Multidimensional and time varying data visualization at ICMC-USP

Luis Gustavo Nonato

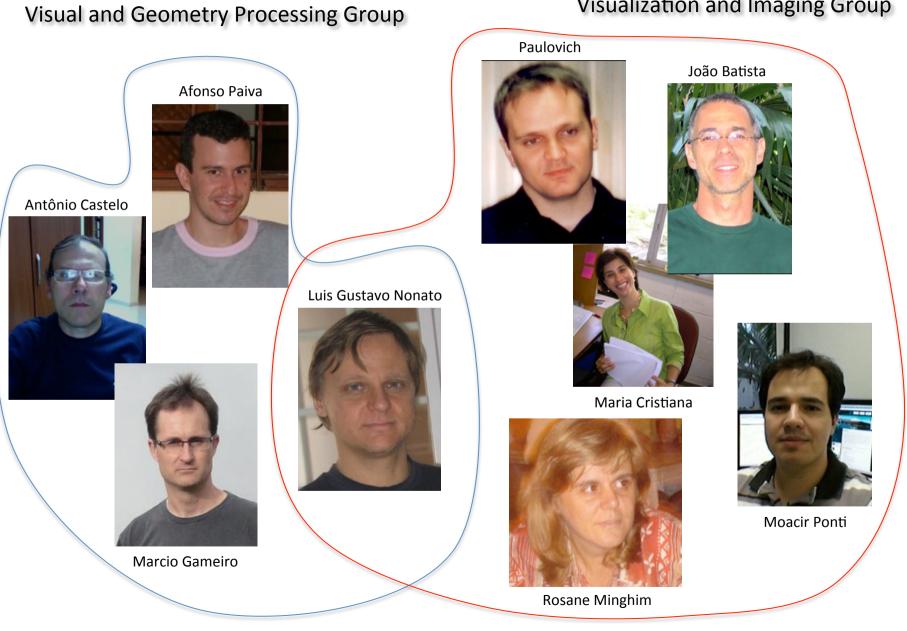
Instituto de Ciências Matemáticas e de Computação Universidade de São Paulo - Brasil



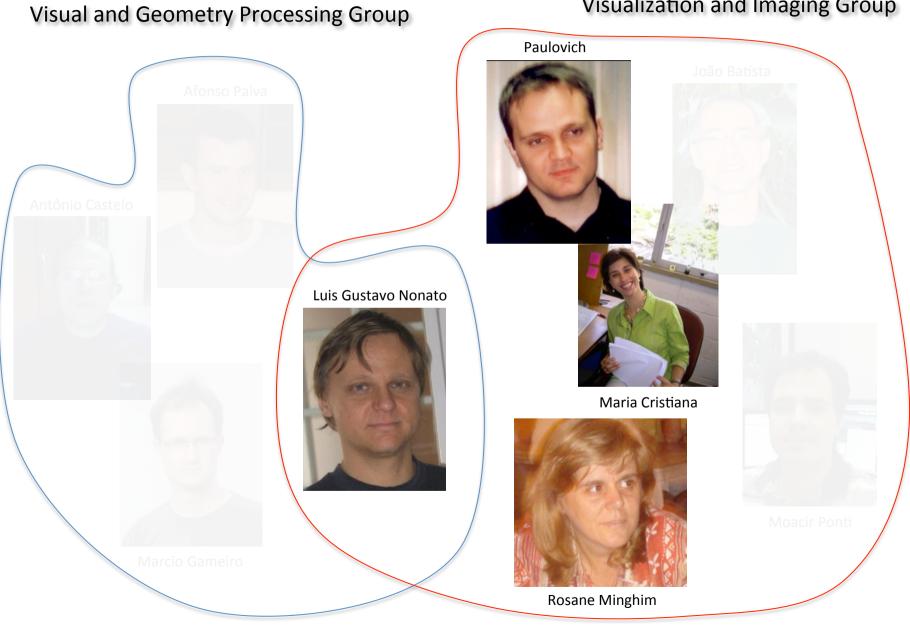








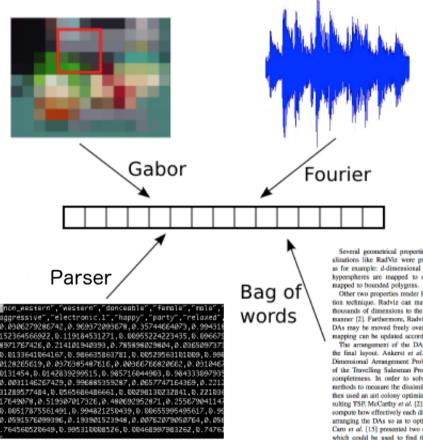
Visualization and Imaging Group



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Researches are focused mainly on multidimensional data visualization

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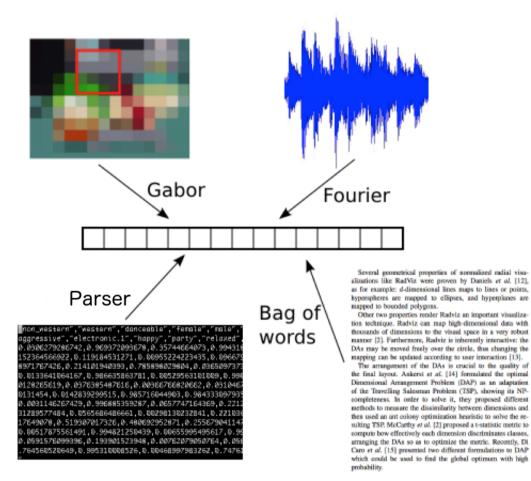


