



Similarity Measure for Network Time Prisms based on Graph-theoretic Measures: An Experimental Analysis

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Introduction

Space-time paths

Traces of an object in space with respect to time

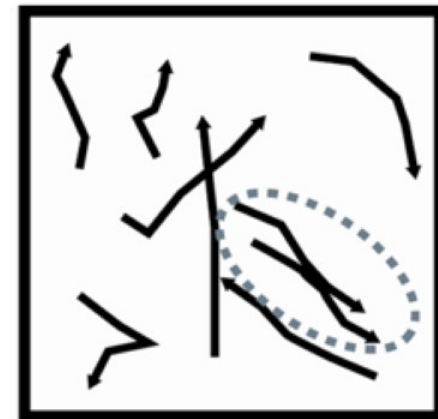
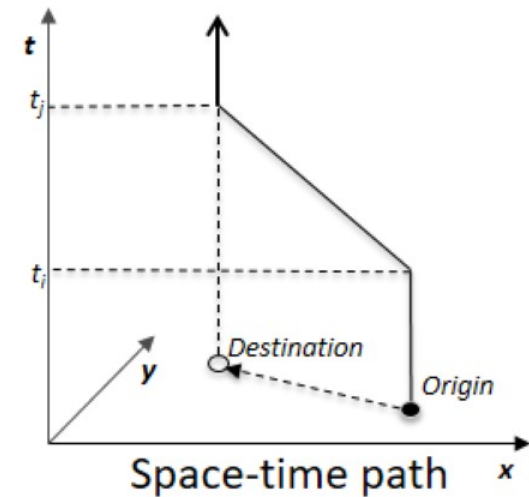
Measures observed mobility

Path similarity measures

Well-developed for space-time paths

Shape-based and time-based methods

Searching for similar paths in the database





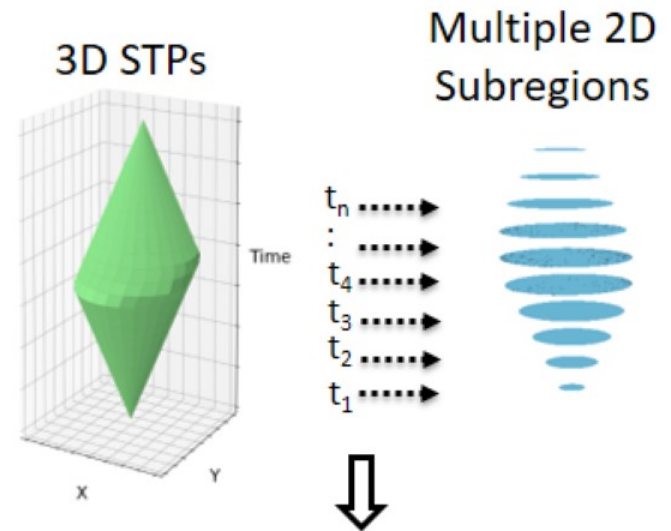
Introduction

Space-time prisms

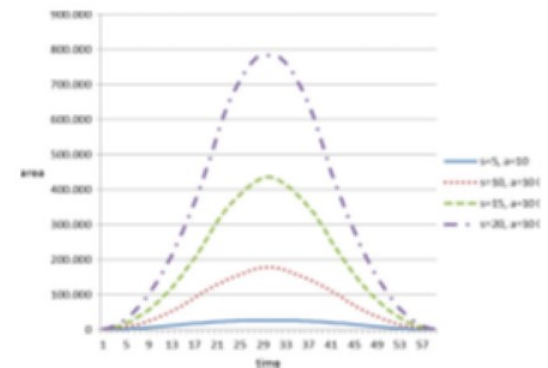
Envelope of space-time paths
Measure of potential mobility and accessibility

Prism similarity measure

Difficulty comparing 3D STPs
Temporal signatures for classical STPs
(Miller, Raubal and Jaegal 2016)



Temporal signatures





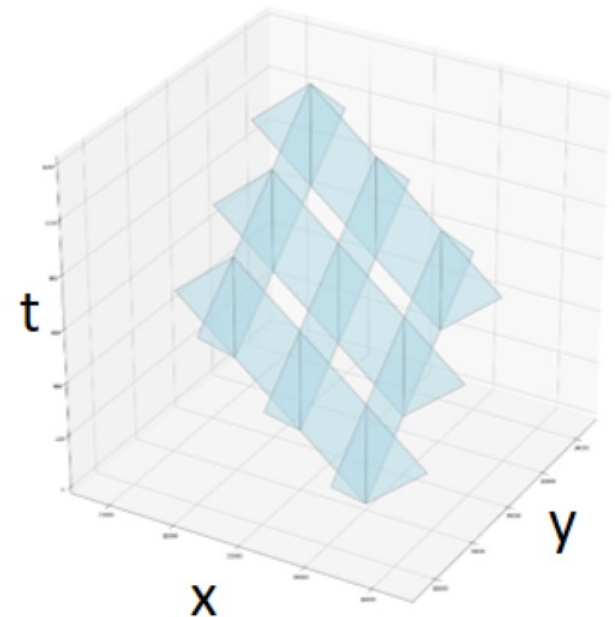
Introduction

Network time prism (NTP)

Extension of STP on a spatial network
Realistic measure of potential mobility
within transport network

