The Space-Time Cube Revisited from a Geo-Visualization Perspective

Menno Jan Kraak
International Cartographic Conference, 2003
Previous Work

’60s Hägerstrand’s space-time model:
• Space-Time Path (STP) – limited by capability constraints, coupling and authority constraints
• Terms – stations, activity bundles, path footprint,
• Space-Time Prism – Potential Path Space (PPS), PPA
• Space-Time cube – 3 dimensions, geography along x-y axis, time along z axis

Figure 1: Authors day at the city of Enschede
Automation and Multiple Views

An interactive visual environment with alternative graphics connected to the cube via multiple linked views

Figure 2: Napoleon's 1812 march into Russia
Axis Rotation and Measurement
Applications and Extended Functionalities

- Orienteering run, fitness run – terrain and it’s effect, reconstruct participant’s trajectory
- Archaeology – spread of civilization, interesting location
Using Additional Views

Figure: Napoleon’s retreat
Critique

Pros:
• Strong tool, can associate axis with other variable
• Scaling along axis possible

Cons:
• Space and time have to be associated to two of the axis
• Need additional views even for basic space concepts like distance

Questions on usability aspects of the cube’s viewing environment:
1. How many views can the user handle?
2. Can multiple STPs be shown?
3. How should the interface look like?
Unfolding the Earth: Myriahedral Projections

Jarke J. Van Wijk
The Cartographic Journal, Feb 2008
Distortion in Map Projection

Terms:
- Myriahedron
- Parallels and meridians
- Graticulated mesh
- Tissot indicatrix
- Conformal projection
- Equal area projection
- terra incognita projection

Factors leading to different requirements
1) intended use of the map
2) the available technology
3) the area or aspect
**Graticulated Mesh Conditions**

- Triangular faces with small area as node and edges as edge of graph $G$
- Foldout connected and can be flattened implies $H_f$ is a spanning tree
- $G_c$ is a spanning tree
- No fold-overs

Algorithm to generate myriahedral:
1. Generate a mesh
2. Assign weights to all edges
3. Calculate a maximal spanning tree $H_f$ using Prim’s algorithm $O(|E| + |V| \log |V|)$
4. Unfold the mesh
5. Render the unfolded mesh
Unfolding mesh

cylindrical

azimuthal

azimuthal, two hemispheres

conical

polyconical
Projections on Platonic Solids

tetrahedron

cube

octahedron

dodecahedron

icosahedron
Defining Mesh

a. Generate mesh lines along and perpendicular to contours of $f$ with the algorithm of Jobard and Lefer;
b. Calculate intersections of these sets of lines, and derive polygons;
c. Tesselate polygons with more than four edges; and finally
d. Use the standard approach to decide on folds and cuts.
Alternate Mesh Definition

Based on vector fields and tensor fields:
Azimuthal projection, random weights added, 81 920 polygons
Critique

Pros:
• Methodologically interesting in Computer Science perspective
• Can use different weight factors according to presentation target

Cons:
• fold-over rare but not restricted
• Most resultant maps unusual and unusable
• High computational complexity
• Cuts are more disturbing than distortions to most users
Geographically Weighted Visualization: Interactive Graphics for Scale-Varying Exploratory Analysis

Jason Dykes and Chris Brunsdon
André-Michel Guerry on Moral statistics:

- Dataset – related data for the departments of France in the early 19th century
- View – uni-variate choropleth maps to identify trends and outliers

Friendly proved some of Guerry’s hypothesis wrong using regression
Summary Statistics

Weighted Mean, \( M(u, h) = \frac{\sum x_i w_i(u)}{\sum w_i(u)} \)

Gaussian decay function, \( w_i(u) = \exp \left( -\frac{|u-u_i|^2}{2h} \right) \)

Redefining weight function as \( W_i(u) = \frac{w_i(u)}{\sum w_i(u)} \)

Then \( M(u, h) = \sum x_i W_i(u) \)

Discrete set of value, probability pairs \( L = \{ x_i, W_i \} \)
Weight Maps and Their Effects
Boxplots, Choropleths and Scalograms
Spatial Views

choropleth map
original values
$x_1$

gw-mean map
geographically weighted mean
$M(u, h) \ (h=50)$

 gw-residual map
map of absolute differences
$|x_1 - M(u, h)| \ (h=50)$

weighting map
weights for a single department
$w_i \ (i=76, \ h=50)$
Linked Views
Directed Geographic Weighting

Take $w_i = w_i \exp \left( -\lambda \cos(\theta - \varphi) \right)$

Directed GW statistics at clock points to reduce computation time.
Critique

Pros:
• Can compare at different scales (different values of $h$ and $\theta$)
• Moving window approach overcomes the abruptness of aggregation based on regional administrative hierarchy
• Ability to strum the set of scalograms

Cons:
• Computationally expensive and hard to search for trends at large number of scales
• Large number of views
Questions?

Thank You