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ÉCOLE POLYTECHNIQUE  
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**Strathclyde**

# A Network Based Kernel Density Estimator Applied to Barcelona Economic Activities

**Ecole Polytechnique Fédérale de Lausanne, Switzerland**  
**LaSIG**

Timothée Produit, Nicolas Lachance-Bernard, Stéphane Joost

**University of Strathclyde, Glasgow, United Kingdom**  
**Urban Design Studies Unit**

Sergio Porta, Emanuele Strano

Fukuoka, ICCSA, March 2010

# Plan

- Goals
- Theory
- Methodology and Algorithms
- Barcelona case study
- Conclusion

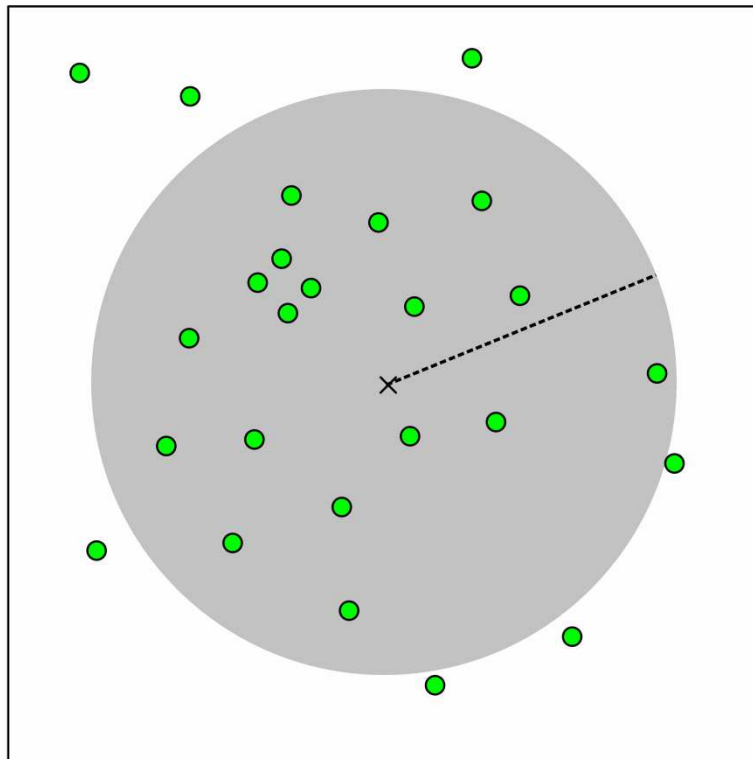
# Goals

- Goals
  - Create a network oriented density indicator to study cities design
  - Compare NetKDE indicator with KDE indicator
  - Complete a proof-of-concept
    - Apply NetKDE to economic activities (points)
    - Apply NetKDE to network edges weighted by centrality indexes (polylines)
- Technologies
  - Python Scripts, PostGIS Database, ArcGIS

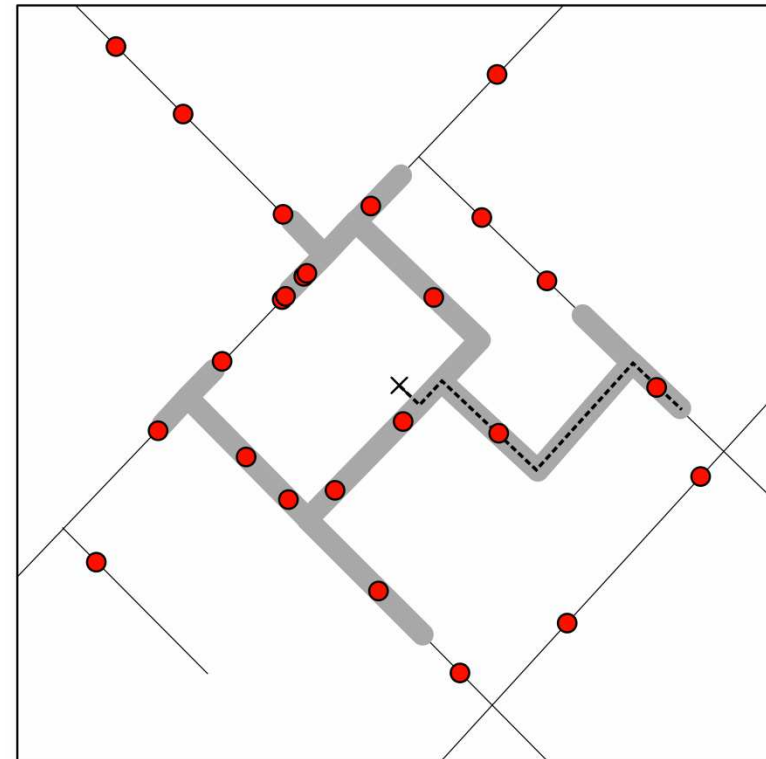
# Theory

- **Kernel Density Estimator (KDE):**
  - Operates in **Euclidean** space
  - Weights events according to their radial distances from grid centroid ▶
- **Network based KDE (NetKDE):**
  - Operates in a **Network Constrained** space
  - Weights events according to the distance measured along this network

