

Stacking-Based Visualization of Trajectory Attribute Data

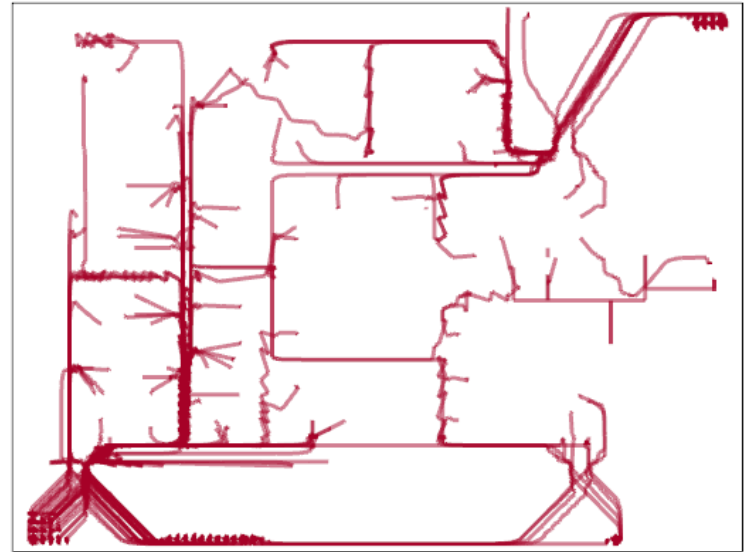
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Data

- Data → set of trajectories → set of points → tuples of form: $\langle \text{space, time, } \underline{\text{attributes}} \rangle$
- **Constrained** movement:
Many trajectory segments with very **similar geometry**
 - **Challenge:** Overplotting in conventional solutions
 - **Benefit:** Exploit similarity for novel solution



VAST Challenge 2008 Evacuation Data

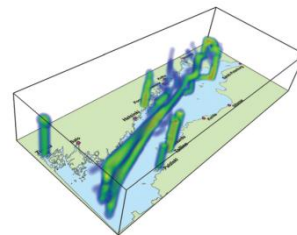
Tasks

- **Goal:** Understand attributes (A) in space (S) and time (T)
- Decompose complex $S \times T \rightarrow A$ task into simpler subtasks:
 1. Consider S and T at **elementary** level (individual items)
 - $T \rightarrow A$ for $s \in S = \text{const.}$
(e.g., variation in speed over the day at selected crossing)
 - $S \rightarrow A$ for $t \in T = \text{const.}$
(e.g., variation in speed along highway at 8 am)
 2. Lift analysis to **synoptic** level (sets of items) to understand overall behavior $S \times T \rightarrow A$

State of the Art

- **Existing solutions:**

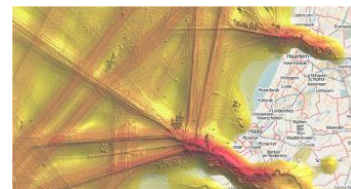
- Only few approaches consider attributes
- Hardly support for synoptic tasks
- Limited in the number of trajectories or overplotting



Demšar et al., 2010



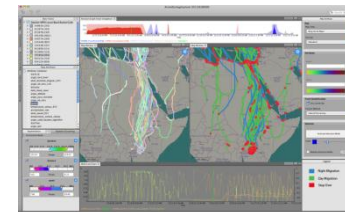
Ware et al., 2006



Willems et al., 2009

- **New solution:**

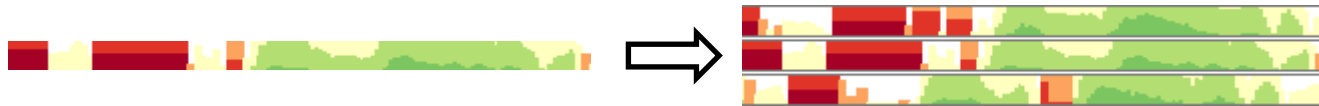
- Integrate space, time, **and attributes**
- Support $S \times T \rightarrow A$ analysis at elementary and synoptic level



