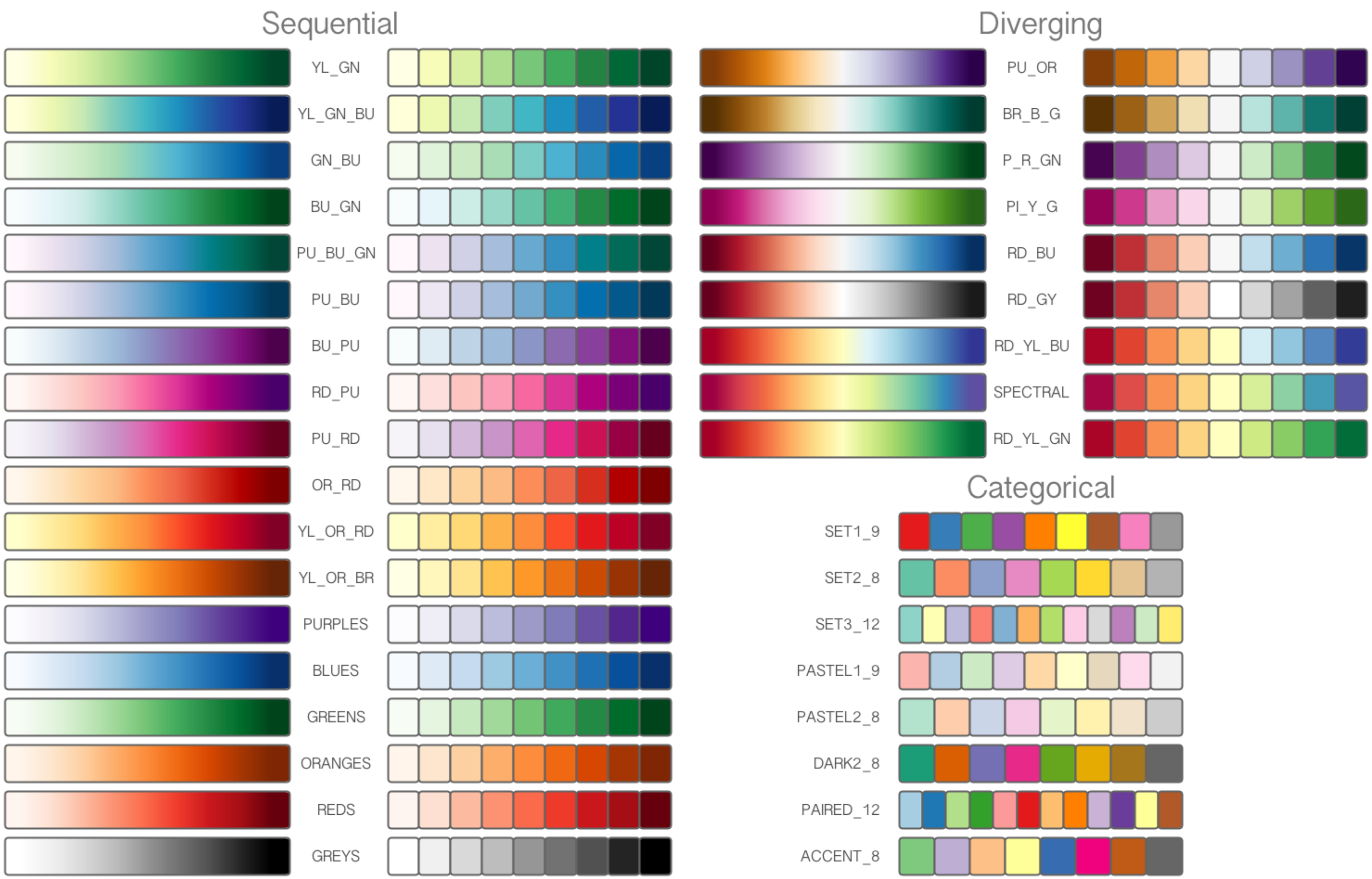
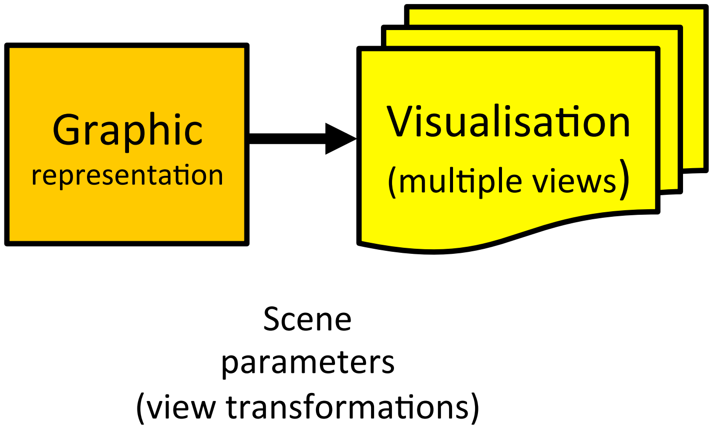


Image: giCentre – Colour, http://www.gicentre.net/utils/colour/

3. User viewpoint



- Change ‘view’ of the data, while preserving data and symbolisation
- Common techniques 2D/3D space
  - Zoom, pan
- Exploration interaction type
  - Similar to direct manipulation, extend concept of moving
- Beware cognitive overloading
  - Adapts to zoom level (e.g., screen clutter)

4. Highlighting and linking data (Voigt, 2002)

Brushing and **linking** are interaction techniques

Used to enhance the data in scatterplot matrices, parallel coordinates and many other visualisations

Brushing means selecting a subset of the data items with an input device (e.g., mouse) for emphasising/de-emphasising features

Can also **link** with tabular data!