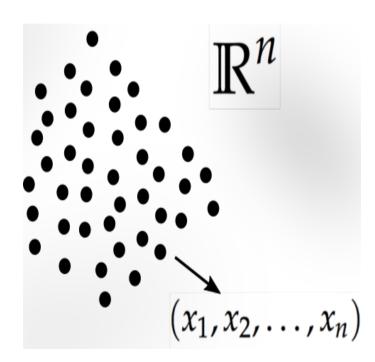
Several geometrical properties of normalized radial visualizations like RadViz were proven by Daniels et al. [12], as for example: d-dimensional lines maps to lines or points, hyperspheres are mapped to ellipses, and hyperplanes are

Other two properties render Radviz an important visualization technique. Radviz can map high-dimensional data with thousands of dimensions to the visual space in a very robust manner [2]. Farthermore, Radviz is inherently interactive: the DAs may be moved freely over the circle, thus changing the mapping can be updated according to user interaction [13].

The arrangement of the DAs is crucial to the quality of the final layout. Ankerst et al. [14] formulated the optimal Dimensional Amangement Problem (DAP) as an adaptation of the Travelling Salesman Problem (TSP), showing its NPcompleteness. In order to solve it, they proposed different methods to measure the dissimilarity between dimensions and then used an ant colony optimization heuristic to solve the resulting TSP. McCarthy et al. [2] proposed a t-statistic metric to compute how effectively each dimension discriminates classes, arranging the DAs so as to optimize the metric. Recently, DL Caro et al. [15] presented two different formulations to DAP which could be used to find the global optimum with high probability.

Researches are focused mainly on multidimensional data visualization





• Multidimensional Projection based Visual Analytics

• Graph based Time-Varying data Visual Analytics

- Multidimensional Projection based Visual Analytics
 - ✓ Supervised Projection Methods
 - ✓ Distortion Analysis
 - ✓ Enriched MP Layout
- Graph based Time-Varying data Visual Analytics

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- Graph based Time-Varying data Visual Analytics
 - ✓ Graph-Wavelets
 - ✓ Multi-way Arrays (tensor decomposition)

Multidimensional Projection techniques aim to embed instances of data in a Cartesian *k*-dimensional space assuming that a (dis)similarity measure between pairs of instances is known.

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Multidimensional Projection @ ICMC

- Pioneered supervised MP methods
- First to propose a local MP method

Multidimensional Projection @ ICMC

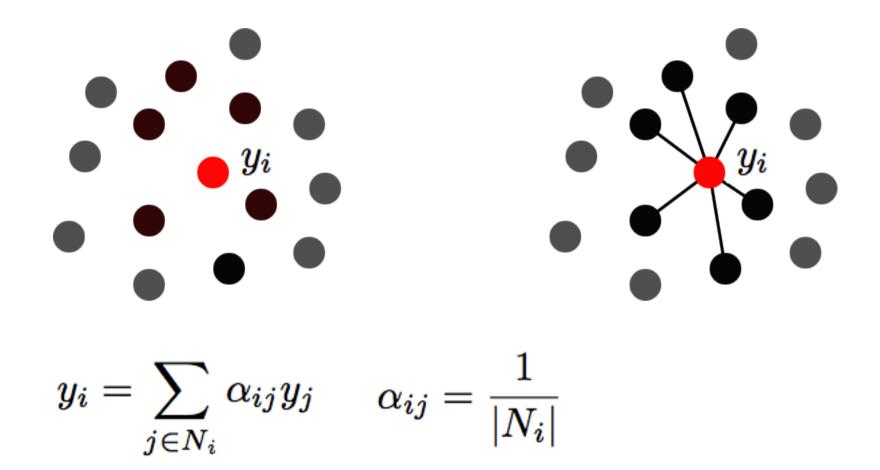
- Pioneered user driven MP methods
- First to propose a local MP method

- ✓ Least Square Projection (LSP)
- ✓ Local Affine Multidimensional Projection (LAMP)

Least Square Projection - LSP

Least Square Projection - LSP

LSP has been tailored to be interactive (supervised), enabling users to steer the projection process. **Multidimensional Space**



A tenable assumption is that neighborhoods should be preserved in the visual space:

$$x_i = \sum_{j \in N_i} \alpha_{ij} x_j \quad \longrightarrow \quad x_i - \sum_{j \in N_i} \alpha_{ij} x_j = 0$$

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$$Lx^{1} = 0 \qquad Lx^{2} = 0$$
$$L_{ij} = \begin{cases} 1 & i = j, \\ -\alpha_{ij} & x_{j} \in N_{i}, \\ 0 & \text{otherwise} \end{cases}$$

