WhereNext: Towards a Cartographic Framework for Movement

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Movement is multidimensional: space, time, context
Human-Centered Data Science Approach to Movement Analytics
Human-Centered Data Science Approach to Movement Analytics

Computational data-driven analytics

Exploratory Visualization

Visual Analytics

Communication Visualization

Exploration

Confirmation

Synthesis

Presentation

Knowledge discovery

Low

High

Human-map interaction

The ‘human’ (general or specialized users)

Data

movement patterns

relation to context

Visual reasoning & knowledge discovery

Dodge & Noi (in review)
Visualization of Movement

Source: Dodge and Noi (in review) CaGIS
Mapping Movement: A Pyramid Framework

Kraak (2014), Mennis, Peuquet, and Qian (2000)

Source: Dodge and Noi (in review) CaGIS
## Elements of the Cartographic Framework for Movement

*Source: Dodge and Noi (in review) CaGIS*

<table>
<thead>
<tr>
<th>1</th>
<th>Vector</th>
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<tr>
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<tr>
<td>13</td>
<td>Movement parameters</td>
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<tr>
<td>14</td>
<td>Context parameters</td>
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<td>Multiple coordinated views (MCV)</td>
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<td>Dynamic querying</td>
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<td>21</td>
<td>Interaction</td>
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<tr>
<td>22</td>
<td>Flexibility</td>
<td>categorical</td>
</tr>
</tbody>
</table>
Movement Data

Trajectories (discrete)

GPS Trajectories of 9 adult albatrosses (90 min resolution), annotated with wind speed (m/s) and wind direction, 6-hour, 2.5°, U/V-wind components NCEP Reanalysis 2 using Env-DATA

Xavier & Dodge (2014)

O-D flows (discrete and aggregate)

US Migration: “Smoothed net migration flows for age 25-29, with population threshold = 1,000,000. The background map shows the net migration rate for age group 25-29.” Guo, 2014

D. Guo (2014)

Movement of humans, vehicles, animals, diseases, natural phenomena, etc.
Data Collection vs Representation Perspectives

Lagrangian perspective:
Observing movement from the perspective of the moving entity; following the entity along its track over time

Eulerian perspective:
Observing movement at fixed locations; recording presence of moving entities at certain locations over time

Dodge (2019), Laube (2014)
Data Collection vs Representation Perspective

Lagrangian perspective:

A female tiger trajectory between Dec 2009 – July 2010 (4874 GPS points)

Tiger activity at different temperature

Car Trips in Milan (O-D flows)

Collaboration with Esri, N. Shephard

Andrienko et al (2017)

Dodge (2019), Laube (2014)
Data Collection vs Representation Perspective

Eulerian perspective:

US Migration: “Smoothed net migration flows for age 25-29, with population threshold = 1,000,000. The background map shows the net migration rate for age group 25-29.” Guo, 2014

D. Guo (2014)
Mapping Movement – Location

Vector representation:
Often for discrete movement and flow lines

Raster representation:
Commonly for aggregate movement and flow density

Dodge et al (2013)


Demsar et al (2014)

**Mapping Movement – Time**

**Attribute presentation using visual variables**

Perin et al. (2018)

**Timeline**

Kraak (2014)

**Animation**

Boyandin et al. (2011)

“Flows of refugees are shown between East Africa and Western Europe.”

**Space-Time Cube**

**Time profile, diagram, charts**
Mapping Movement – Location, Time, Attributes

Location and time

Movement parameters:
speed, acceleration, turn angle, etc.

Context parameters:
The condition and circumstances of movement, environment, geography, behavior, mode, interactions, etc.
Location, Time, Attributes

Location and time

Movement parameters:
speed, acceleration, turn angle, etc.

Context parameters:
The condition and circumstances of movement, environment, geography, behavior, mode, interactions, etc.
Location, Time, Attributes
Bertin’s Visual Variables

<table>
<thead>
<tr>
<th>Visual variables</th>
<th>Moving points</th>
<th>Trajectory</th>
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<td>2D space (x,y)</td>
<td>2D space (x,y)</td>
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<td>size</td>
<td>3D space-time (x,y,t)</td>
<td>3D space-time (x,y,t)</td>
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<td>transparency</td>
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Collaboration with Esri, N. Shepard
Other Cartographic Elements: Visual Variables, highlighting, dynamic displays, 2D/3D environments

Collaboration with Esri

N. Shepard

UC SANTA BARBARA
Interaction Elements, Exploratory Tools, Flexibility

http://geog.ucsb.edu/~dodge/dynamovis

Developers (undergraduate students): Glen Xavier, Pinki Wong, Kate Carlson

MacEachren et al., (2004), Roth (2013)
Visualization of Movement and Flows

A decade in review (2010-2020)

Source: Dodge and Noi (in review) CaGIS

Cluster 1: Interactive Visual Analytics of Aggregate Movement
Cluster 2: Communicative Visualization Methods to Map Aggregate Movement
Cluster 3: Exploratory and Dynamic Visualization of Trajectories
Summary and Future work

- Many interesting work on visualization of movement and flows
- Integration of movement and context parameters
- Interactive and flexible Visualizations for movement (discrete and aggregate forms)
- Usability studies and evaluation
- WhereNext? Evaluate the elements of the framework
THANK YOU!

Many thanks to all collaborators and students who made this research possible, including Evgeny Noi (UCSB), UMN undergrads (Pinki Wong, Kate Carlson); Glenn Xavier (UCCS), Esri team: Nathan Shephard, John Grayson.

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