4. Highlighting portions of data

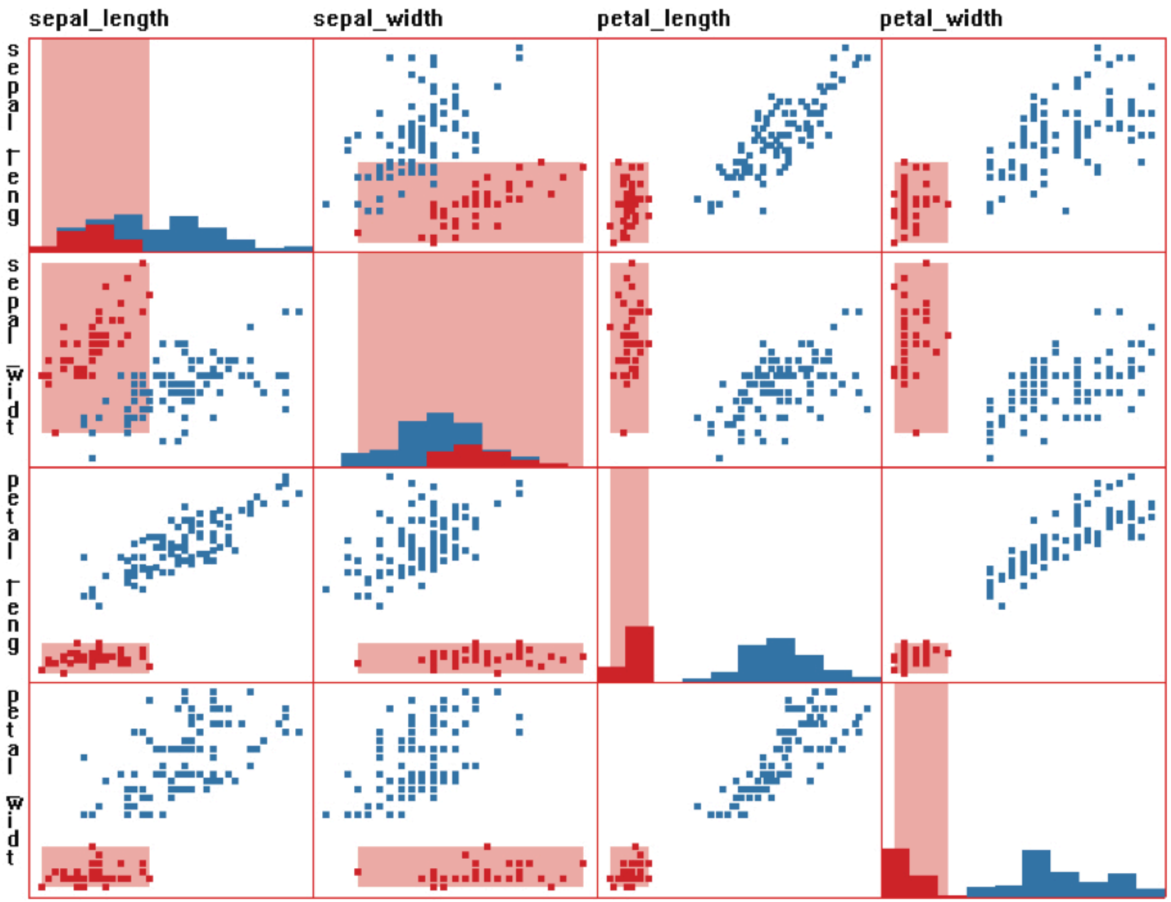


Image: Ward et al. (2010

5. Multiple views

Displaying more than one thing at a time **to compare things visually**

- Map + table + graph + numerical summaries

Relies on careful organisation of information

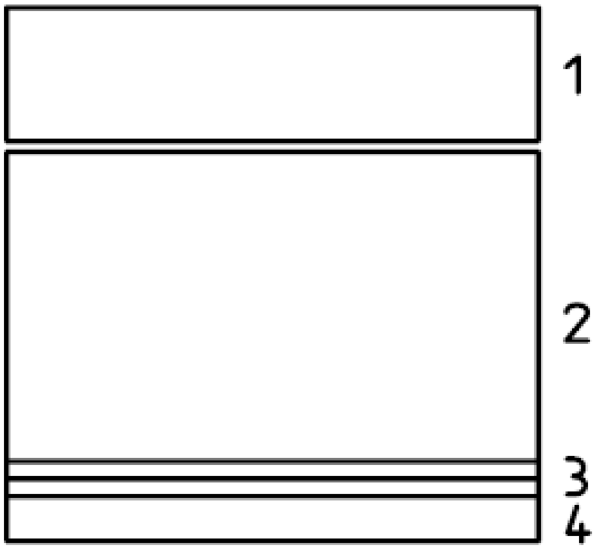
- Detailed in ISO 9241-12:1998

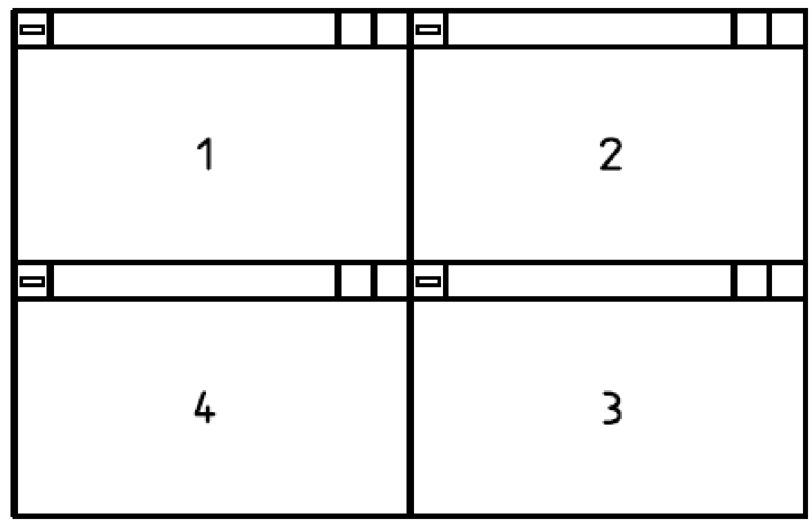
Techniques

- Multiple windows with relationships (primary, secondary)
  - Same data, different symbolisation
  - Small multiple (e.g., maps for individual time steps)
  - Overview + detail (e.g., varying temporal granularities)
  - Focus + Context

5. Multiple views (ISO, 1998)

Conceptual model: How are these windows related?





1 Identification area
2 Input/output area
3 Control area
4 Message area

1 Window 1
2 Window 2
3 Window 3
4 Window 4

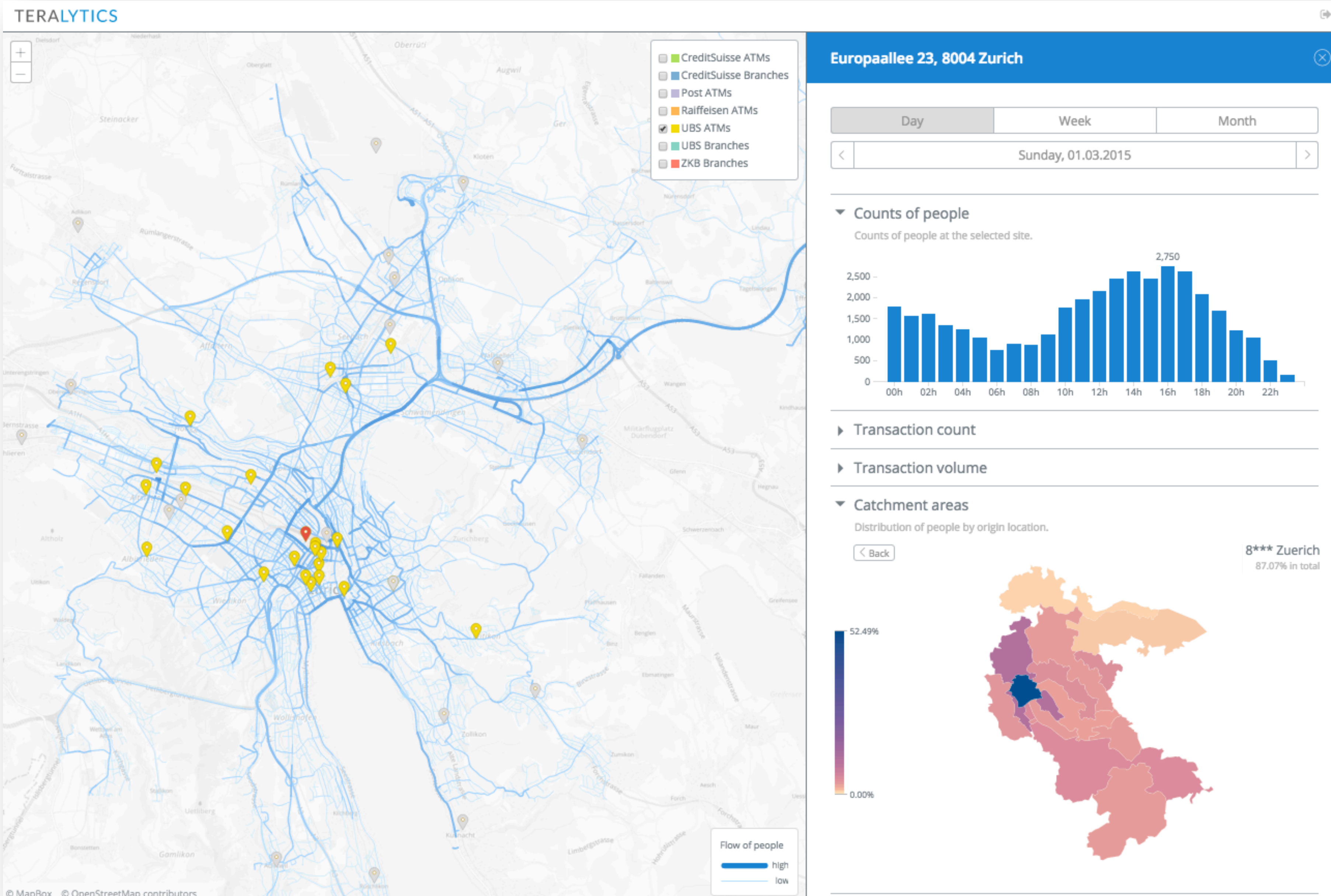


Image: Teralytics, Ilya Boyandin (2016)