NTP similarity measure

No measure exists

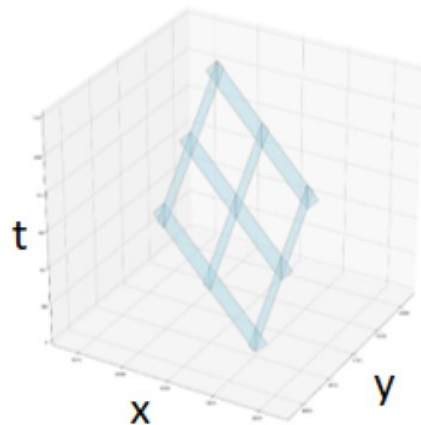




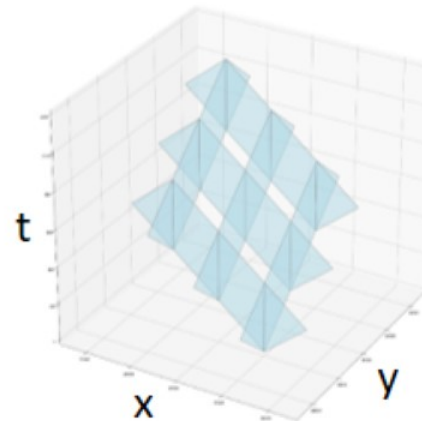
Introduction

Objective

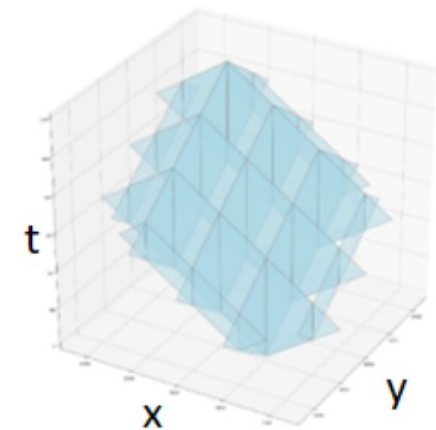
Develop a method for measuring NTP)



Slow speed limit



Medium speed limit



Fast speed limit

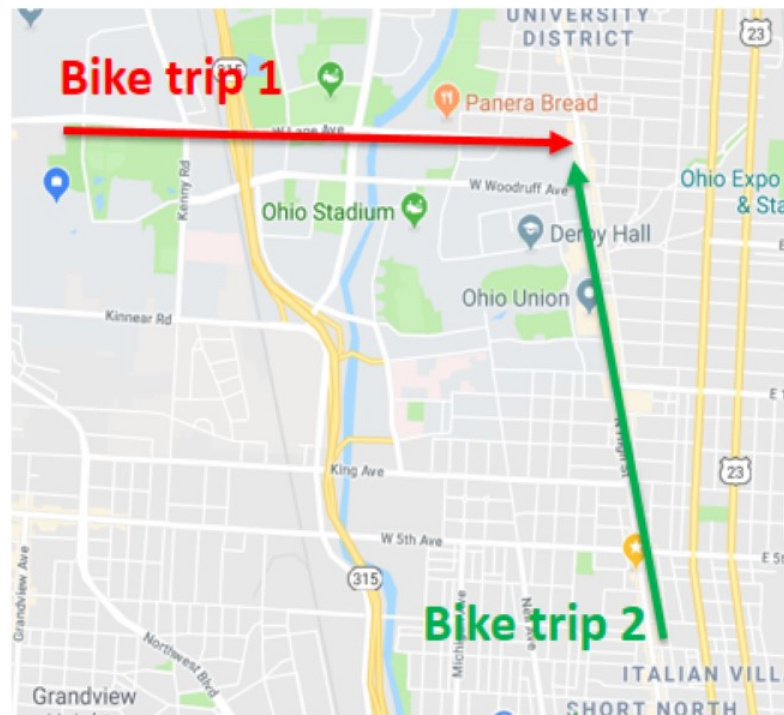
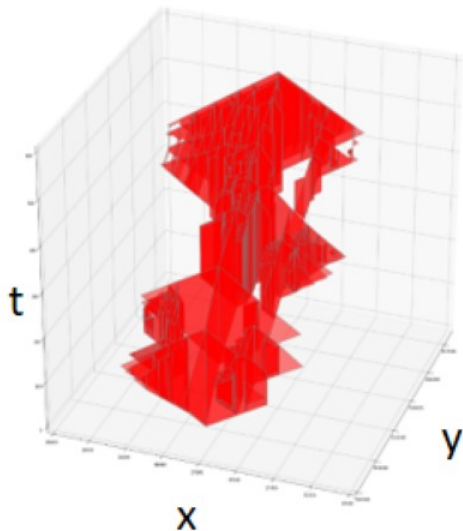
Compare the effectiveness of graph theoretic indices in NTP similarity measurement