Spretke et al., 2011

General Approach

- Trajectory \rightarrow band
- Attribute values \rightarrow color
- Bands \rightarrow stack
- Grouping and ordering
 - Exploit spatial, temporal, or attribute similarity



Color-coded bands support
elementary * $\rightarrow A$ tasks

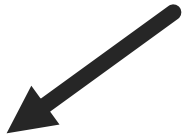
Stack of bands¹ supports
synoptic * $\rightarrow A$ tasks

¹ Inspired by Tuan Nhon Dang et al.'s "Stacking Graphic Elements to Avoid Overplotting", 2010.

Time and Space

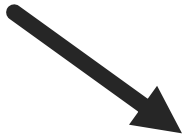
Color-coded bands support **elementary** $* \rightarrow A$ tasks

Stack of bands supports **synoptic** $* \rightarrow A$ tasks



$T \rightarrow A$

Focus on time
Time graph



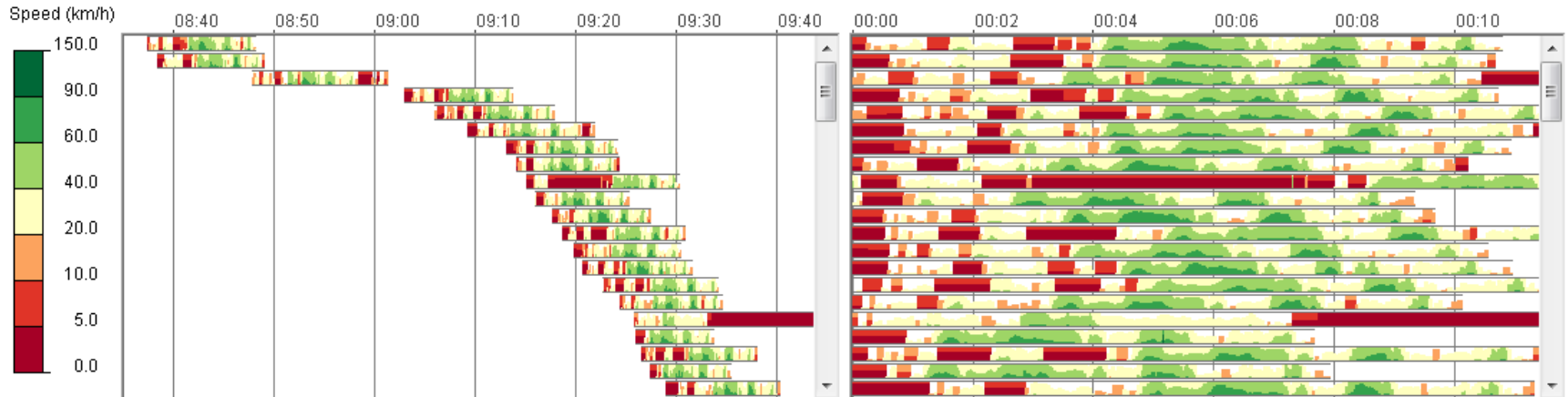
$S \rightarrow A$

Focus on space
Trajectory wall
with **time lens**

Focusing on Time

The 2D Time Graph

- Visualize $T \rightarrow A$
- 1D time along 1st dim.
- Stacking along 2nd dim.