5. Multiple views – Small multiple (spatio-temporal dataset)

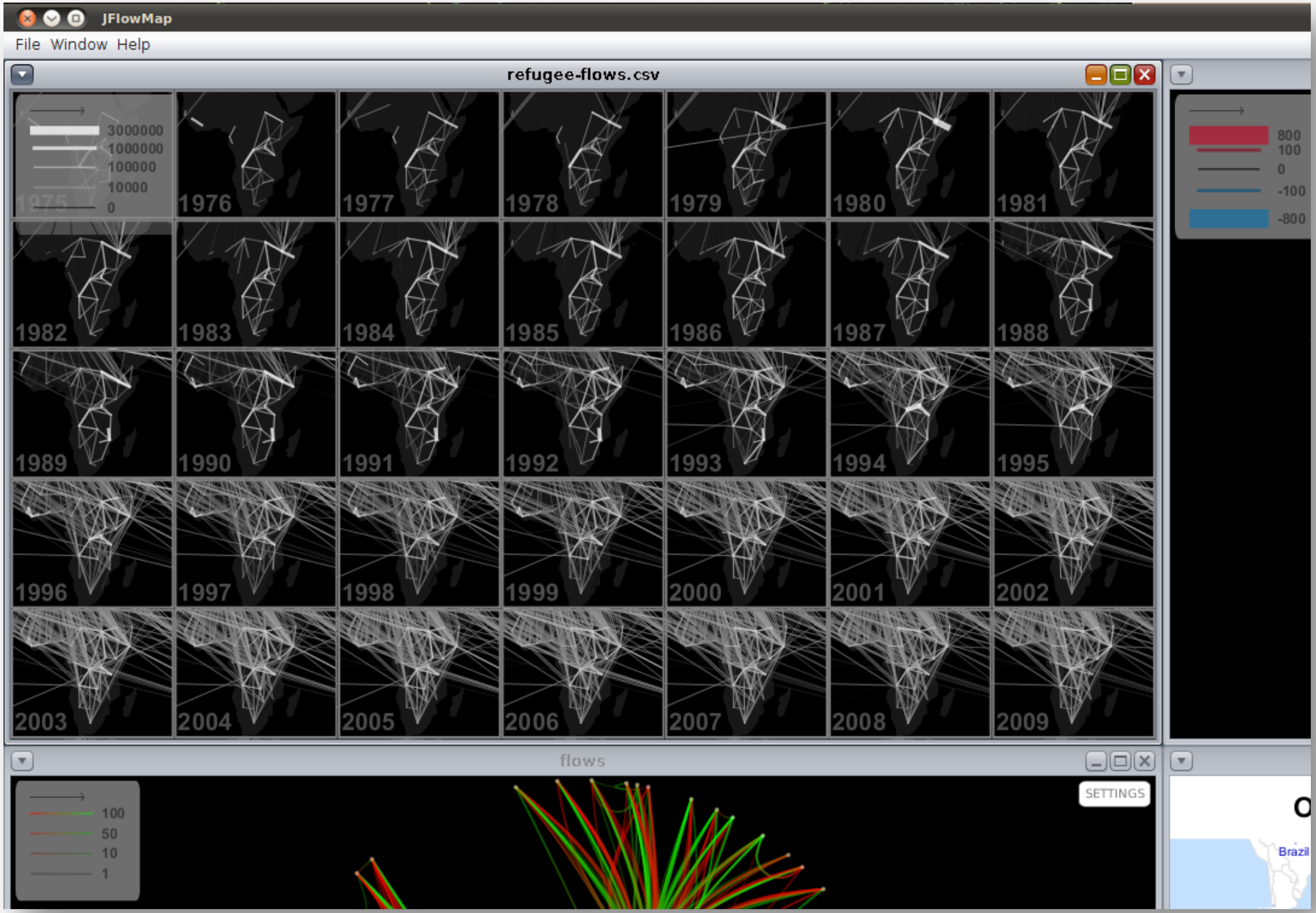


Image: JMapFlow, Ilya Boyandin (2010)