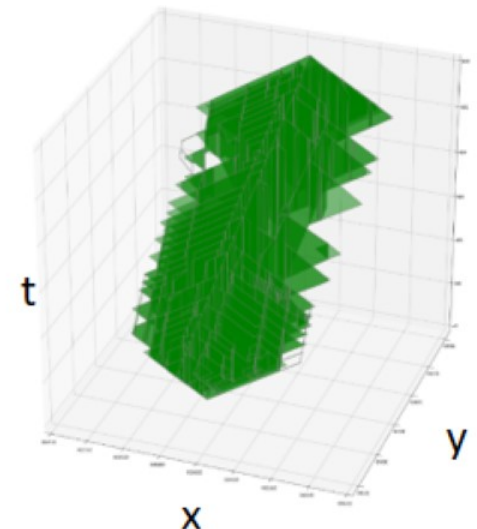
Methodology

An example of NTP similarity analysis

**Bike trip 1
NTP**



**Bike trip 2
NTP**

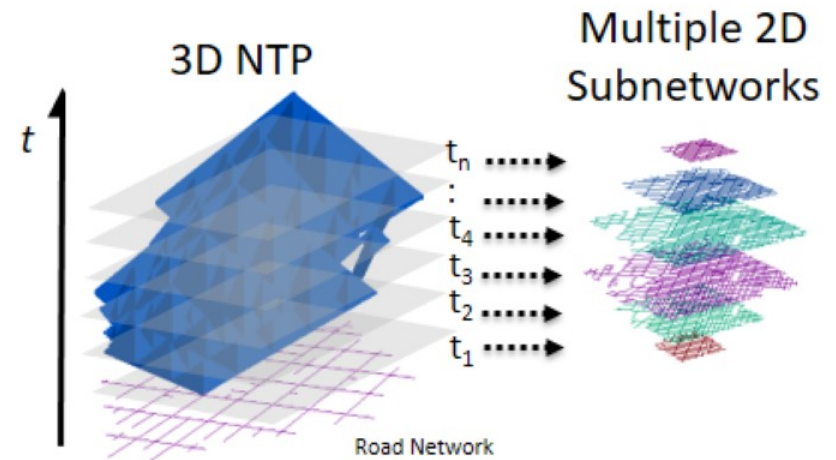


Methodology

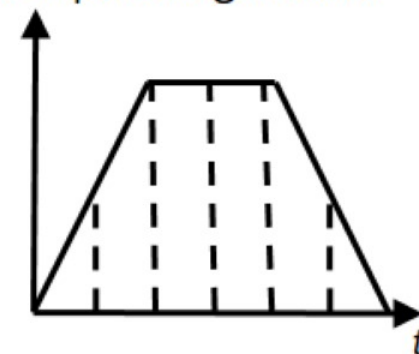
General approach

Temporal signature

- Temporally sweep NTP and measure subnetwork properties
- One 3D NTP - > Multiple 2D subnetworks
- Construct temporal profile curves
- Compare curves using existing path similarity measures