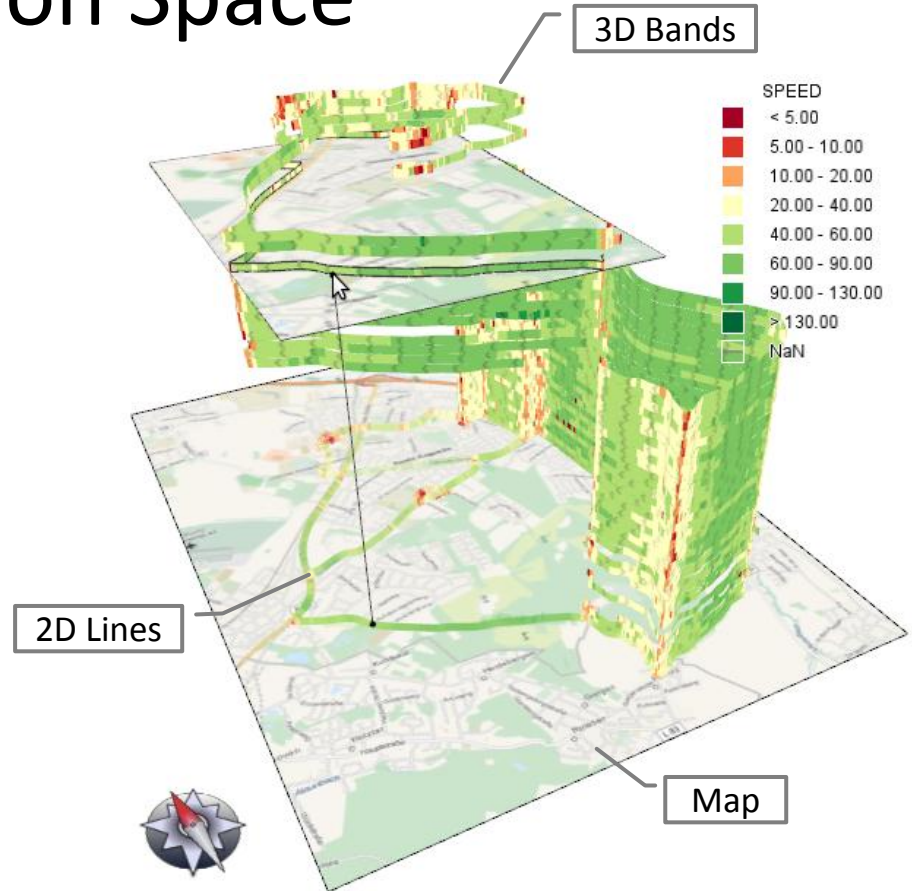


Focusing on Space

The Trajectory Wall

- Visualize $S \rightarrow A$
- 2D space use 1st and 2nd dim.
- Stacking along 3rd dim.

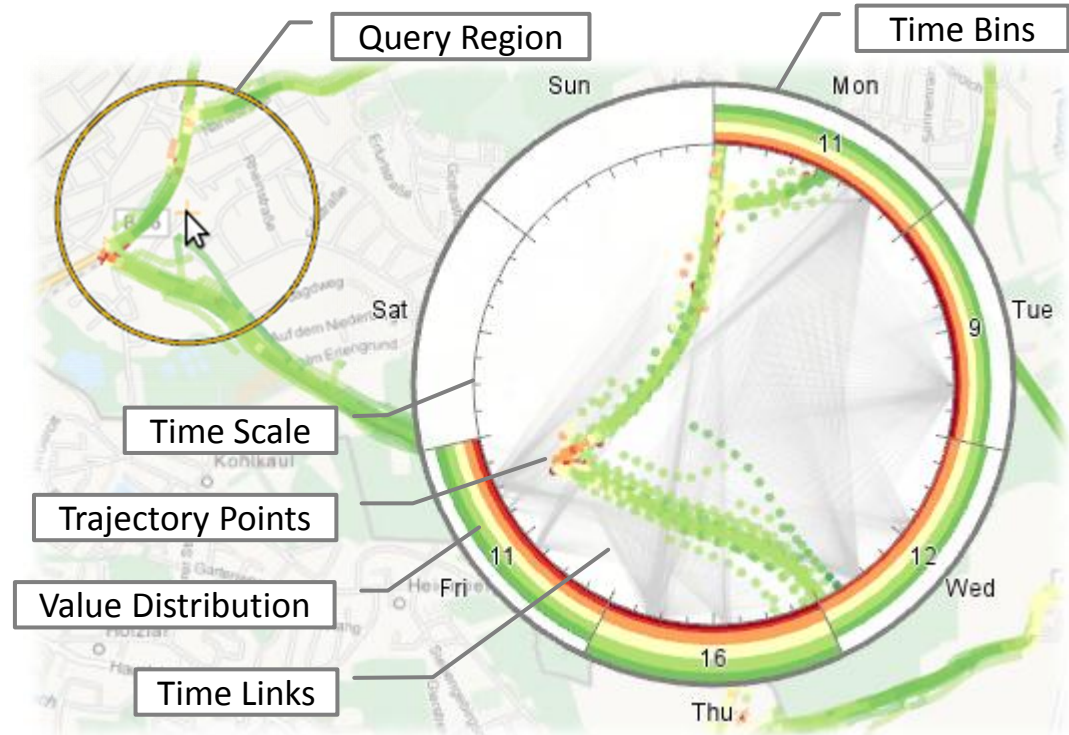
- Enhanced hybrid solution
 - **Overview:** 2D lines on map
 - **Detail:** 3D bands in stack
 - View-dependent blending