# KDE vs NetKDE



X Raster Cell    ● Events    ----- Bandwidth

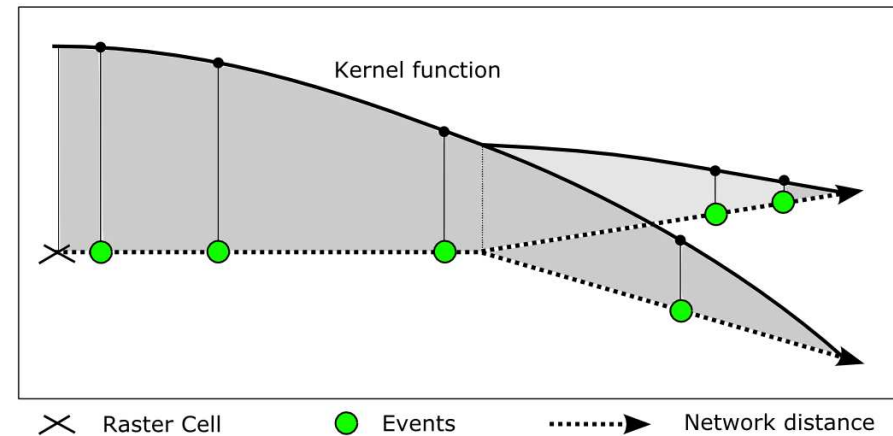
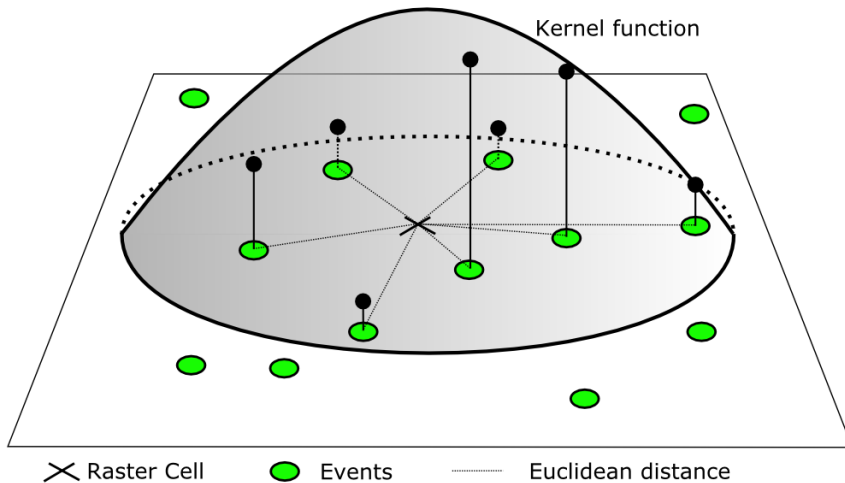


X Raster Cell    ● Proj. event    — Network  
----- Bandwidth    — Short. Path Tree

**KDE:** For each raster cell, events inside a radial bandwidth contribute to density evaluation.

**NetKDE:** For each raster cell, projected events along a network bandwidth contribute to density evaluation.

# KDE vs NetKDE



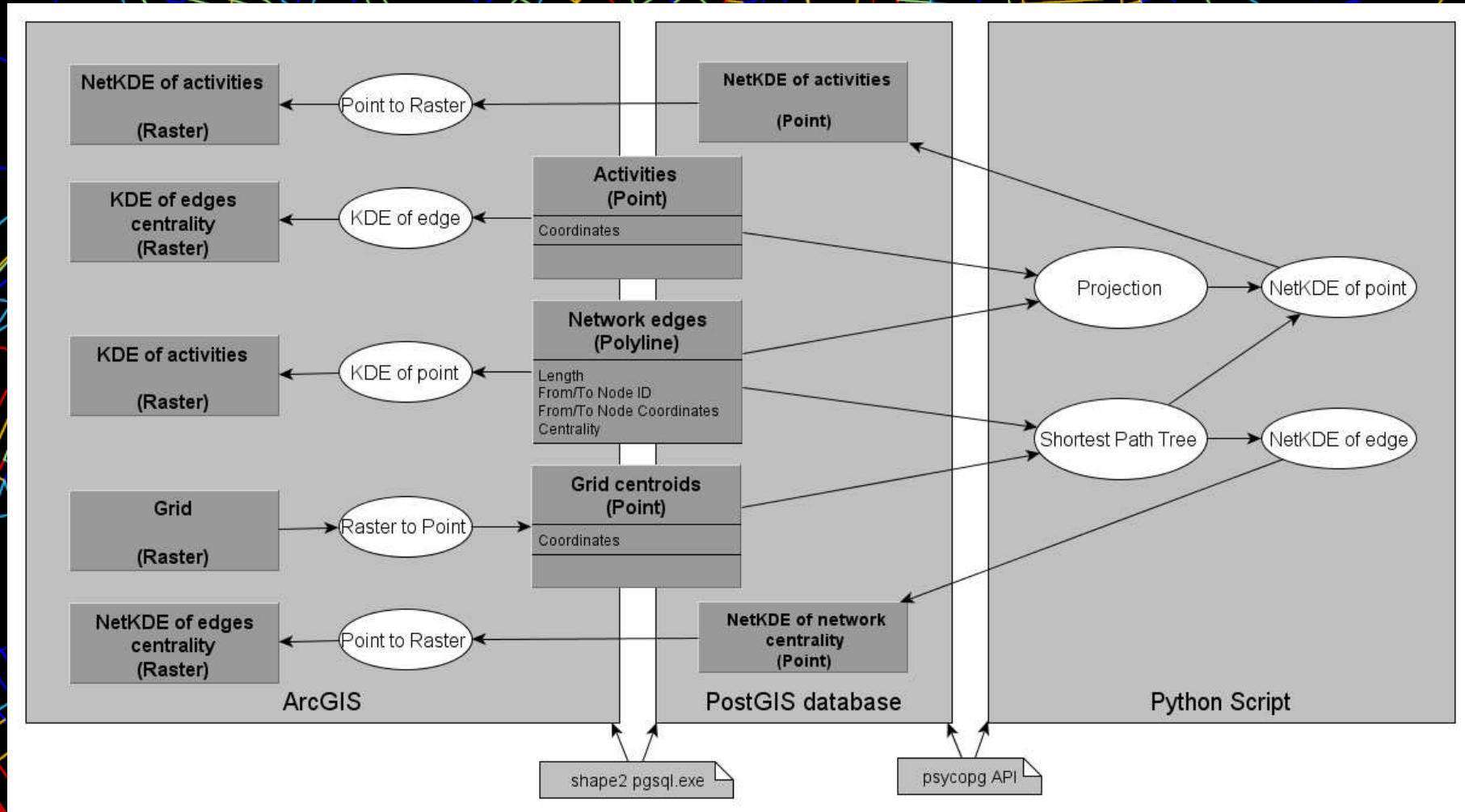
$$\hat{f}_h(x_j) = \sum_{i=1}^n \frac{1}{h^2} K\left(\frac{x_j - x_i}{h}\right)$$

$$K(x_i) = \begin{cases} \frac{1}{3\pi}(1 - t_i^2)^2 & \text{if } t_i^2 < 1 \\ 0 & \text{otherwise} \end{cases}$$