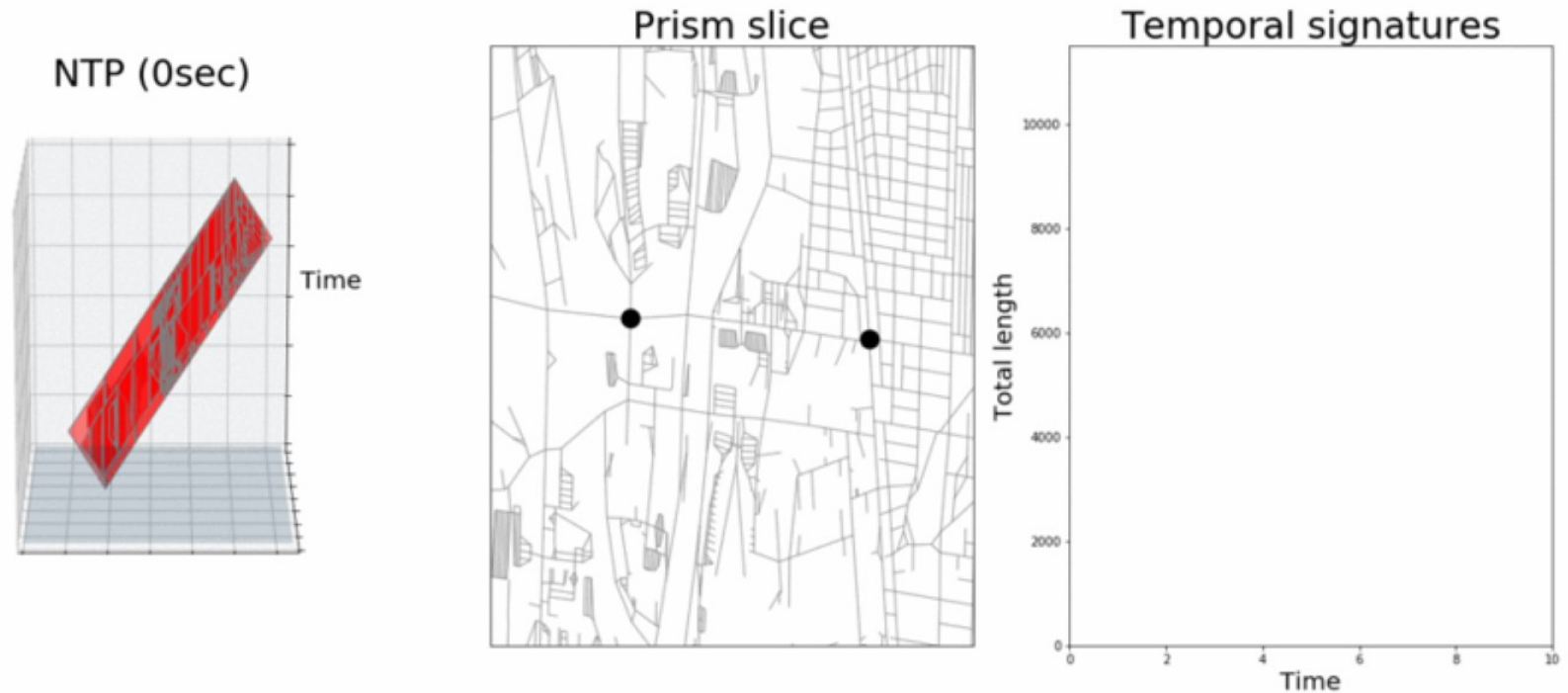
Temporal signatures





Methodology

General approach **Temporal signature**



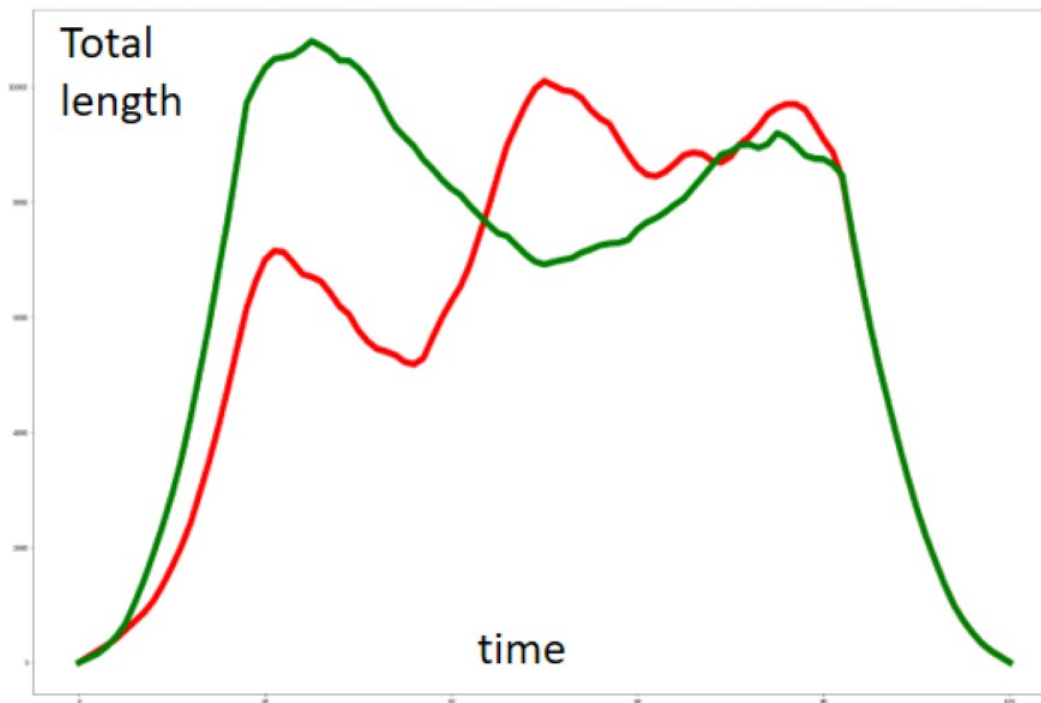
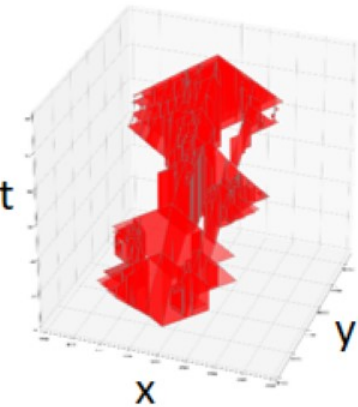


Methodology

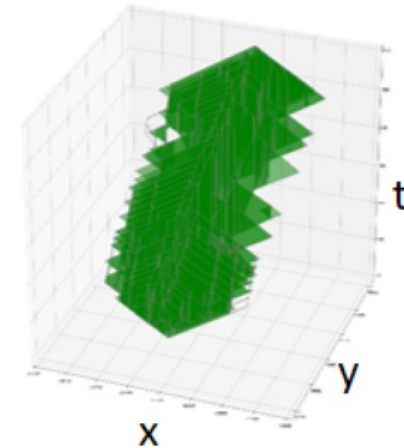
An example of NTP similarity analysis

Temporal signatures

**Bike trip 1
NTP**



**Bike trip 2
NTP**





Methodology

Graph theoretic measures for NTP similarity

Size

- **Number of edges**
- **Number of vertices**
- **Total length of edges**

Connectivity

- **Number of cycles**
- **Alpha index:** cycles/all possible cycles
- **Beta index:** edges/vertices
- **Gamma index:** edges/all possible edges
- **Organic Ratio (r_n)⁽¹⁾:** less connected vertices / vertices

Hierarchy

- **Assortative coefficient:** Correlation coefficient of degree between pairs of linked vertices



Simulations: Overview

Objective

Compare the performance of graph theoretic indices for NTP similarity measure

Design

Generates three groups of NTPs with different trip parameter level
Evaluate how well an index capture the three known clusters