Integrating Time and Space

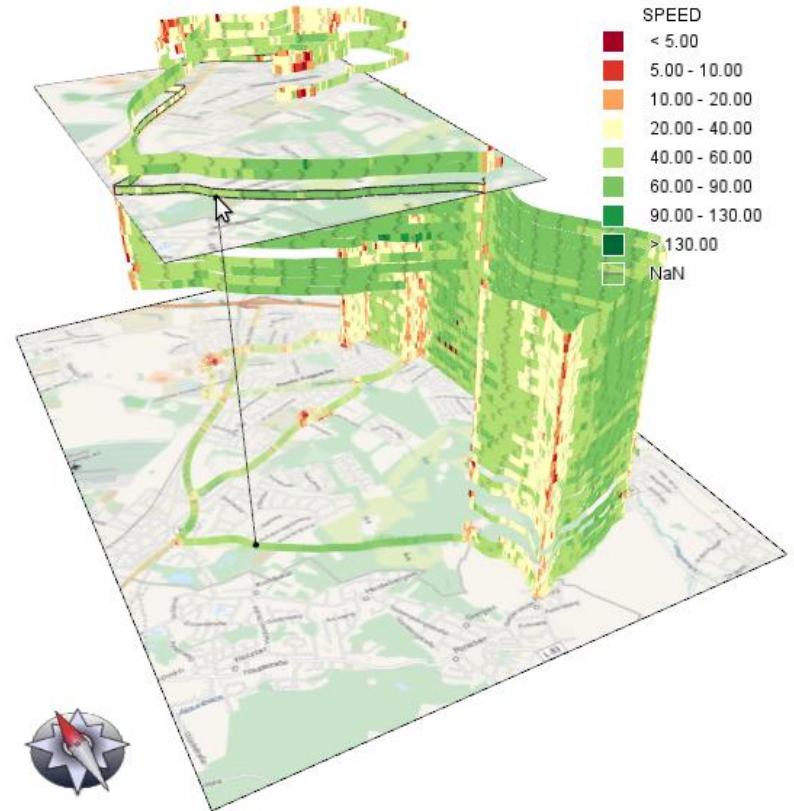
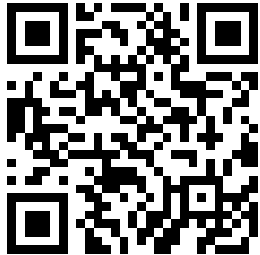
The Time Lens

- Query region
- Temporal aggregation in cyclic time model (count, dur., avg. dur.)
- “Radial histogram”
 - Cyclic time model
 - Visualizes
 - Trajectory points
 - Aggregates
 - Value distribution