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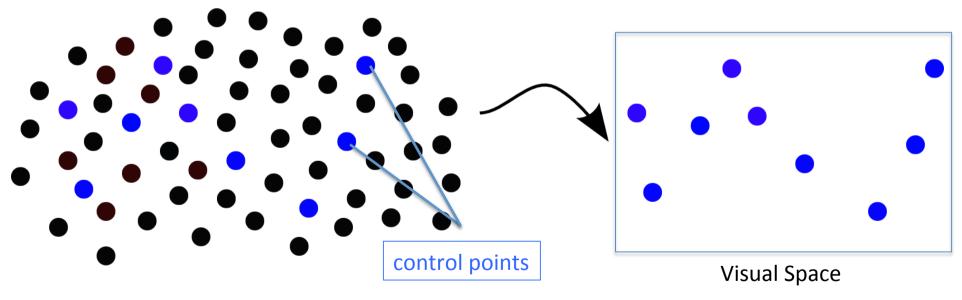
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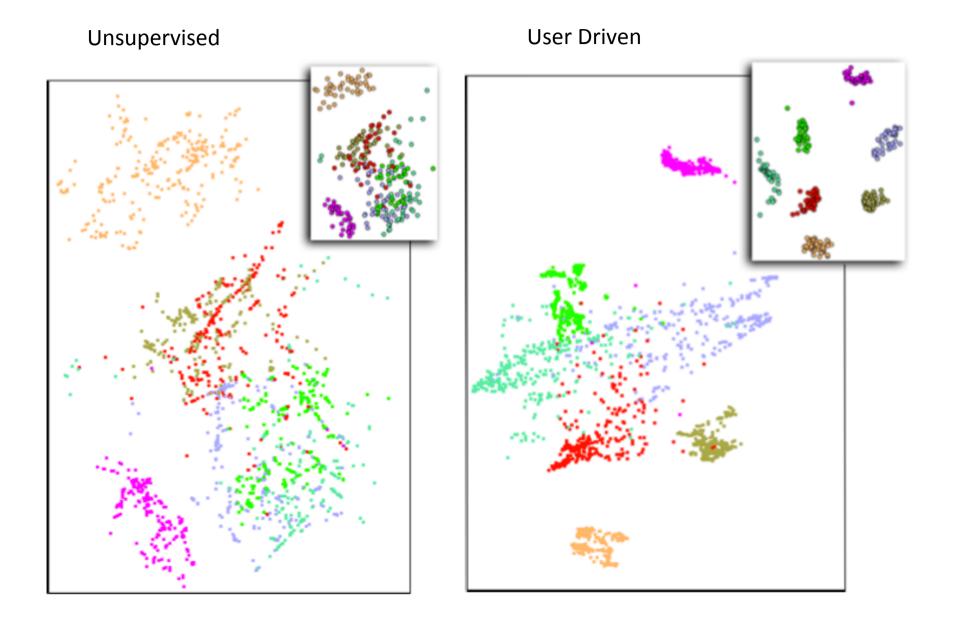
Laplace systems: constraints are need to ensure non-trivial solution

$$L_{ij} = \left\{ egin{array}{ccc} 1 & i=j, \ -lpha_{ij} & x_j \in N_i, \ 0 & ext{otherwise} \end{array}
ight.$$

Constraints for the homogeneous systems are given by control points in the visual, which can be interactively displaced to steer the projection process. Constraints for the homogeneous systems are given by control points in the visual, which can be interactively displaced to steer the projection process.



Multidimensional Space



Although LSP allows for user interaction it has two main drawbacks:

1. LSP is not super fast

can not handle massive data sets

2. LSP mapping is global

small changes in the control points affects the whole layout

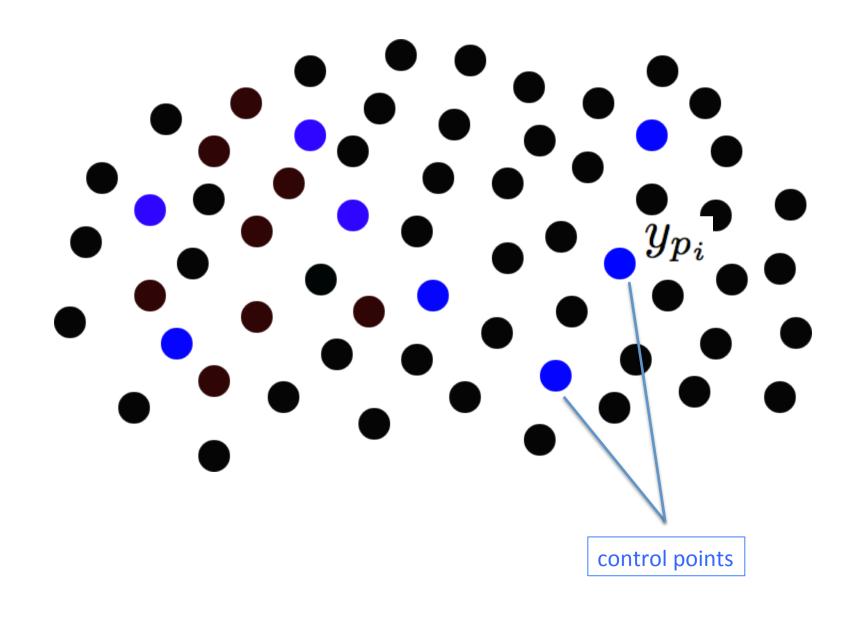
Local Affine Multidimensional Projection (LAMP)