**KDE:** The Kernel function weights events according to their radial distance

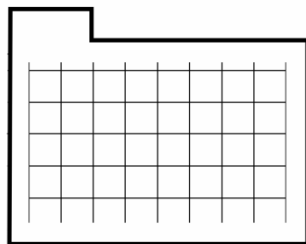
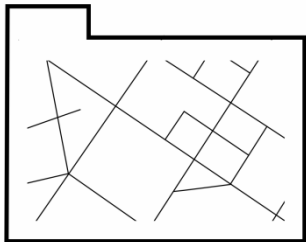
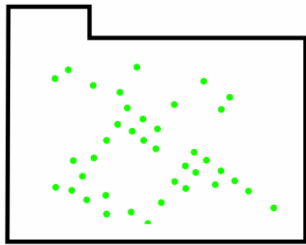
**NetKDE:** The Kernel function weights events according to the distance measured along the network

# Methodology





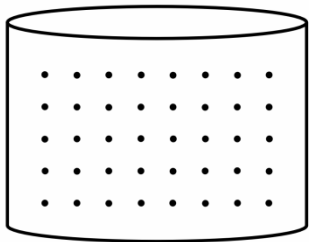
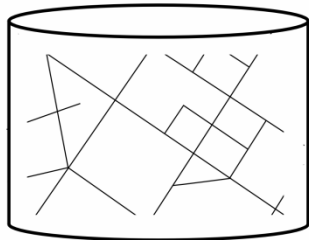
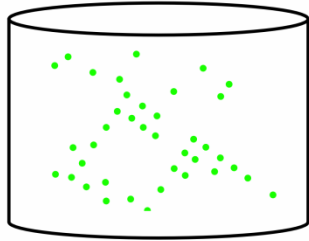
# Input data



ArcGIS

- » Activities are stored in a shape file,
- » Network is stored in a shape file,
- » Creation of a raster grid covering the extent of the network