5. Multiple views – Overview + Detail (temporal dataset)

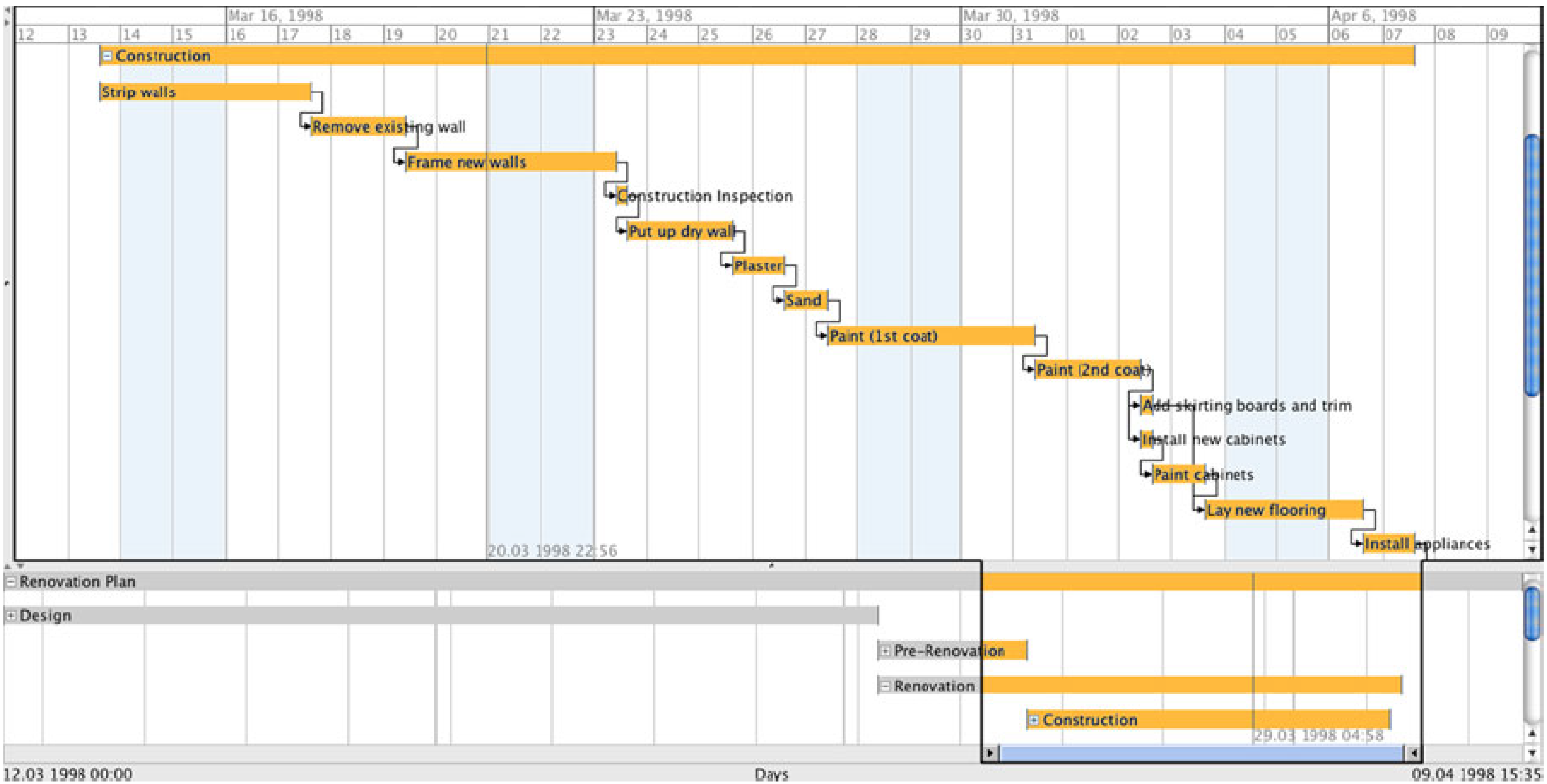


Image: Aigner et al. (2011)

5. Multiple views – Focus + Context (temporal dataset)

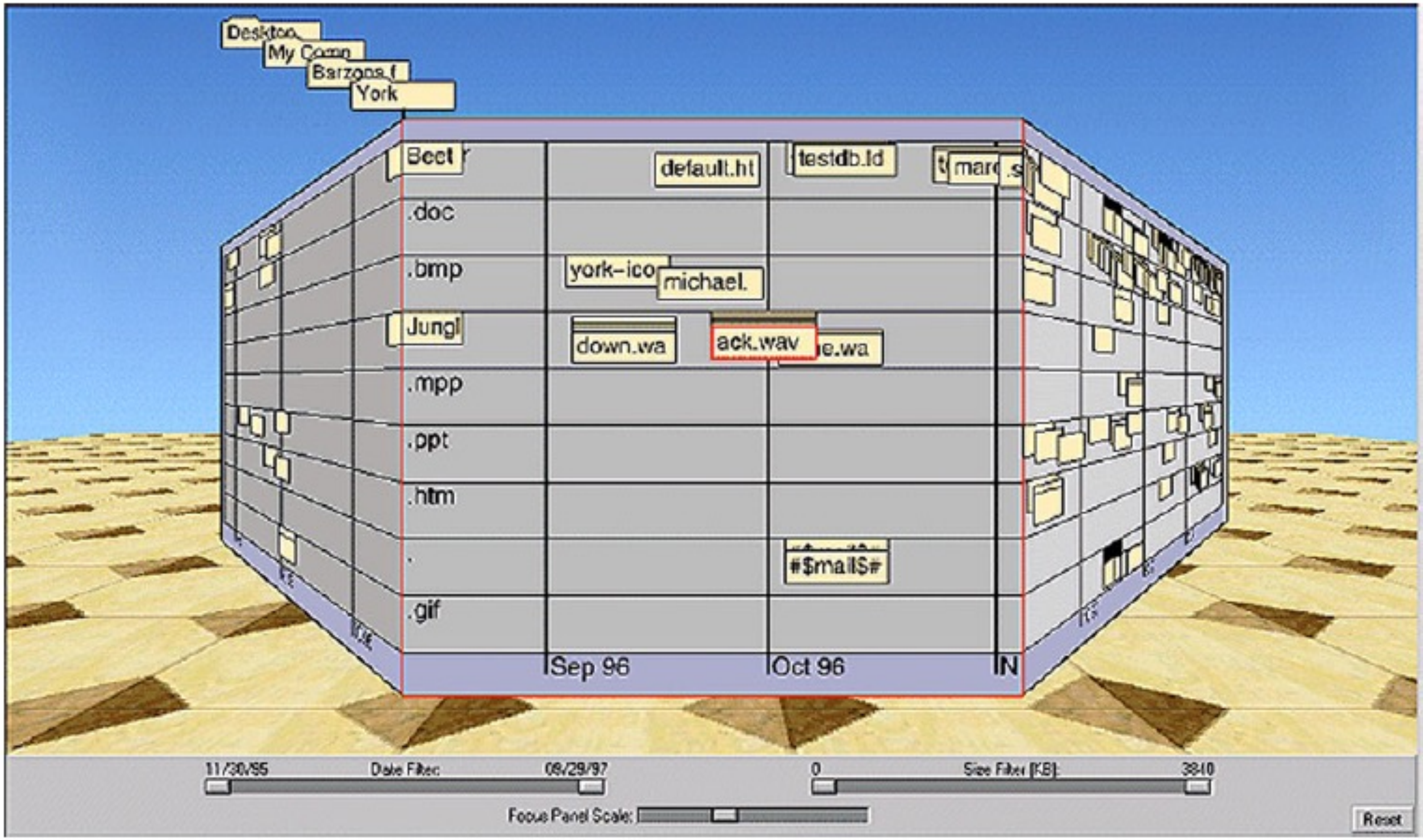


Image: Inxight Federal Systems

6. Dynamic Re-expression

Allow the user to create different representations

- Switch from a choropleth map to a proportional symbol map
- Add new windows to explore

More information: Dykes (1997) Exploring spatial data representation with dynamic graphics

7. Animation

An integral part of visualisation required for big data sets, which may increase usability

- Temporal
- Non-temporal

Characterized by the visual variable **motion** (ref. previous lecture)

May be conjunction!

e.g. position or colour

More information: Kraak (2007) Cartography and the use of animation
http://link.springer.com.ezp.lib.unimelb.edu.au/content/pdf/10.1007%2F978-3-540-36651-5_22.pdf