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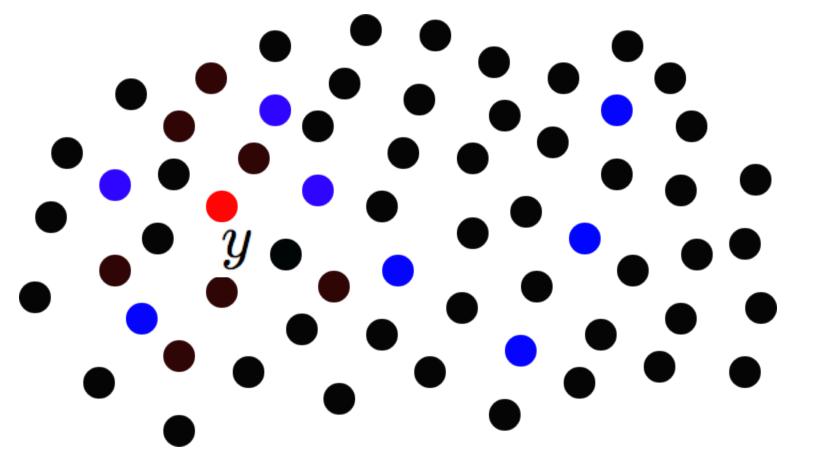
LAMP has been designed to be local,

interactive, and computationally efficient.

Multidimensional space



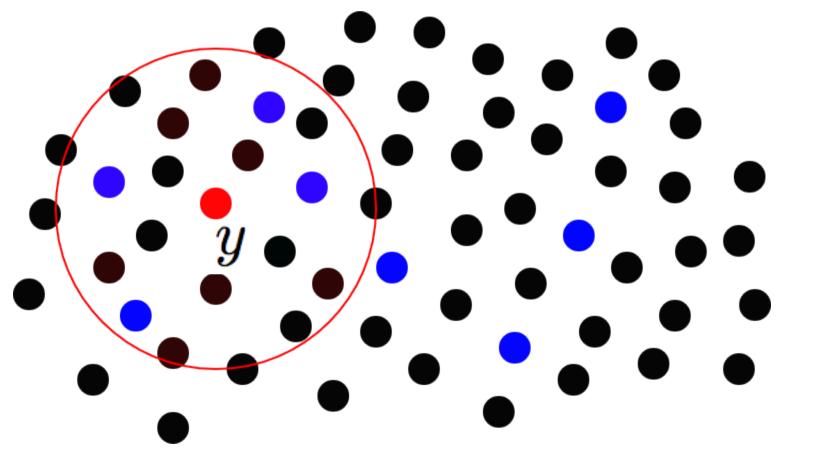
Multidimensional space



 $f_y(y_i) = y_i M + t$

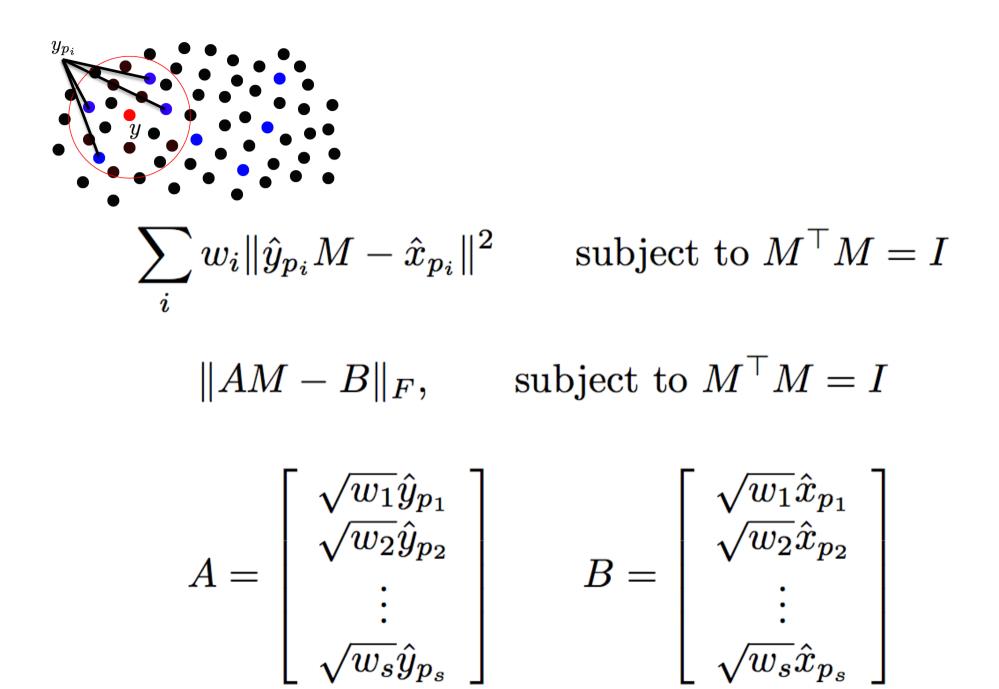
Each point is mapped to the visual space using its own affine transformation