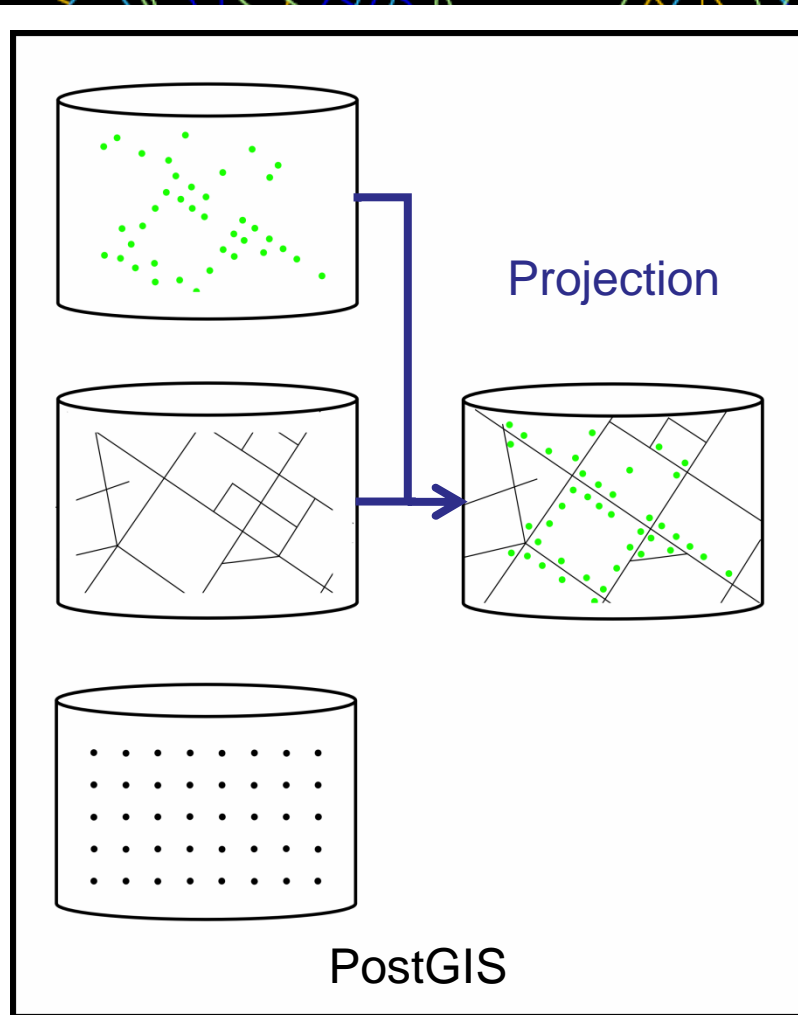
# Conversion



PostGIS

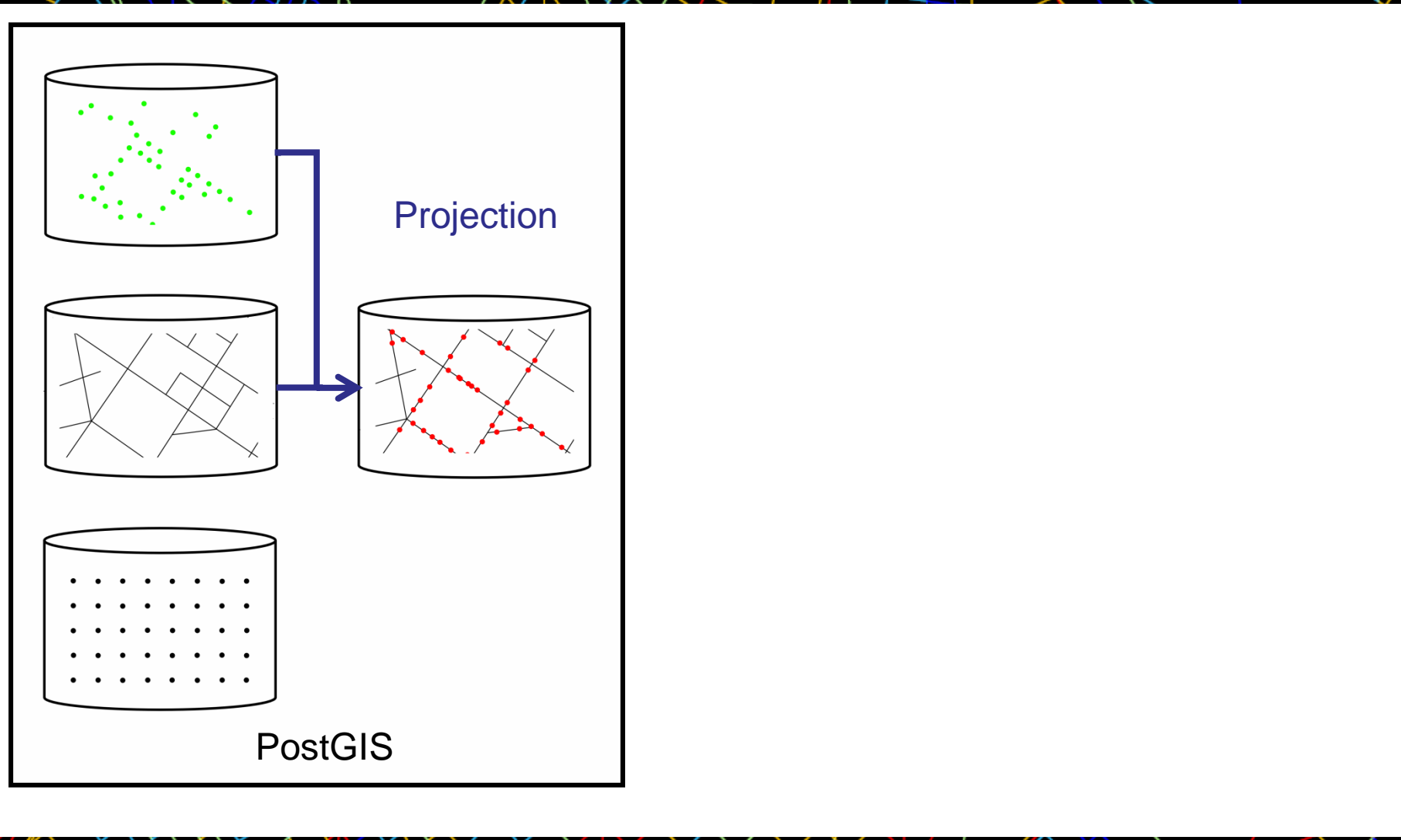
- » Files are exported into a PostGIS database
- » The raster grid is converted into points