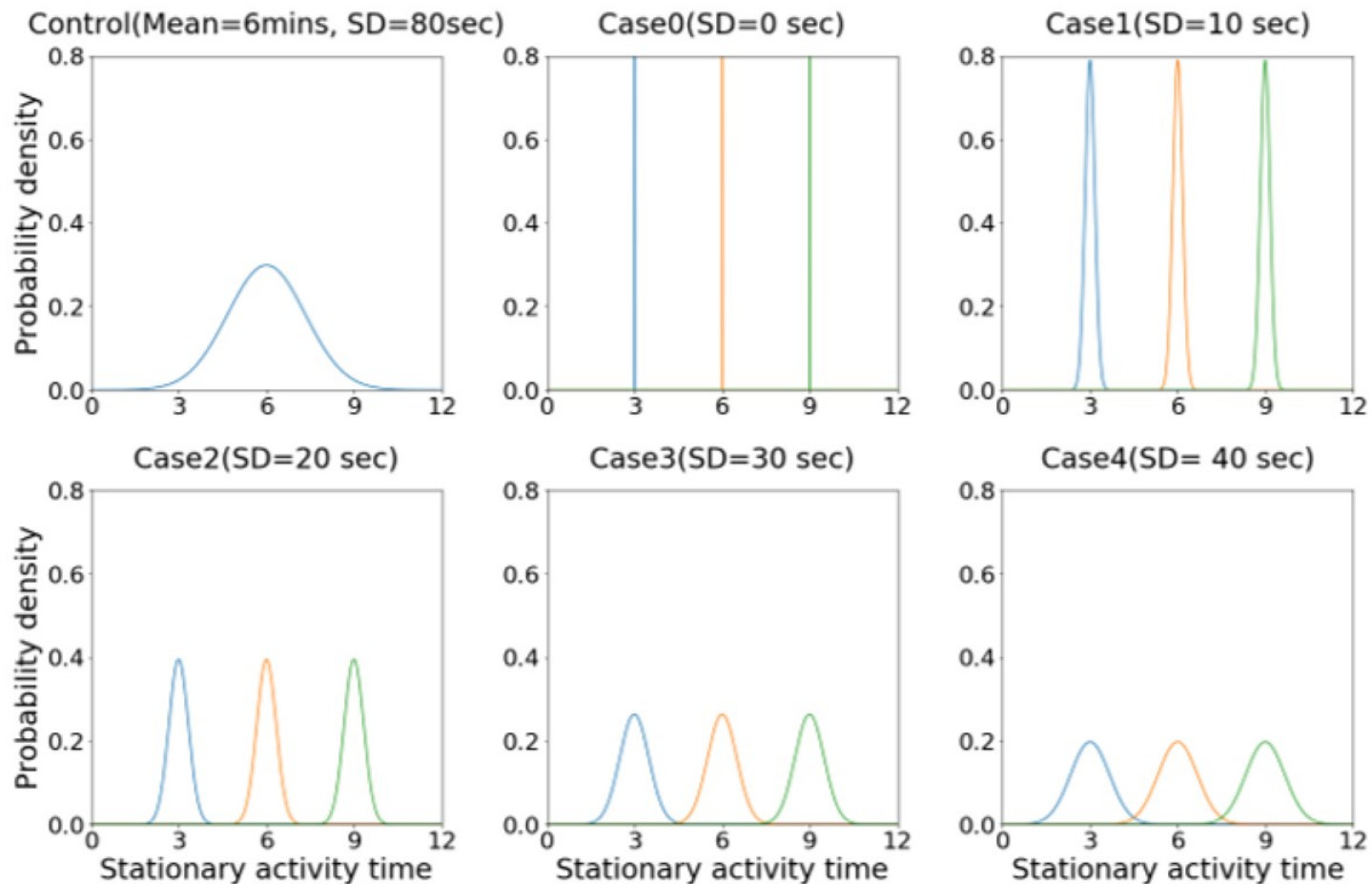
Trip parameter

1. Stationary activity time – 3 levels (3, 6 and 9 minutes)
2. Speed limits on network – 3 levels (40, 55 and 70 km/h)
 - 2.1 Uniform on the entire network
 - 2.2 Randomly assigned edge by edge
 - 2.3 Randomly assigned vertical and horizontal line in by line