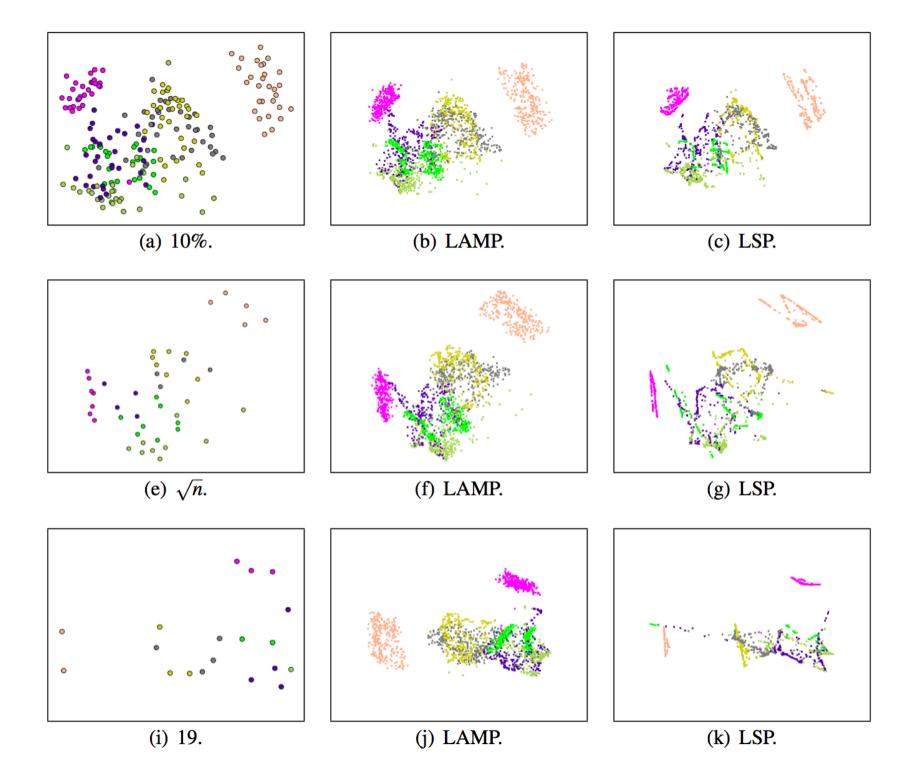
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Point-based layouts allow to visualize neighborhood relation and well defined clusters.



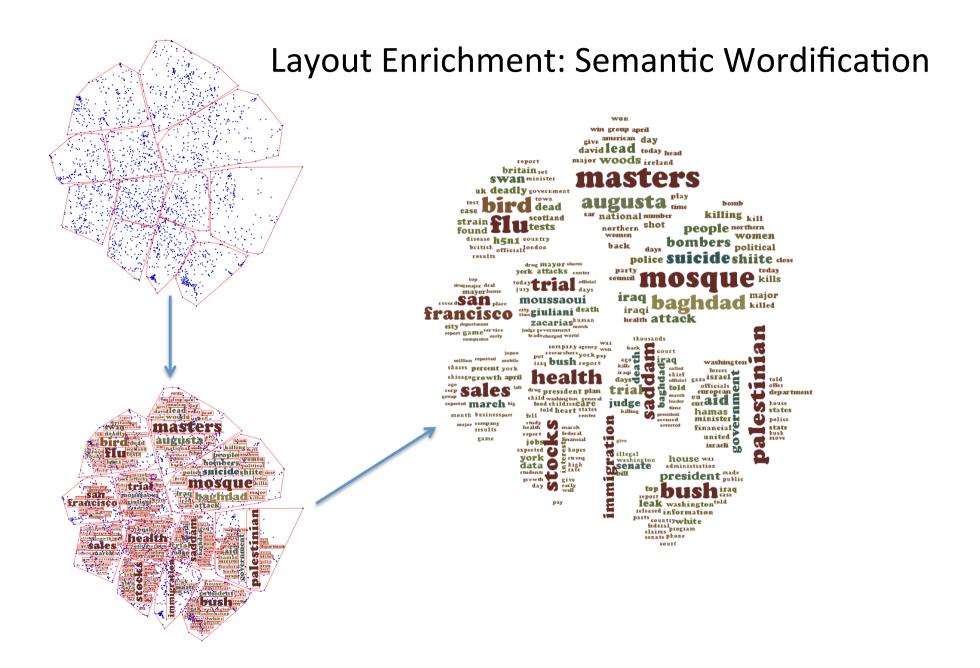
Point-based layouts allow to visualize neighborhood relation and well defined clusters.

However, information such as:

- which are the content of the data in each region?
- which are the most relevant attributes in each region?

can not directly be obtained from the layout.

Layout Enrichment



Layout Enrichment: Web Search Visualization

Jaguars, Jaguar Pictures, Jaguar Facts - National Geographic animals.nationaloeographic.com/animals/mammals/iaguar/

Learn all you wanted to know about **jaguars** with pictures, videos, photos, facts, and ... Photo: A young female **jaguar** stopped in its tracks ... Big Cats **Features** ...