7. Animation

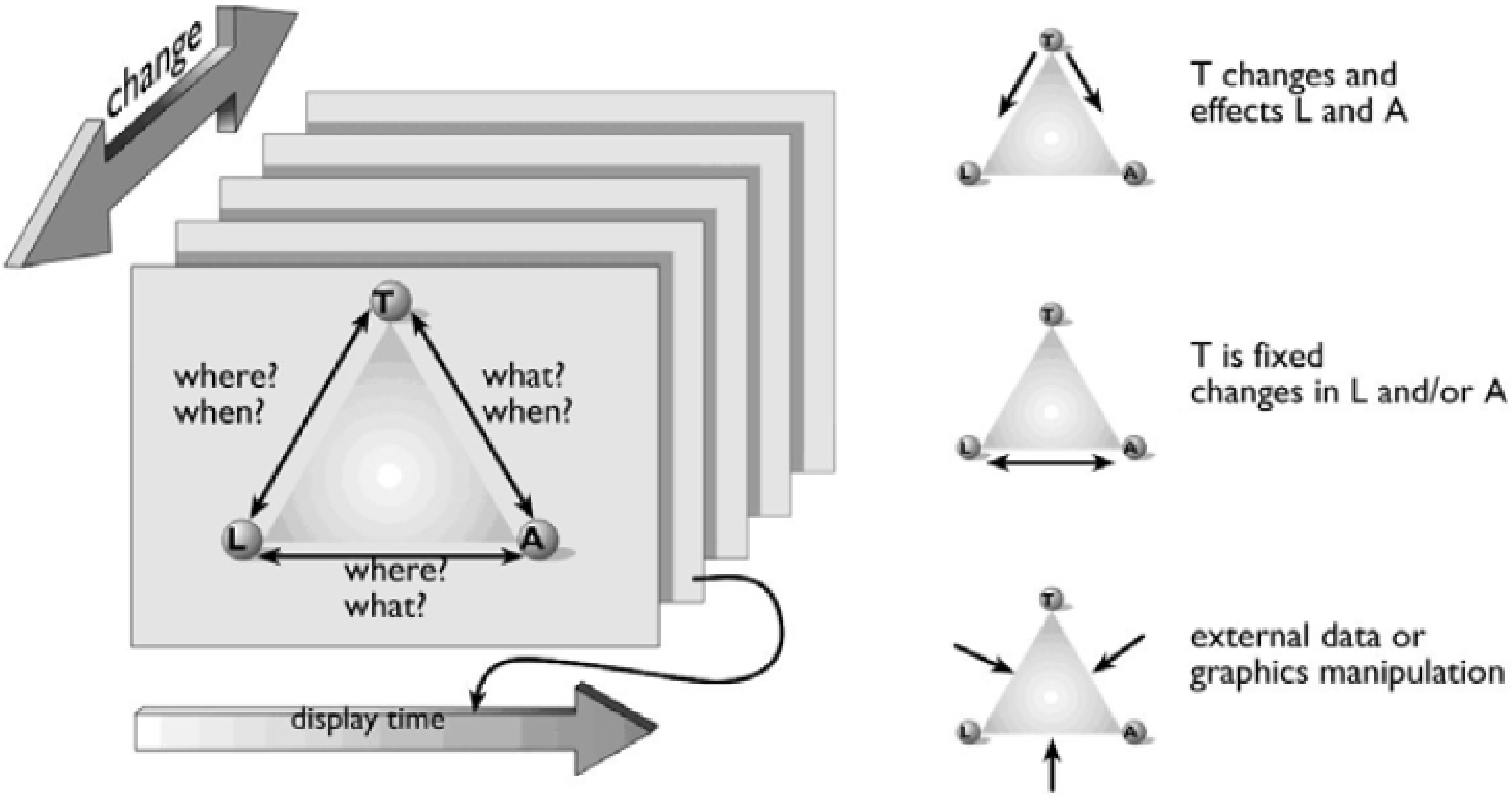


Image: Kraak (2007)

7. Animation

when + where → what, to state the properties of an object at a given time

when + what → where, to state the location(s) of an object at a given time

where + what → when, to state the time(s) when an object is at location(s)

(Peuquet, 1994)

7. Animation

Six different dynamic visual variables:

- Duration
- Display time
- Change rate
- Frequency
- Order
- Synchronisation

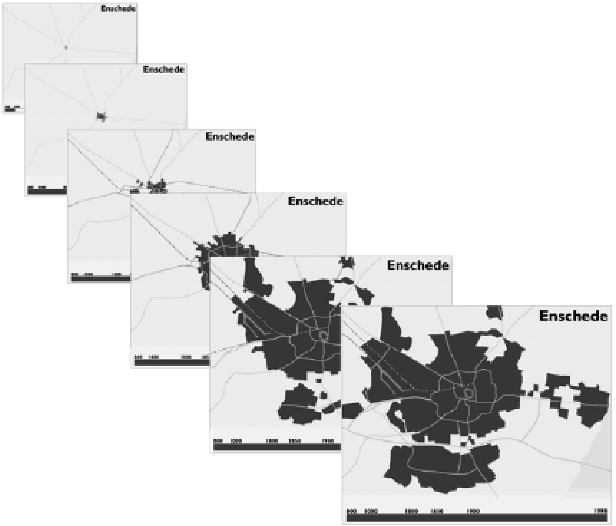
Rhythm (e.g., duration + change rate + frequency)

7. Animation Types (Kraak, 2007)

a) Time Series

Change in location and or attributes
Animation time units (frames) can be seconds, weeks, or years

Lack of data can result in abrupt changes between frames



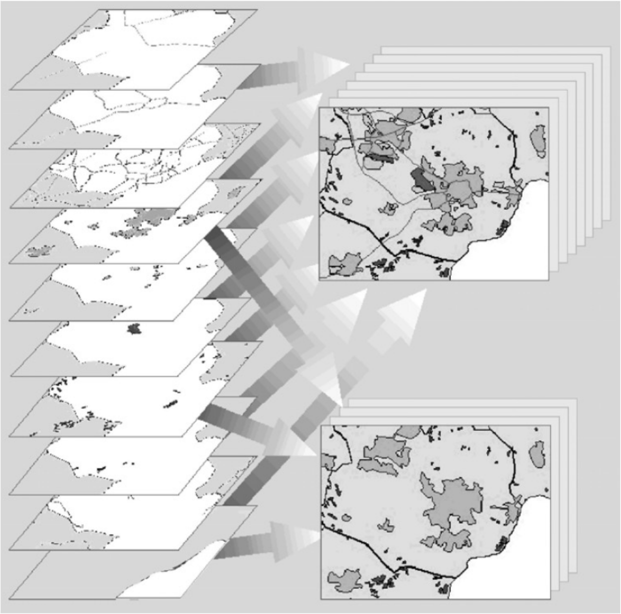
Example: World CO2 carbon emissions: http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11719

7. Animation Types (Kraak, 2007)

b) Successive build-up

Change in location and or attributes with time fixed

Represent complex processes using successive map layers to explain an object



Example:
The socio-economic conditions for a Local Government Area (LGA)

7. Animation Types (Kraak, 2007)

c) Changing representations

Location, attribute and time fixed

The same data is shown from a different graphic or classification perspectives

Example:
An animation displaying quantitative maps based on different classification methods

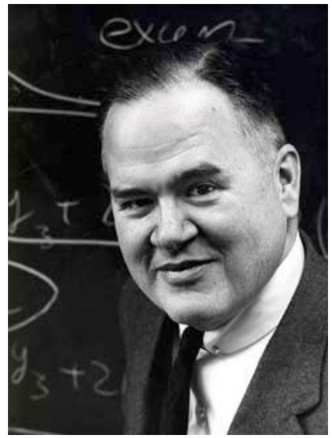


Image: http://quotesgram.com/john-tukey-quotes/

Three components of EDA

1. Graphical presentation
2. Provision of flexibility in viewpoint and in facilities
3. Intensive search for parsimony and simplicity

REPRESENTING TIME & INTERACTION

REPRESENTING TIME

Time can be considered unidirectional (i.e., the arrow of time)

Ordinal

- Relative order relations only (e.g., before, after)

Discrete

- Temporal distance can be assigned between two points where there is a smallest possible unit, e.g., seconds

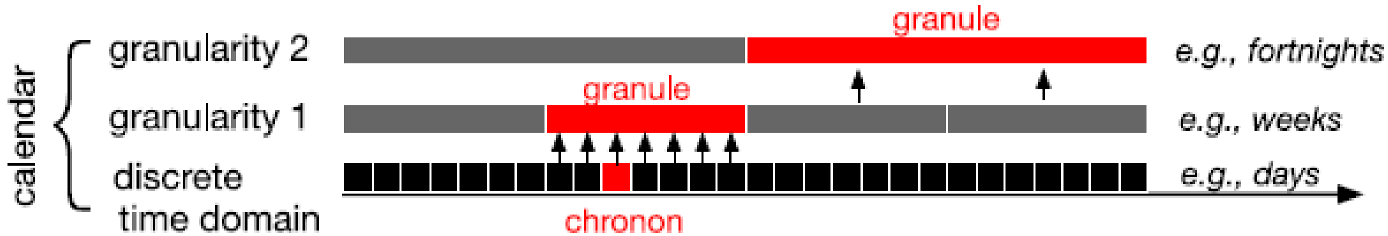
Continuous

- A real number can be determined between two points

More information: Aigner et al. (2011) Visualization of Time-Oriented Data
http://link.springer.com.ezp.lib.unimelb.edu.au/content/pdf/10.1007%2F978-0-85729-079-3.pdf