Simulation - Control and cases

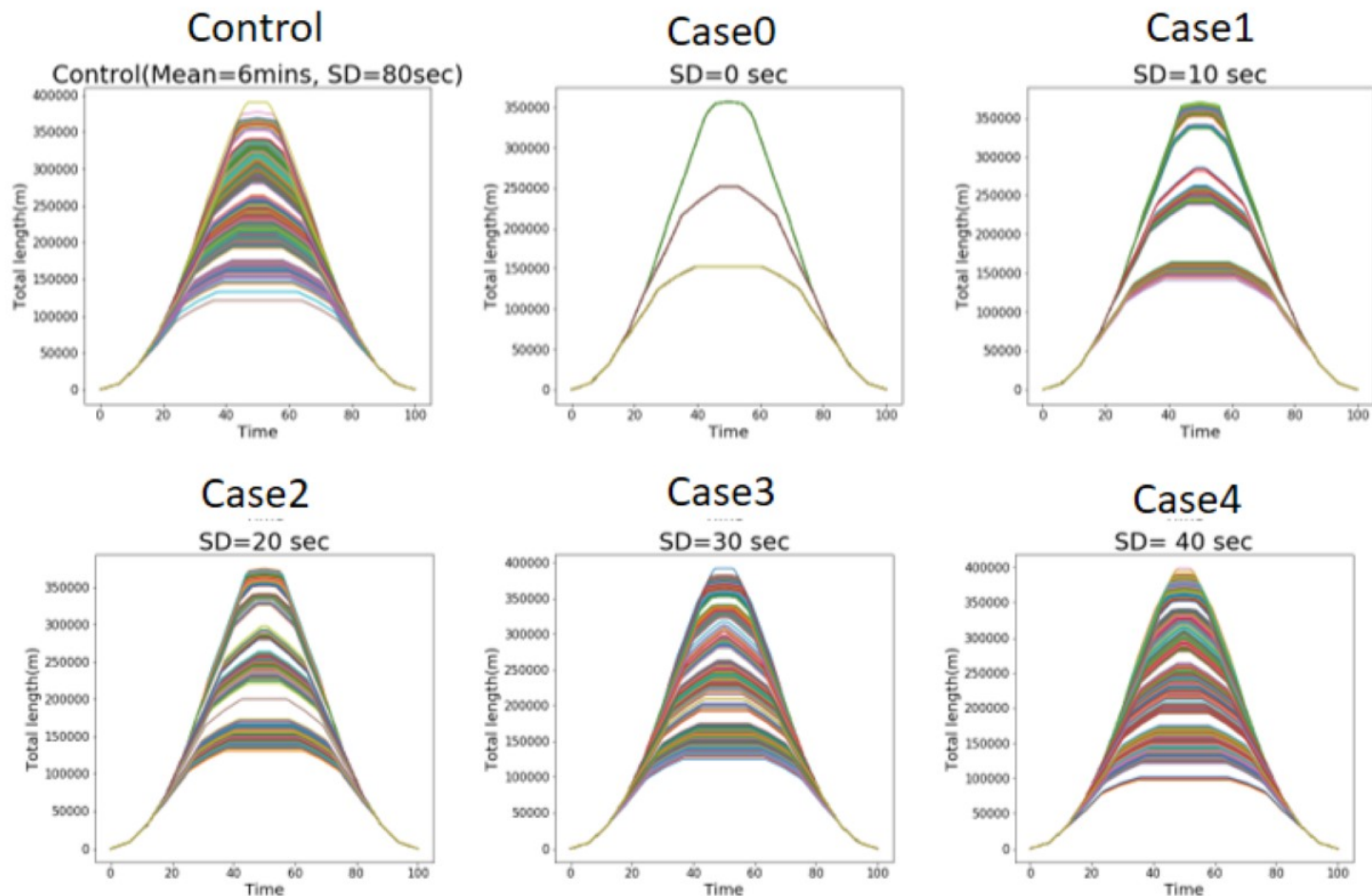
Probability density curves of stationary activity time





Simulation 1 – Varying stationary activity time

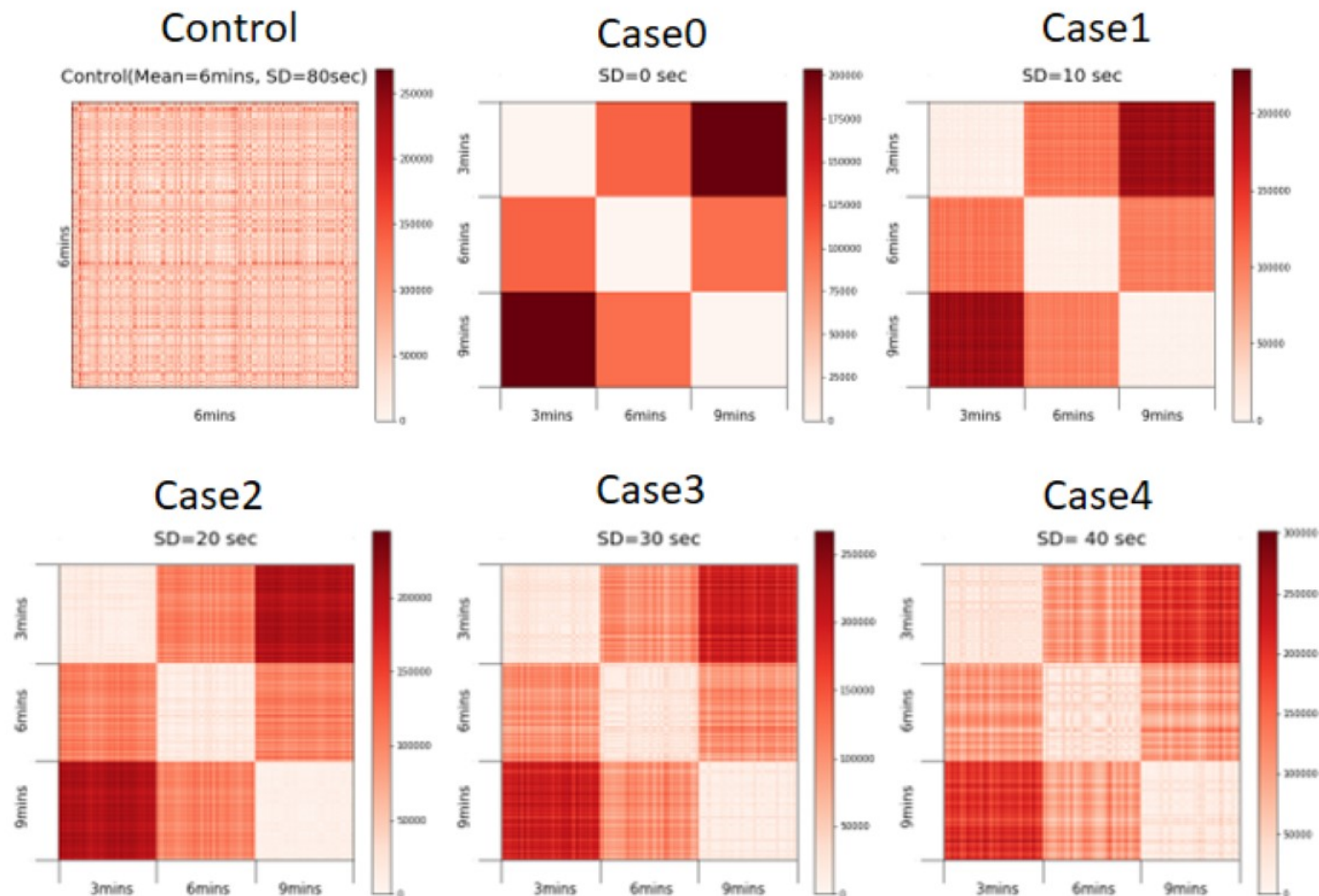
Temporal profiles (Total length index)