Jaguar International - XF Models and Features

www.jaguar.com > Home > XF Jaguar XF: A sporting saloon with a choice of four trim levels and six engines including 3.0 Litre V6 Diesel S. Find out more about the XF, XF Portfolio and XFR.

Jaguar USA - FEATURES DISCLAIMER

www.jaguar.com/us/en/features_disclaimer These features are not a substitute for driving safely with due care and attention and will not function under all circumstances, speeds, weather and road ...

Jaguar USA - EXTERNAL FEATURES

www.jaguar.com > ... > XJ > MODELS & PRICING > FEATURES Elegant design **features** enhance the bold, sporting profile of the XJ. ... All XJ models

feature a dramatic full-width glass roof, sweeping back from the top of the ...

Jaguar International - XK Models and Features

www.jaguar.com > Home > XK Available in coupe or convertible bodystyles, the XK is available with a choice of two performance engines. Find out more about XK, XK Portfolio and XKR.

Jaguar Specifications | Engine Performance & Jaguar Features ...

www.motortrend.com/used_cars/01/jaguar/specifications/ The Motor Trend used car buyer's guide has detailed used Jaguar specifications, performance, standard equipment and comprehensive Jaguar data.

Atari Jaguar - Wikipedia, the free encyclopedia en.wikipedia.org/wiki/Atari_Jaguar

Jump to <u>Other Jaguar features</u>: RAM: 2 MB on a 64-bit bus using 4 16-bit fast page mode DRAMs; Storage: Cartridge – up to 6 MB; DSP-port (JagLink) ...

Used Jaguar Specifications, Options, & Jaguar Features at ... www.automobilemag.com/used car.../01/jaguar/index.html

View comprehensive used Jaguar specifications and car data at Automobile Magazine.

Pear-Shaped Tripod Vessel with Modeled Jaguar Features | Michael ... carlos.emory.edu/pataky_jaguar - United States

Pear-Shaped Tripod Vessel with Modeled **Jaguar Features**. Central America, Costa Rica/Nicaragua, Greater Nicoya, Pataky Polychrome, Pataky Variety. Period ...

Xclusively Jaguar - Features - For all your Jaguar needs.... Jaguar ... www.xclusively-jaguar.co.uk/xj06 features.php

Esta-jane Mace was nominated by her employer, **Jaguar** Land Rover, as a potential candidate for the City of Coventry Freemen's Guild Apprentice of the Year ...

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Jaguars, Jaguar Pictures, Jaguar Facts - National Geographic animals.nationalgeographic.com/animals/mammals/jaguar/ Learn all you wanted to know about jaguars with pictures, videos, photos, facts, and ... Photo: A young female jaguar stopped in its tracks ... Big Cats Features ...

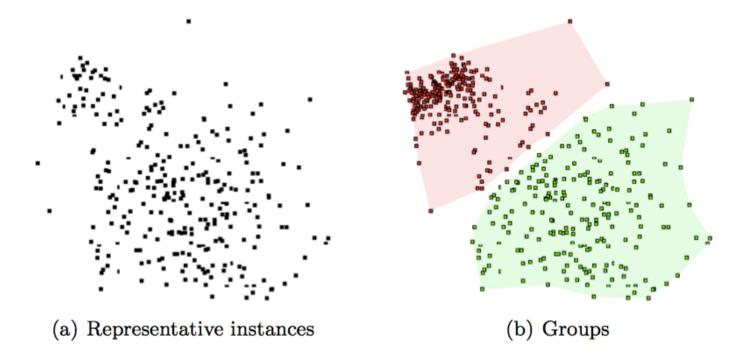
Jaguar International - XF Models and Features

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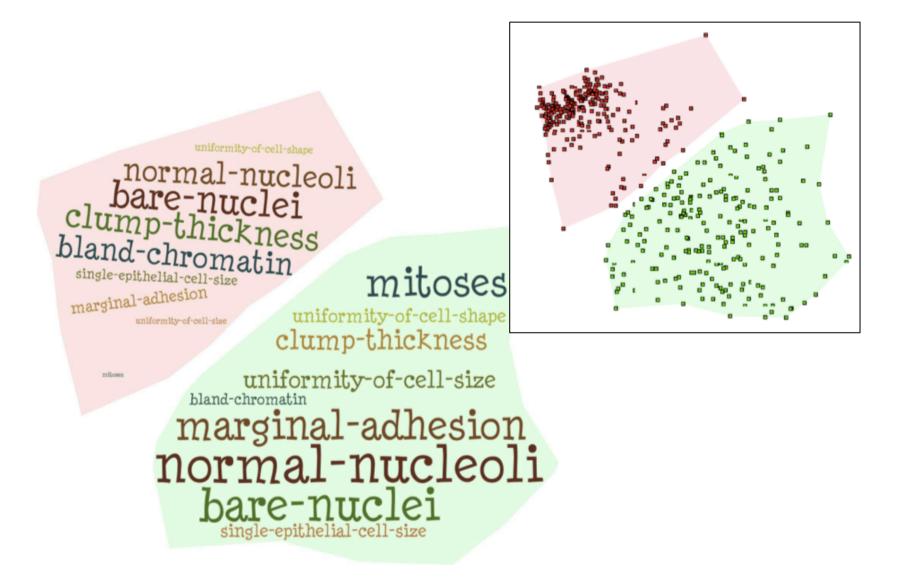
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Layout Enrichment: Attribute Relevance