# Activities projection

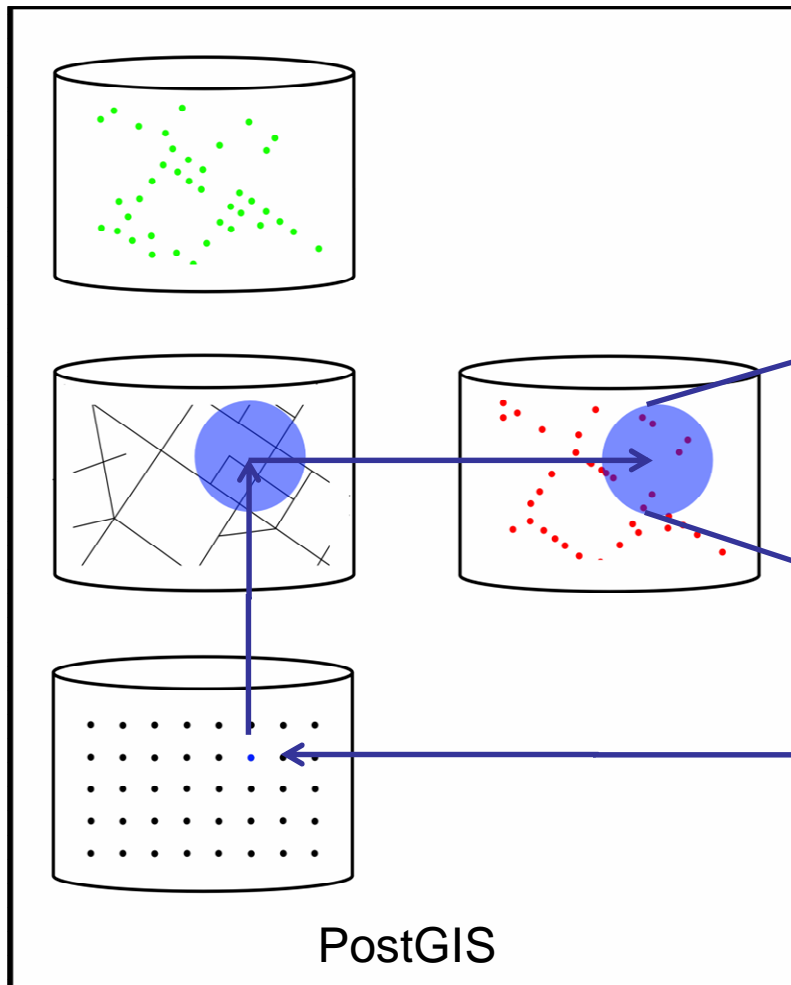


- » Activities are projected on the nearest edge

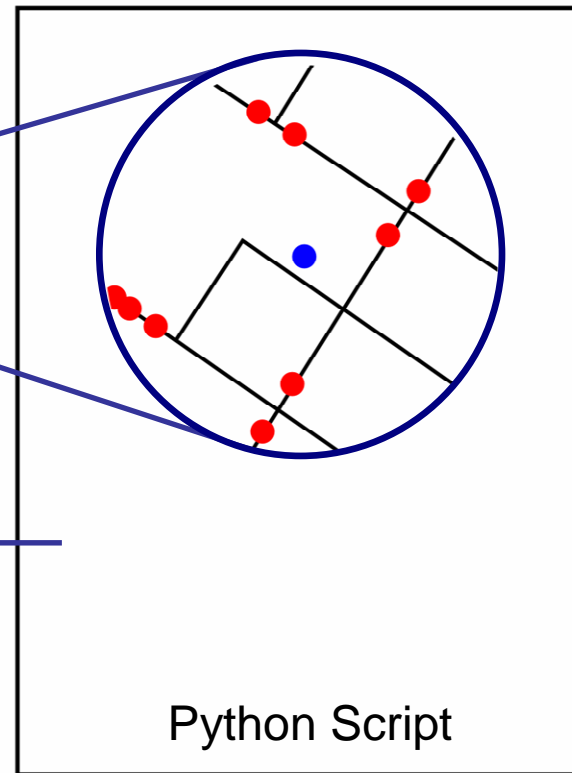
# Activities projection



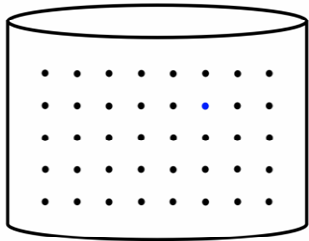
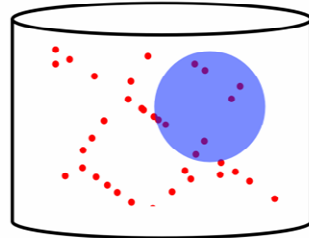
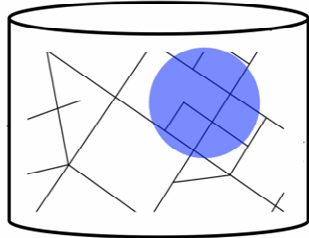
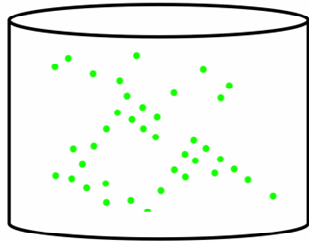
# Calculation



For each cell of the grid (represented by its centroid), the script imports the surrounding network and projected activities

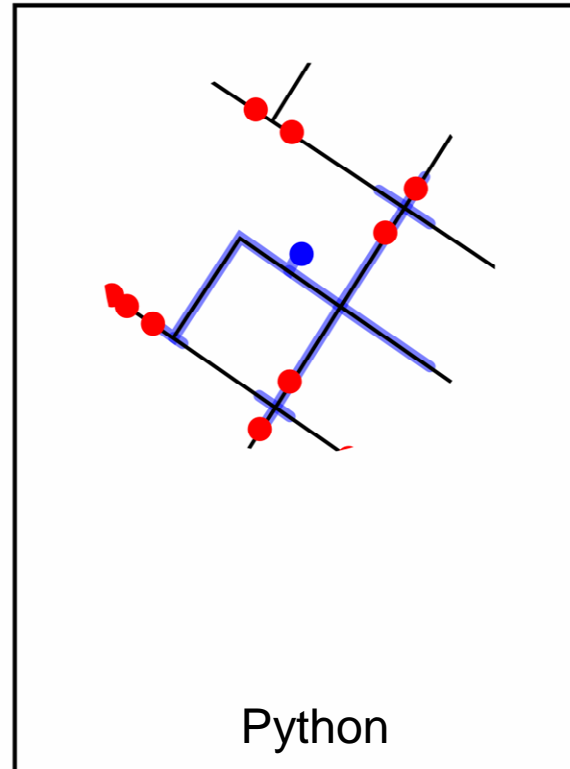


# Calculation



PostGIS

The Script compute a Shortest Path Tree for the current raster cell, the NetKDE of point and the NetKDE of edges.



Python

# Barcelona Case Study

- **Material**

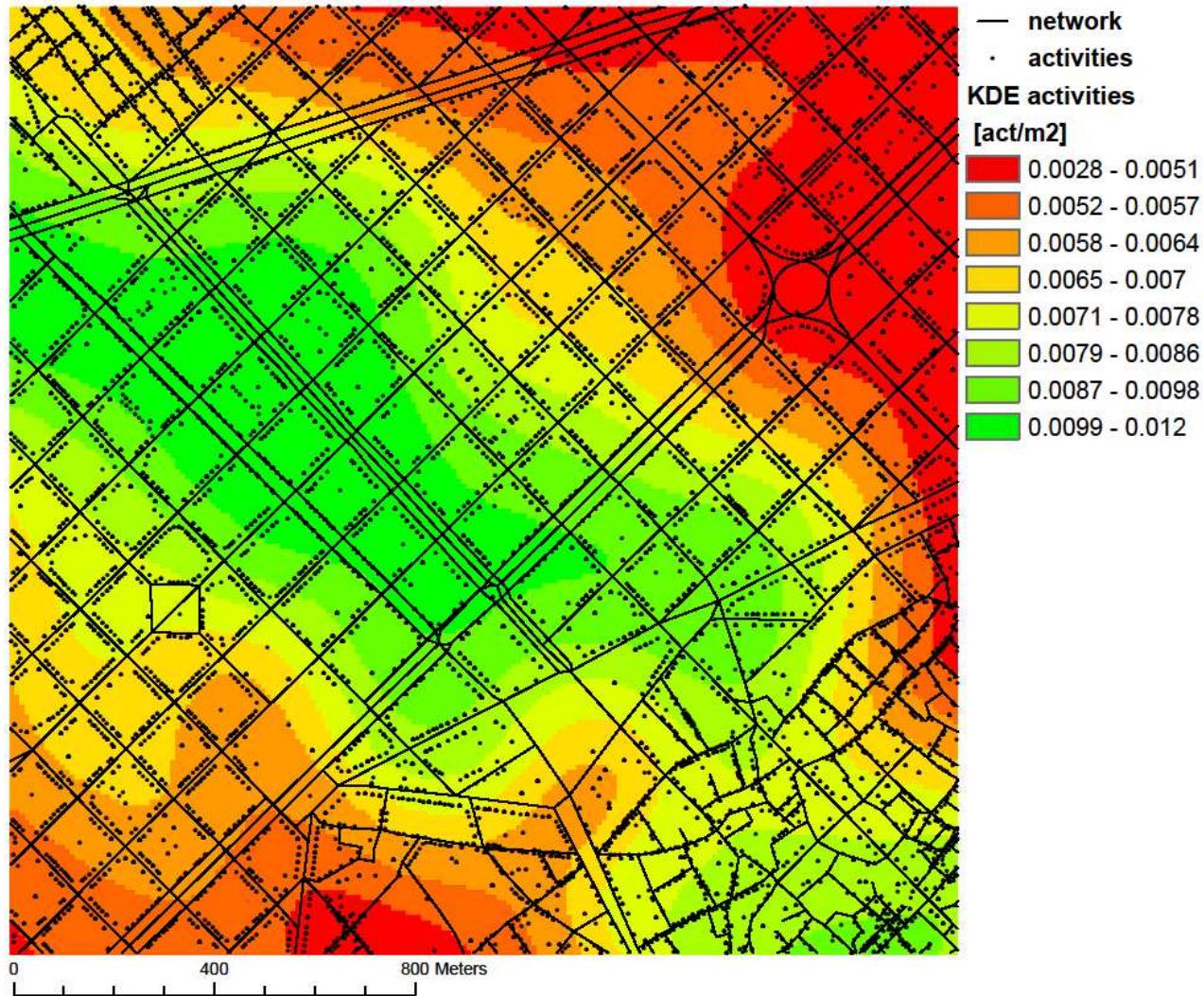
- **Network:** 11,000 edges
- **Activities:** 166,000 economic activities listed by the *Agencia de Ecologia Urbana* in 2002