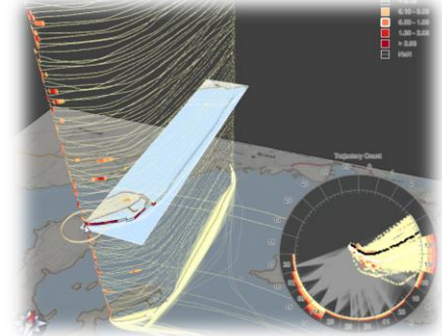
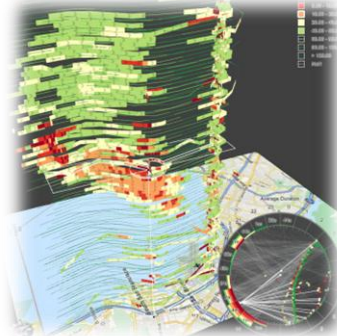
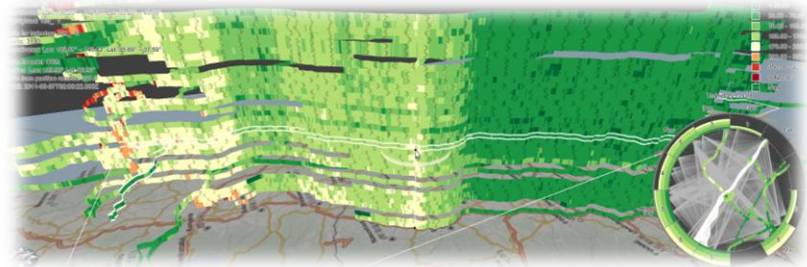
Demo

- Stand-alone version of **Trajectory Wall**
- Available at:
<http://goo.gl/wIC1k>



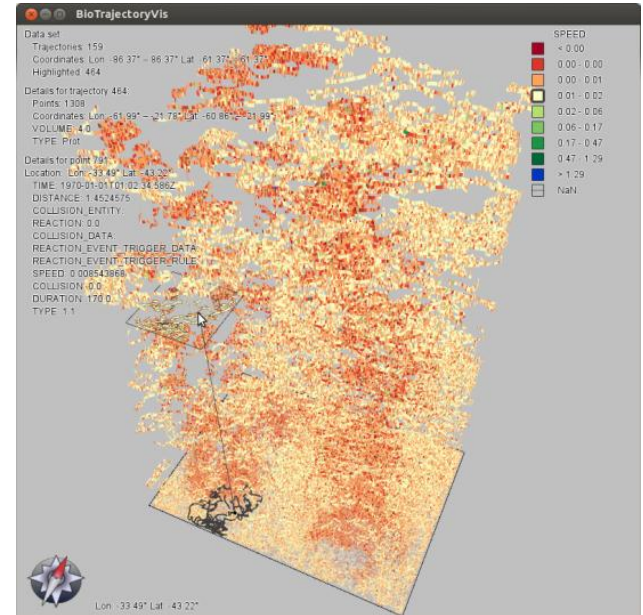
User Feedback and Application

- Preliminary study of Trajectory Wall
 - 15 participants
 - Interactive exploration in 3D
 - Mostly positive feedback
- Application within VAnalytics
 - Radiation in Japan (1.9M)
 - Speed of taxis (10.5M)
 - Tortuosity of vessels (700k)



Summary

- Novel visualization approach for movement data
 - Integrate **space**, **time**, and **attributes**
 - Support analysis of functional dependency $S \times T \rightarrow A$
 - Investigate individual trajectories and sets of them
- Future work
 - Consider events, features, etc.
 - Deal with unconstrained movement: “Trajectory Hairball” vs. “Trajectory Wall”



The End

Most interesting finding

$$T \times S \times A_G \times A_N \rightarrow V_p$$

Tominski, **S**chumann, **A**ndrienko, **A**ndrienko \rightarrow **V**isWeek **p**aper

Thanks for the collaboration!

Thank you for attending!

Multiple Attributes

Visualization of a **single attribute**



What about **multiple attributes**?

- Visual solution
 - Subdivide bands
 - Color-code each sub-band individually
- Algorithmic solution
 - Compute multivariate clustering
 - Color-code cluster affiliation