Simulation 1 – Varying of stationary activity time

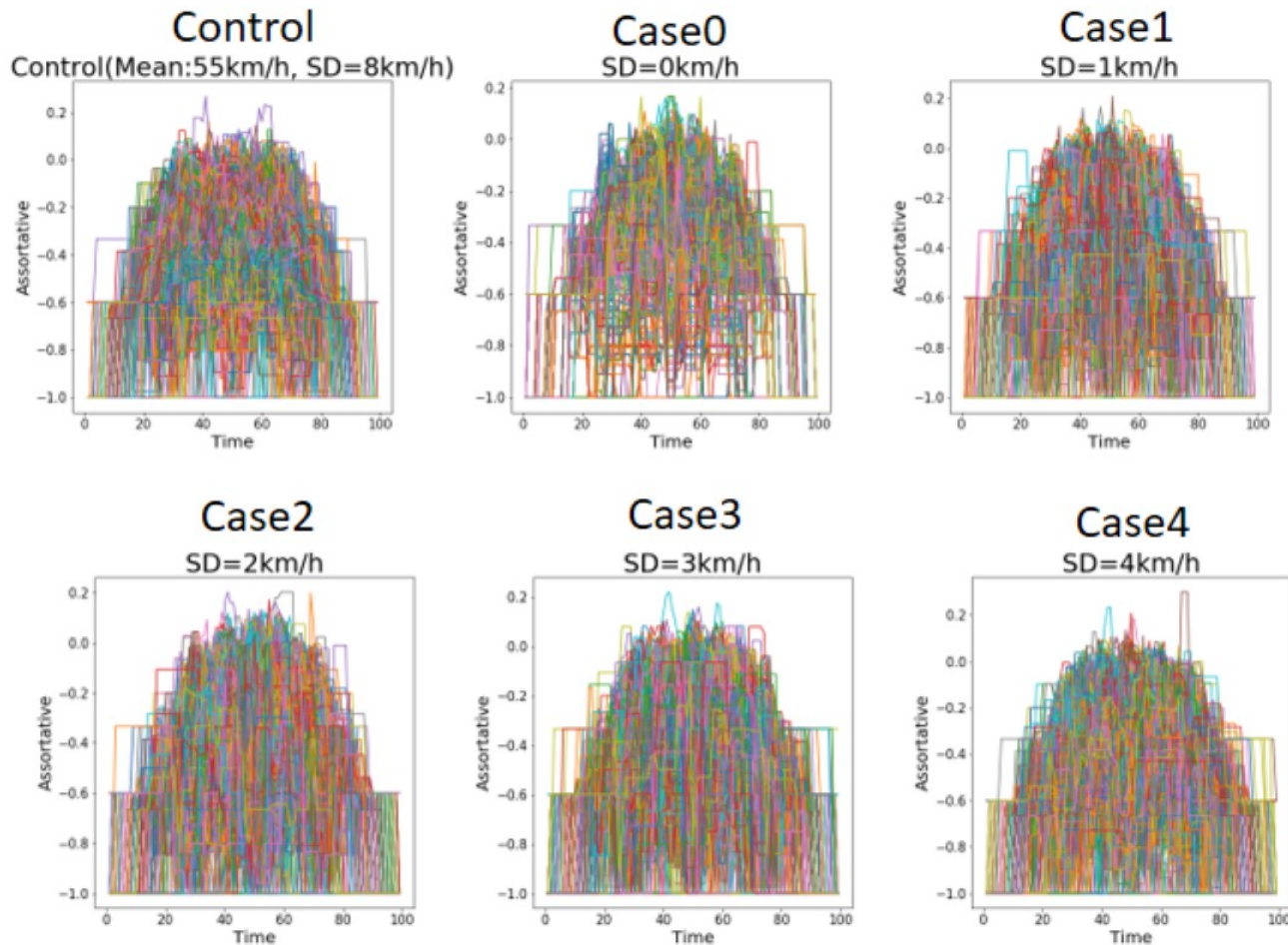
Fréchet Distance Heatmaps (Total length index)