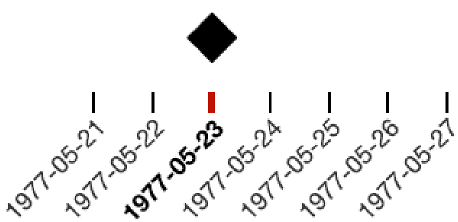
REPRESENTING TIME – Granularity and time primitives

Granularity

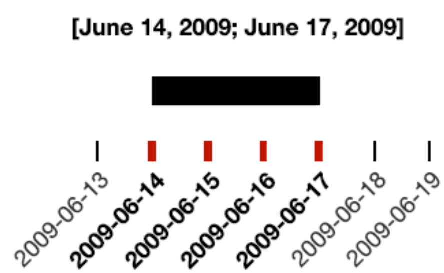


Primitives

Instant



Interval



Span

Images: Aigner et al. (2011) Visualization of Time-Oriented Data
http://link.springer.com.ezp.lib.unimelb.edu.au/content/pdf/10.1007%2F978-0-85729-079-3.pdf

More information: http://kartoweb.itc.nl/kobben/D3tests/tracksViewer/gpsTrack.html

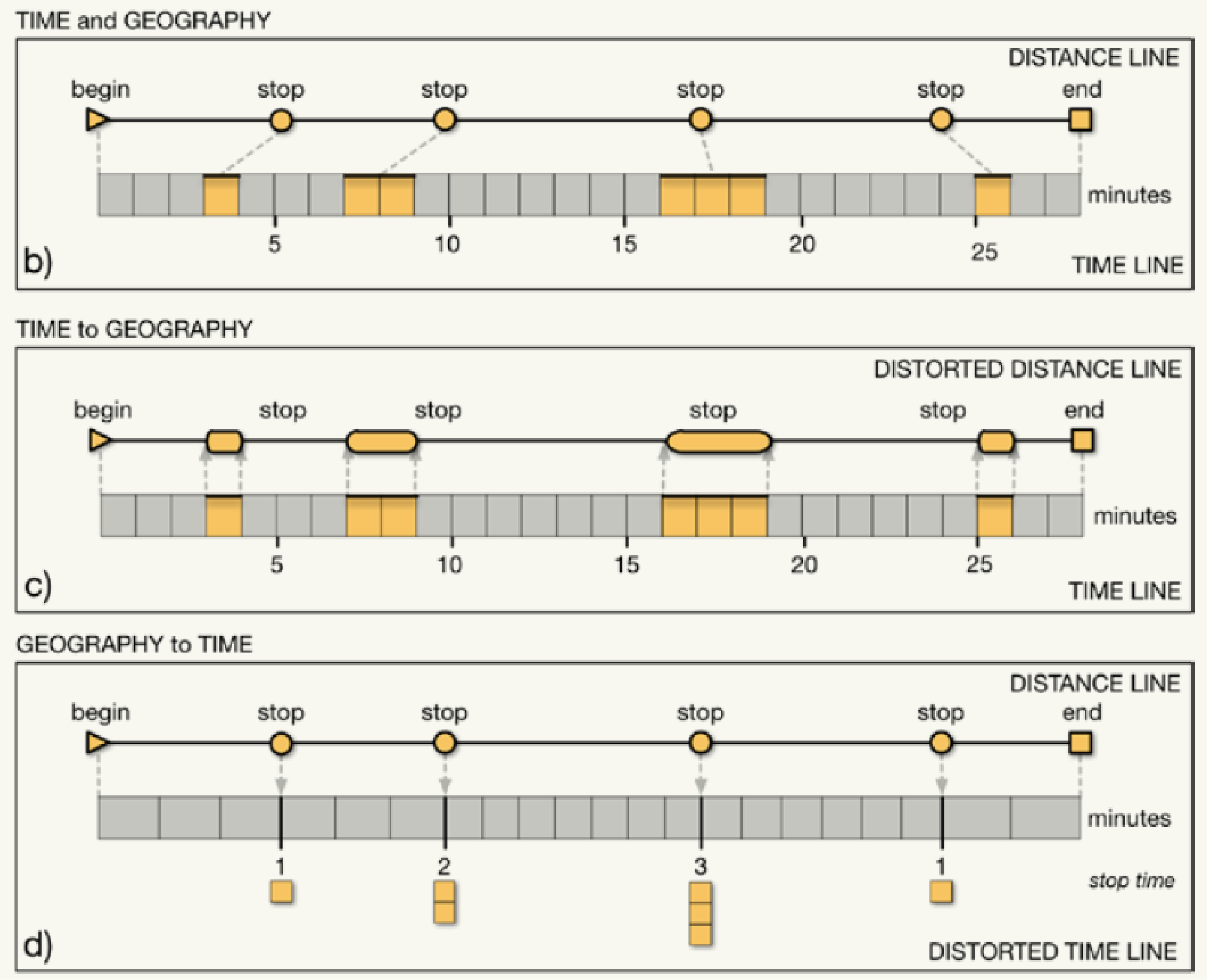


Image: Kraak et al. (2014)