- **Computation**

- 926,000 raster cells, 10 meter resolution
- 400 meter bandwidth
- **33 hours** (Intel(R) Core(TM)2 Quad CPU, Q950 @ 3.00GHz, 2.99Ghz, 7.83 GB of RAM)

- **Zoom in on the center of Barcelona**

# Kernel Density of activities



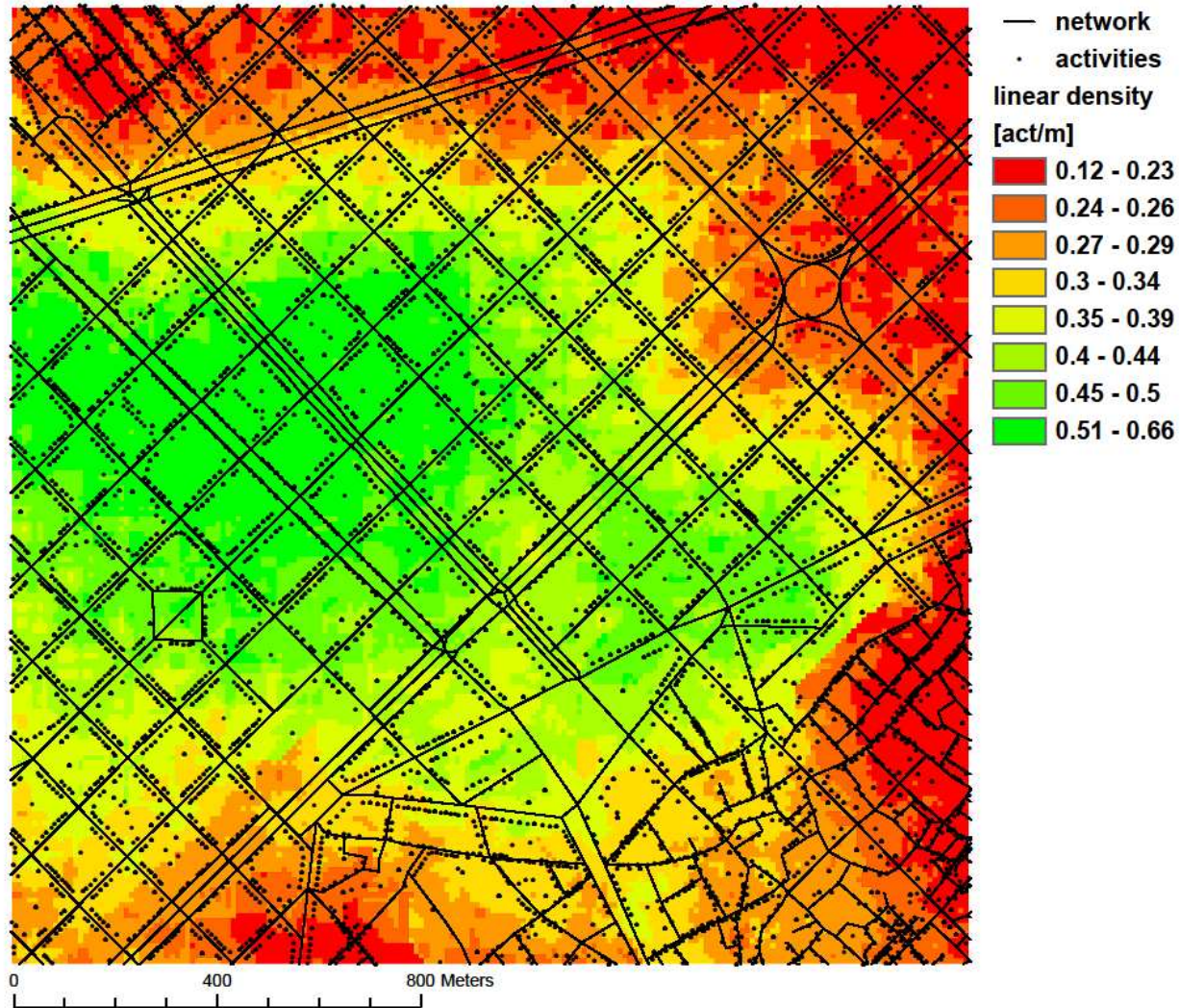
Several activities  
can be located at  
the same place