Layout Enrichment: Attribute Relevance

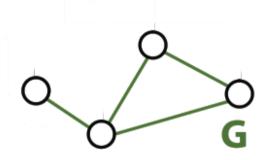


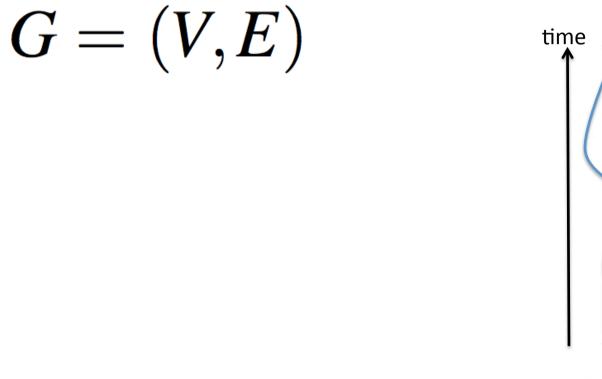
Graph based Time Varying Data:

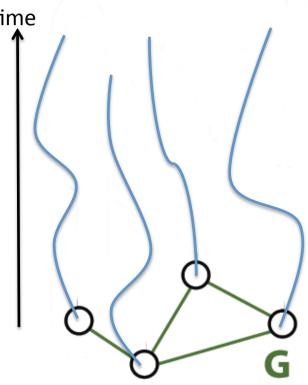
Graph based Time Varying Data:

Graph Signal Processing

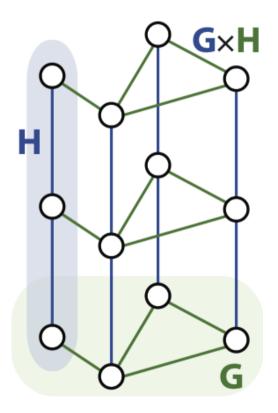
G = (V, E)

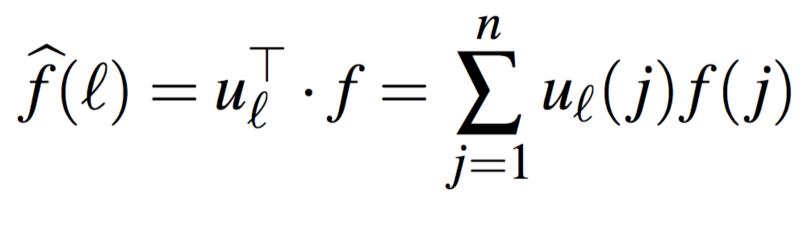




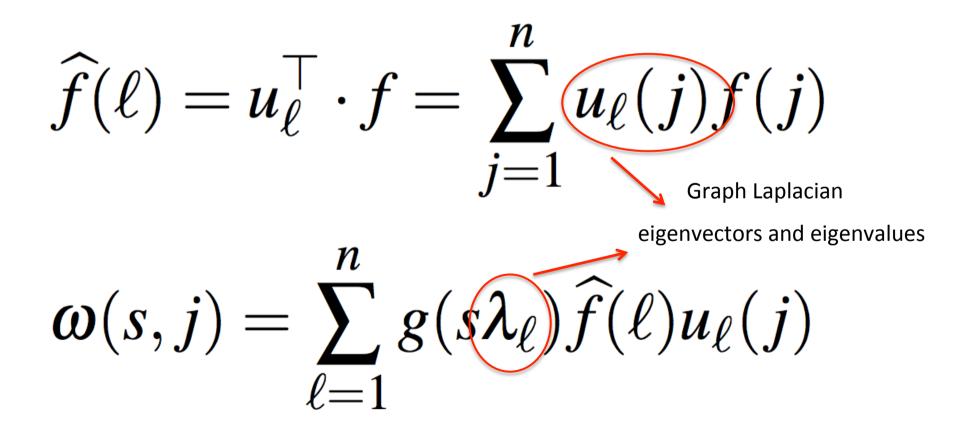


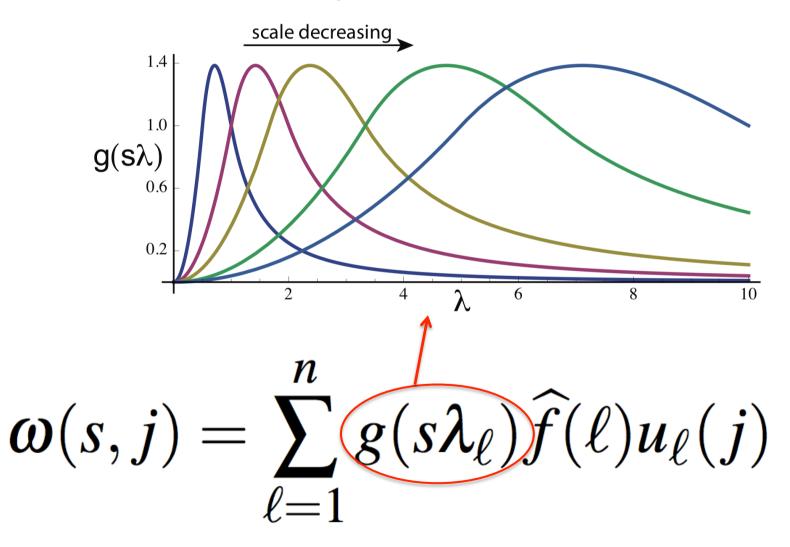
$$G = (V, E)$$
$$f : G \times H \to \mathbb{R}$$