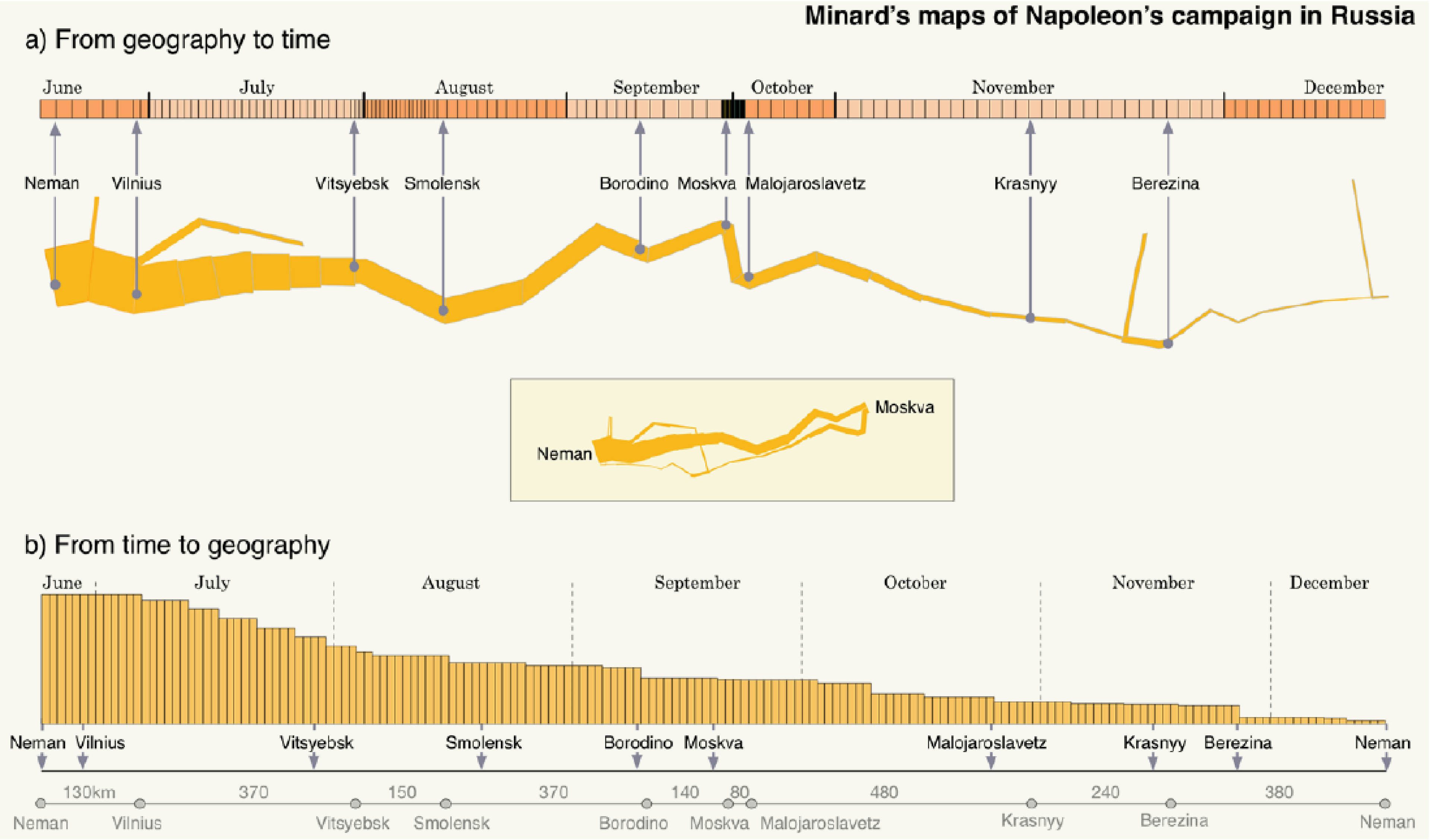


Image: Kraak et al. (2014)

TRAJECTORY VISUALISATION EXAMPLE

A trajectory is defined as a sequence of time-stamped locations:

$$(x,y)_{T_1}, (x,y)_{T_2}, \ldots, (x,y)_{T_t}$$

where $T_1 \ldots T_t$ are t consecutive time steps

Points recorded by GNSS, RFID or WiFi receivers

Each location may have attributes associated with it

Big datasets may need to undergo simplification for visualisation

e.g., Douglas–Peucker algorithm

More information: Gudmundsson, Laube, and Wolle (2012) Computational Movement Analysis
http://link.springer.com.ezp.lib.unimelb.edu.au/chapter/10.1007/978-3-540-72680-7_22

MOVEMENT SPACES

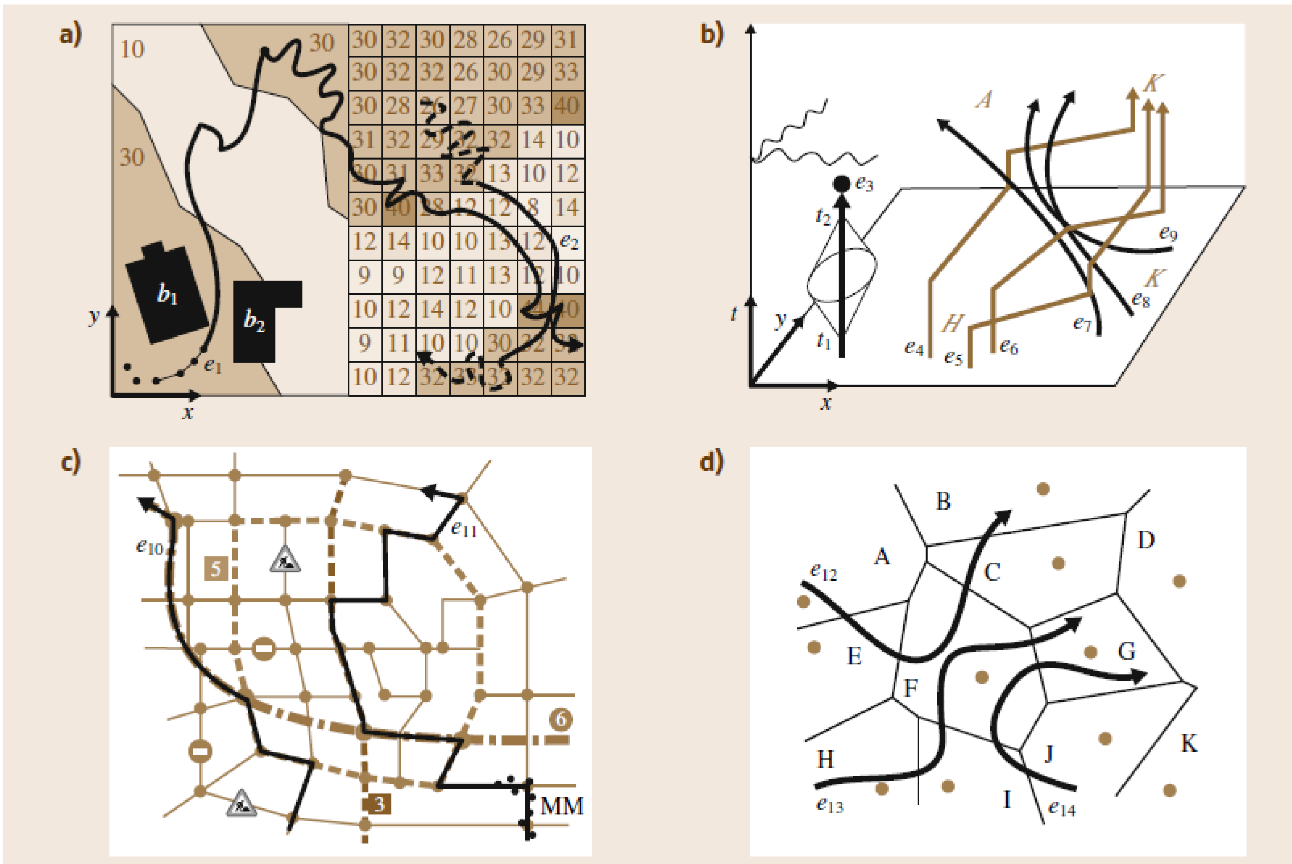
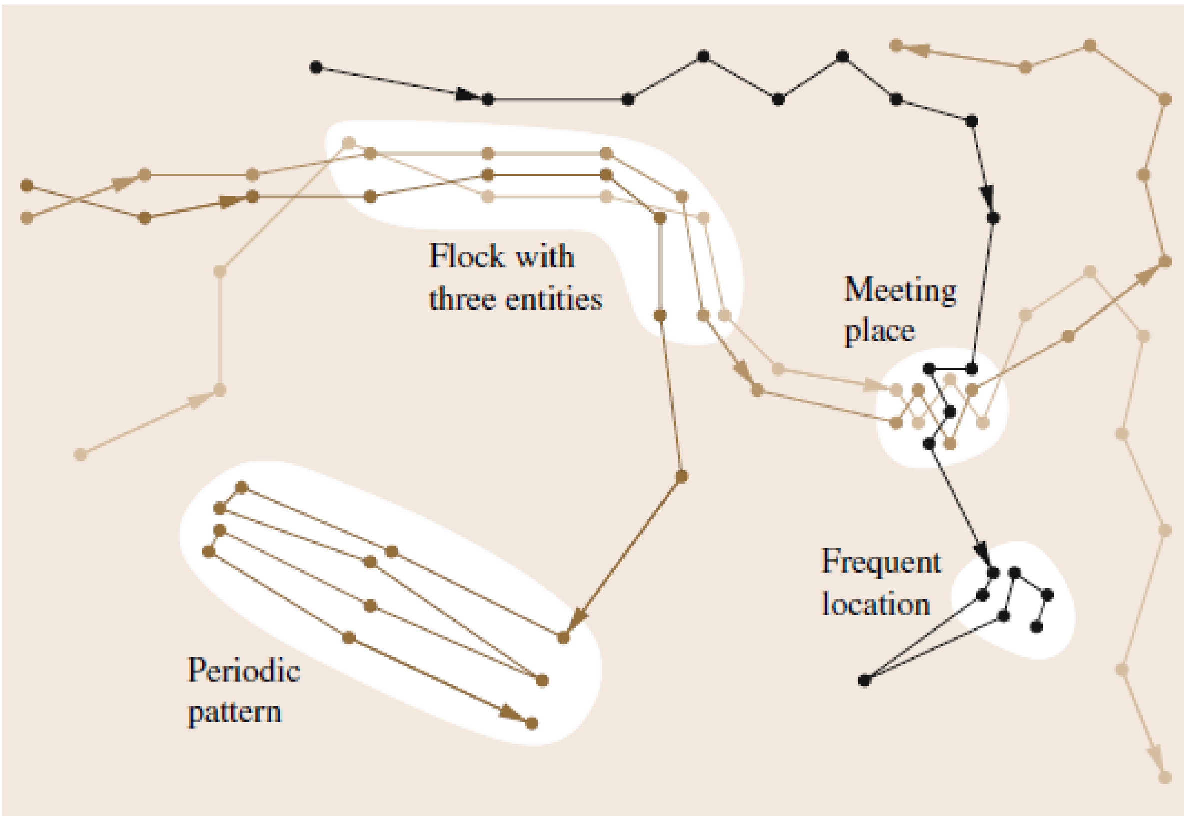