Bandwidth = 400m

Computed with  
ArcGIS



# Linear Density

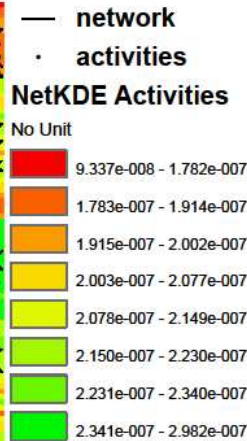
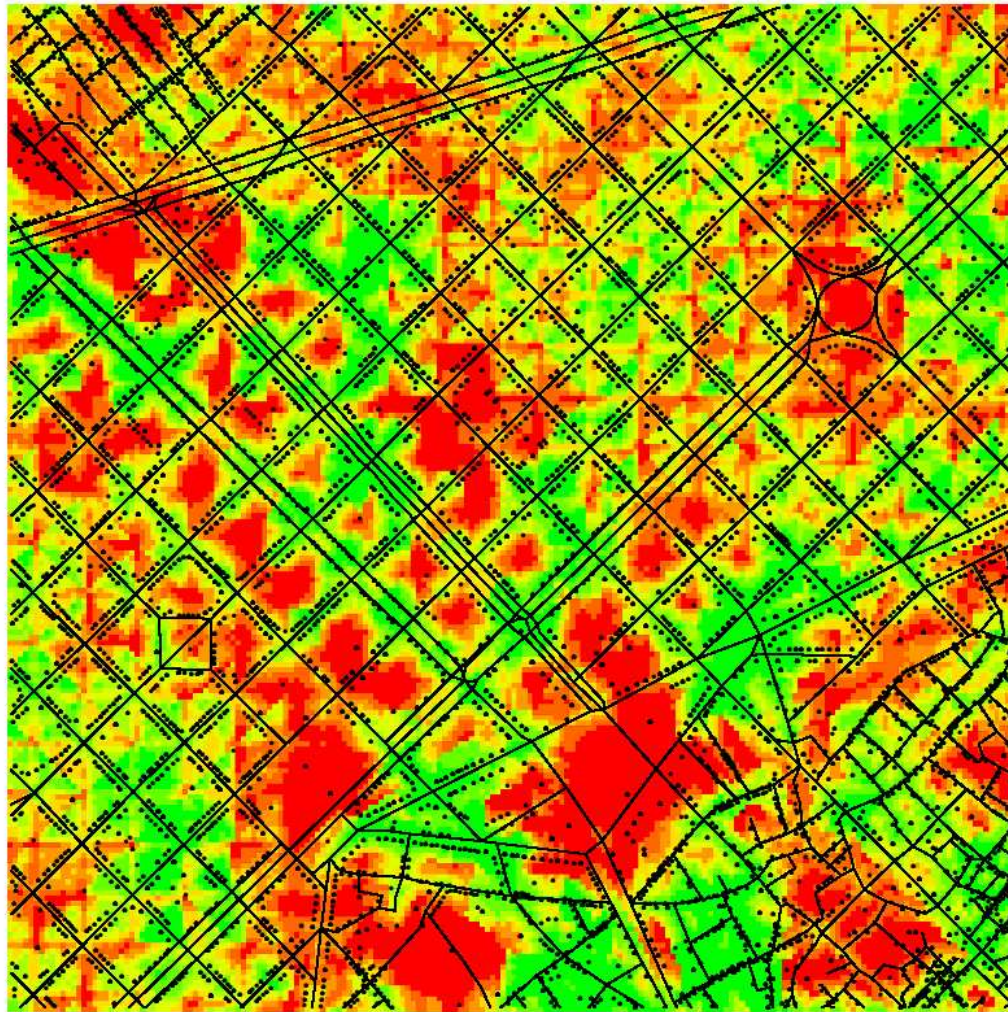