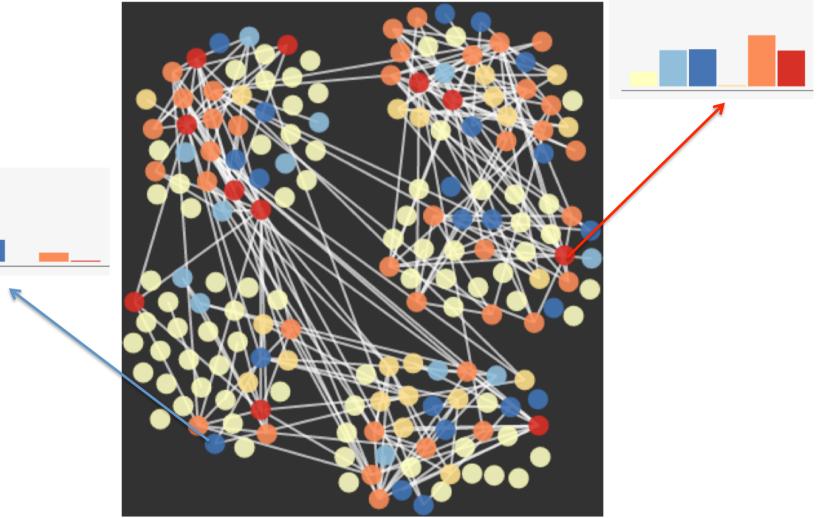


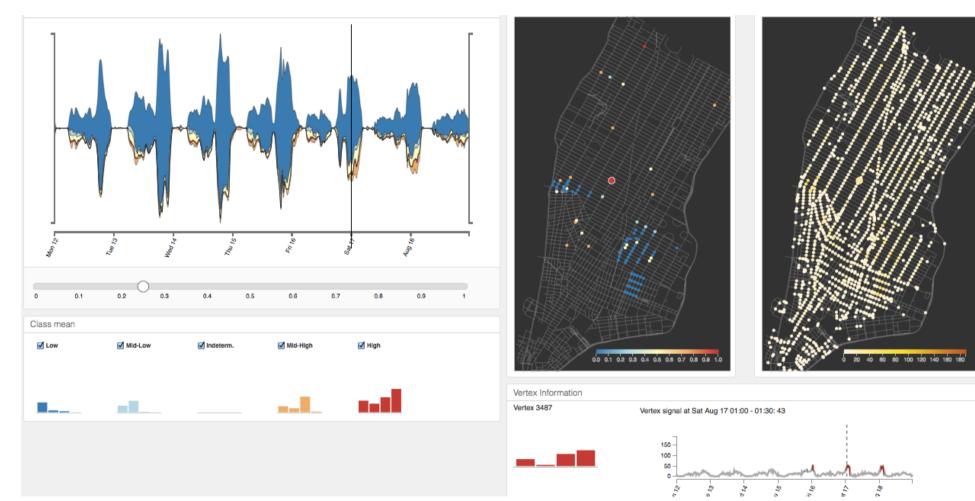


 $\boldsymbol{\omega}(s,j) = \sum_{\ell=1}^{n} g(s\lambda_{\ell}) \widehat{f}(\ell) u_{\ell}(j)$





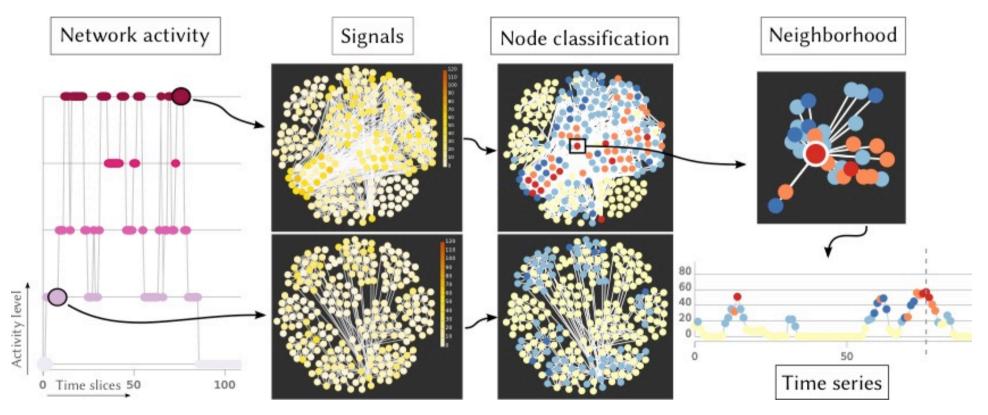




Taxi Data



Taxi Data



Dynamic Networks

Thanks for your attention !!