Simulation 2 – Varying speed limits (random by line)

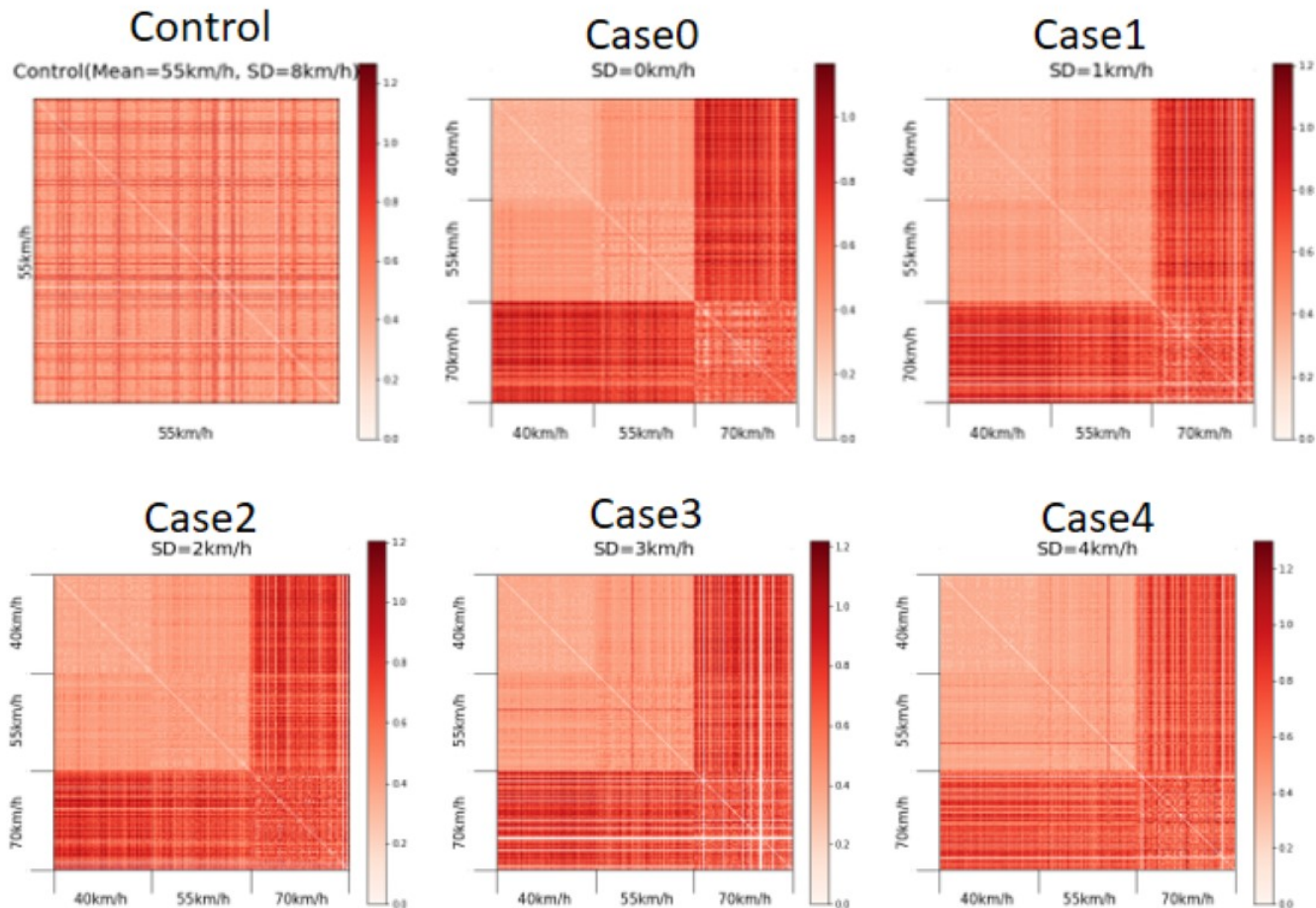
Temporal profiles (Assortative coefficient)





Simulation 2 – Varying speed limits (random by line)

Fréchet Distance Heatmaps (Assortative coefficient)





Evaluation summary - Silhouette coefficient

	Indices	Stationary activity time	Speed limits			Average
			Uniform speed	Random speed by edges	Random speed by lines	
Size	Total length	0.857	0.826	0.687	0.536	0.726¹⁾
	Nodes	0.810	0.609	0.513	0.368	0.575
	Edges	0.810	0.616	0.560	0.425	0.603
Connectivity	Alpha	0.798	0.534	0.484	0.421	0.559
	Beta	0.799	0.453	0.345	0.278	0.469
	Gamma	0.797	0.496	0.073	0.039	0.351
	Cycles	0.809	0.619	0.526	0.456	0.603²⁾
	Organic	0.796	0.453	0.318	0.236	0.451
Hierarchy	Assortative coefficient	0.832	0.459	0.111	0.062	0.366

1) Significantly different from other size measures at the significance level 0.05

2) Significantly different from other connectivity measures at the significance level 0.05 except Alpha index



Conclusion

Next steps

Compare graph theoretic index for different trip parameters

Simulation on empirical transportation networks

NTP clustering and aggregation techniques

Network semantics – walkability, business locations, traffic and crime



Thank you! Questions?

Contact

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