Linear density of activities =

Nbr. Act./ Length of SPT

Same scale

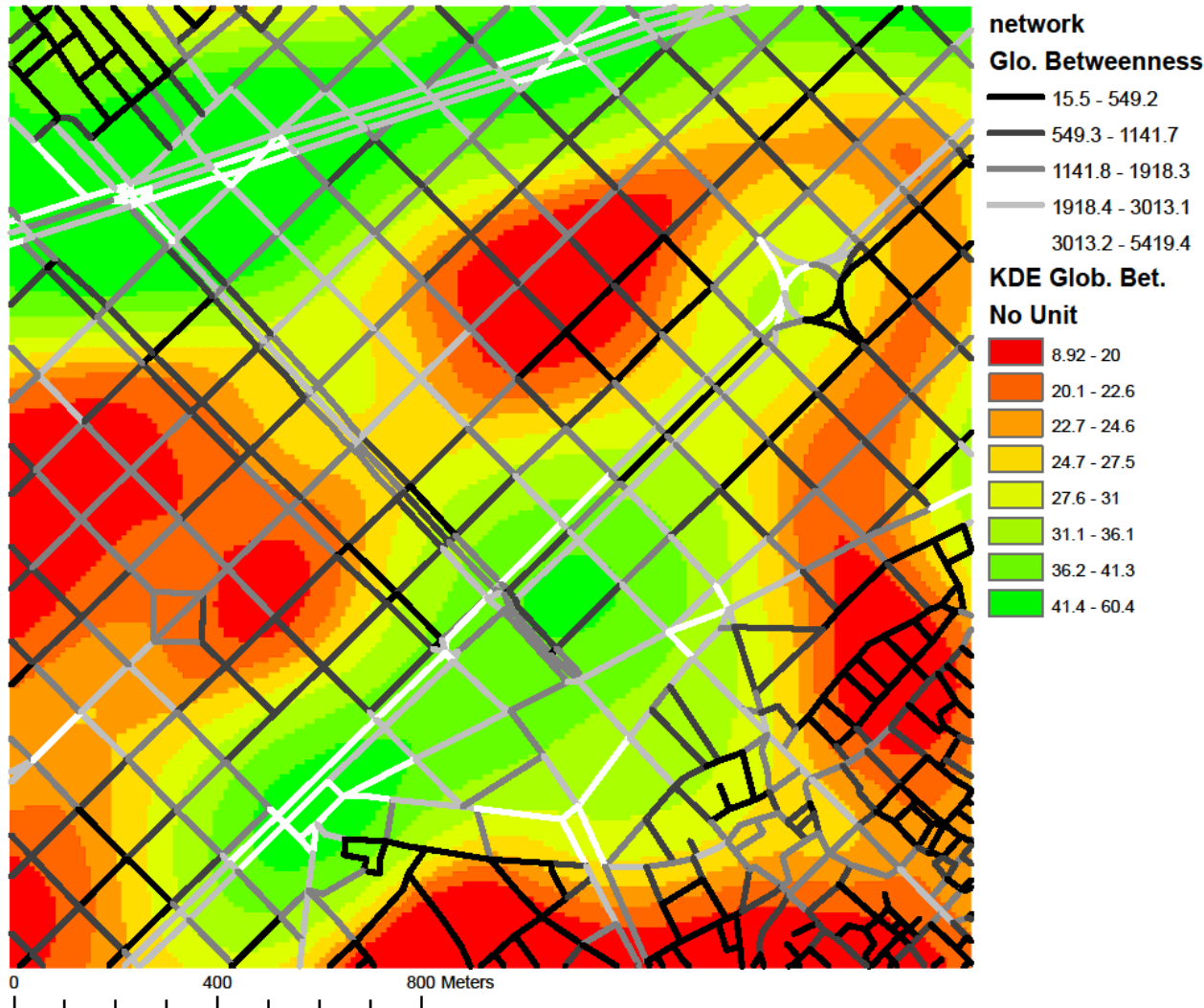
# NetKDE of activities



Kernel formula  
applied to activities  
projected on the  
network,

Smaller patterns

# KDE of global betweenness

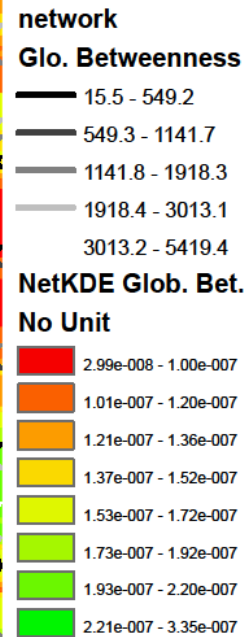
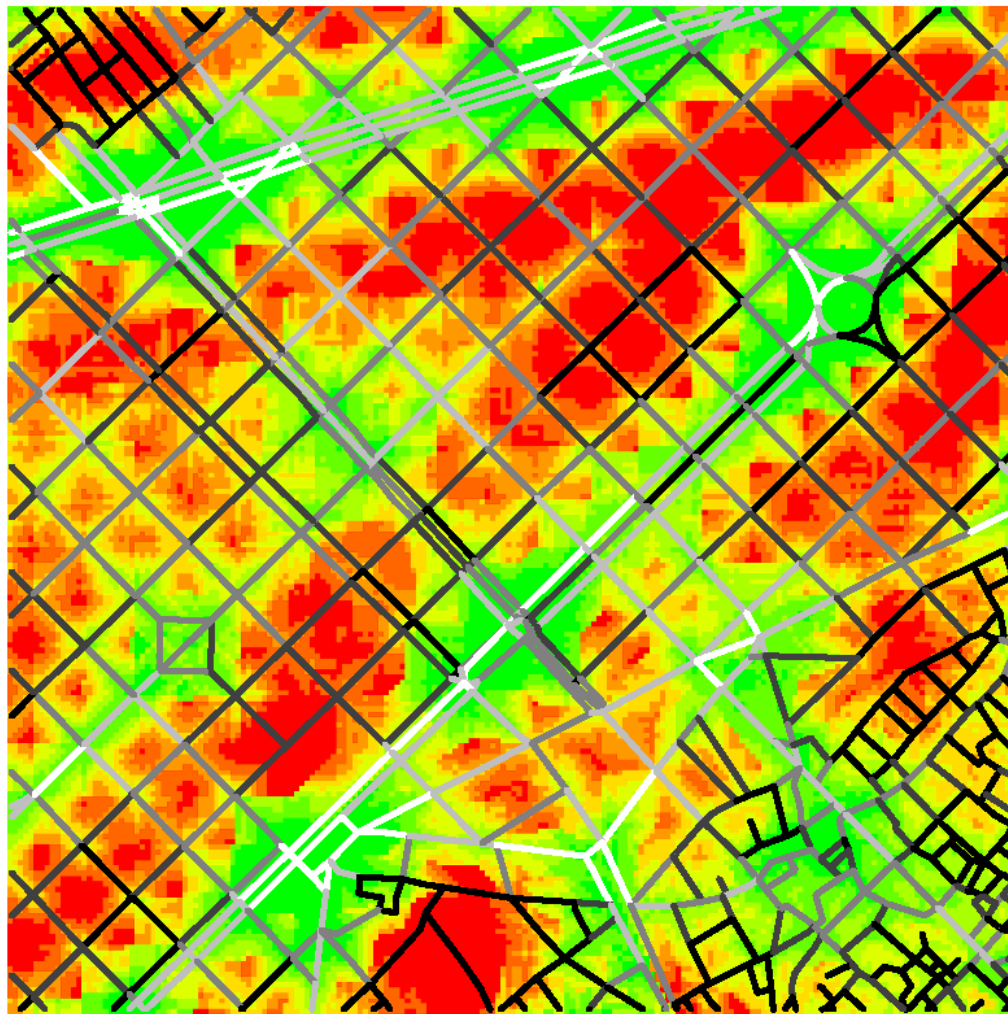


Global betweenness is an indicator characterizing the centrality of an edge.

Values of edges are generalized to the entire space.

Computed with ArcGIS.

# NetKDE of global betweenness



For NetKDE of edges, the inputs are the middle of edges and global betweenness.

# Conclusion

- This work proposes an innovative density indicator based on a road network, to better fit the urban constraints on human mobility.
- The processing using a PostGIS database is stable and fast.
- Here are presented the first evaluation of the results
- Current researches are related to:
  - Proofing NetKDE versus KDE (sensitivity and geostatistical analysis)
  - Correlation analysis between Activities and NetKDE centrality indicators
  - Research on other cities : Barcelona, Glasgow, Geneva, Bologna, Roma