Fig. 22.2a–d Four basic movement spaces: (**a**) 2-D Euclidean space, (**b**) 3-D space–time cube, (**c**) network space, an
(**d**) irregular tessellation, e.g., phone tower cells

More information: Gudmundsson, Laube, and Wolle (2012) Computational Movement Analysis
http://link.springer.com.ezp.lib.unimelb.edu.au/chapter/10.1007/978-3-540-72680-7_22

2D – Visually identify patterns



A constant moving time window may be used

More information: Gudmundsson, Laube, and Wolle (2012) Computational Movement Analysis
http://link.springer.com.ezp.lib.unimelb.edu.au/chapter/10.1007/978-3-540-72680-7_22

2D vs 3D – Visually identify patterns

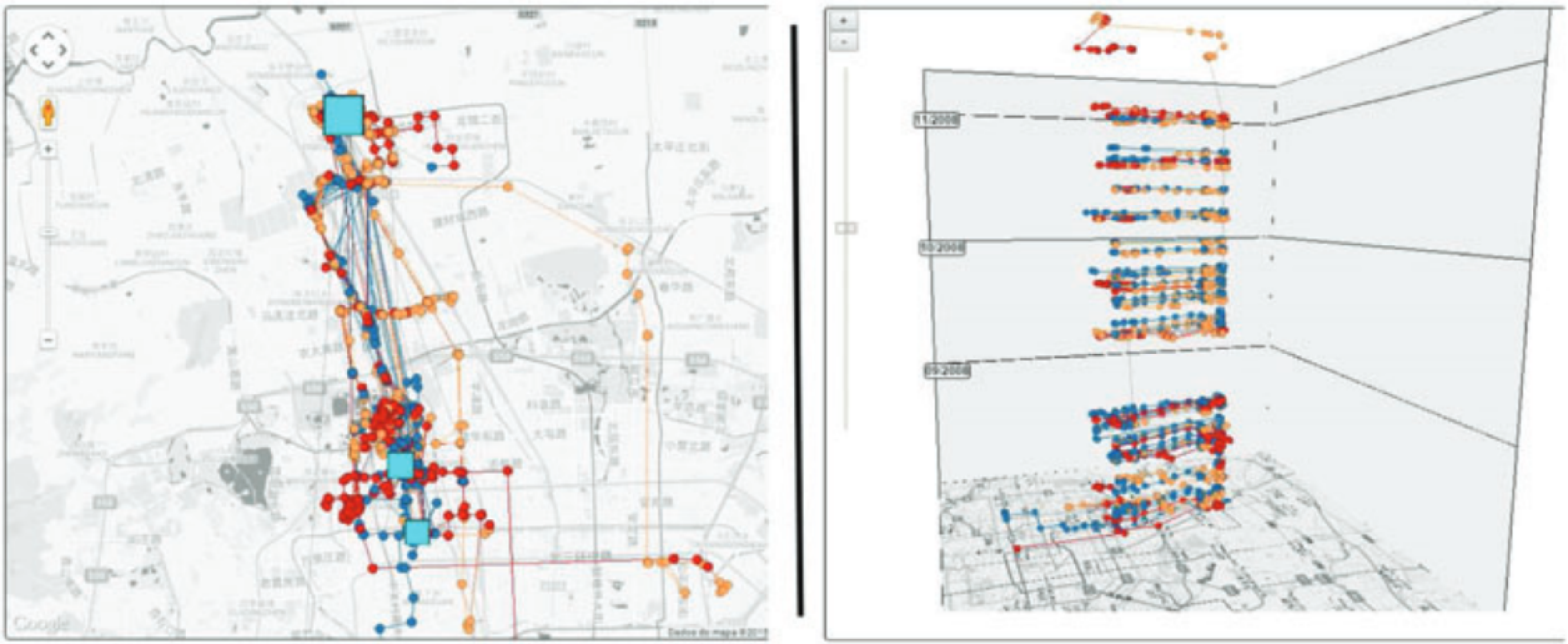


Image: Gonçalves et al. (2015)
http://www.tandfonline.com.ezp.lib.unimelb.edu.au/doi/full/10.1080/17489725.2015.1074736

THINGS TO CONSIDER

Time granularity, primitives and duration

Critique: http://casualdata.com/senseofpatterns/

Time vs Distance scales: What's going on?!

Visual clutter

Overlapping trajectories in 2D

Important, as movement can be considered regular

Visualisation

Visual variables

Motion (6 dynamic visual variables)

TRAJECTORY VISUALISATION EXAMPLES

- Zhang et al. (2013) Visual analysis design to support research into movement and use of space in Tallinn: A case study

Access: http://openaccess.city.ac.uk/2383/
Vimeo: https://vimeo.com/72028093

- Kraak et al. (2014) Integrated Time and Distance Line Cartogram: a Schematic Approach to Understand the Narrative of Movements

  Access:
  https://eds-a-ebscohost-com.ezp.lib.unimelb.edu.au/eds/pdfviewer/pdfviewer?vid=1&sid=075dbe31-c53e-4f97-9a01-12423ba585c3%40sessionmgr4008&hid=4210

- giCentre (2016) Animal Movements
  Vimeo : https://vimeo.com/channels/gicentre/171595827

OTHER TEMPORAL EXAMPLES:

- Time varying (University of Rostock)
  - http://survey.timeviz.net/
- GeoTime
  - http://geotime.com/products/geotime/arcgis
- giCentre (UCL)
  - Bicycle hire visualisations
    - http://www.staff.city.ac.uk/~sbbb717/tfl_bikes/
    - http://www.staff.city.ac.uk/~jwo/cyclehire/

EXAMPLE GEOVISUALISATION TOOLS:

- GeoVISTA Toolkit (@ PSU)
  - https://www.geovista.psu.edu/geoviztoolkit/
- AURIN (@ The University of Melbourne)
  - http://www.aurin.org.au

← Login with your UoM username password

READING

Andrienko and Andrienko (2003) Interactive maps for visual data exploration

Access: http://www.tandfonline.com.ezp.lib.unimelb.edu.au/doi/abs/10.1080/136588199241247