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A Network Based Kernel Density Estimator Applied to Barcelona Economic Activities

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LaSIG

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Urban Design Studies Unit

Sergio Porta, Emanuele Strano

Fukuoka, ICCSA, March 2010

Plan

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

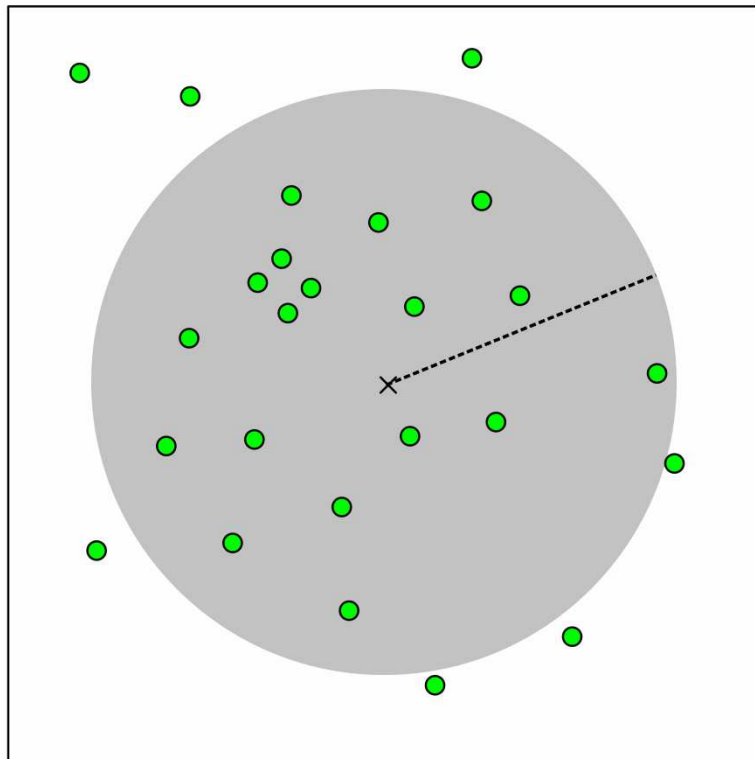
Goals

- 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

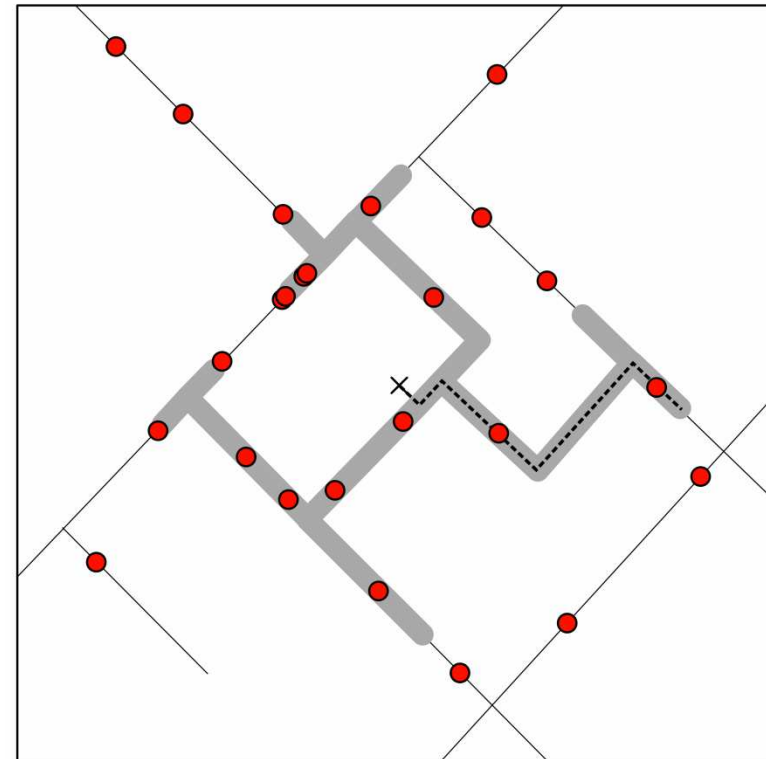
Theory

- **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

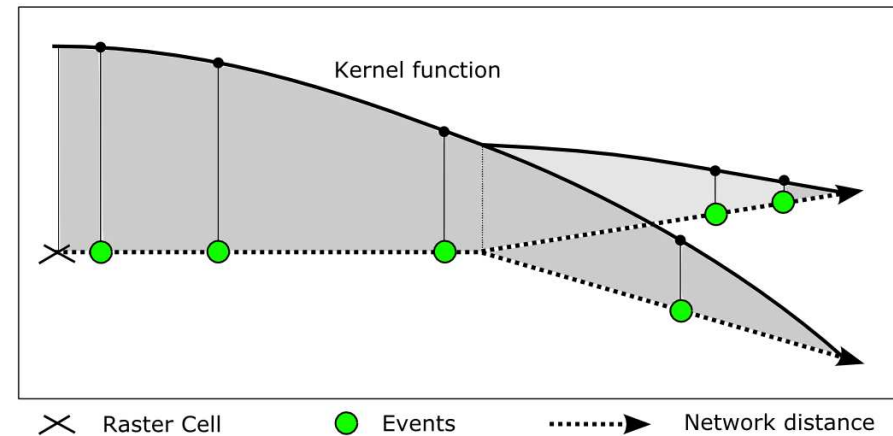
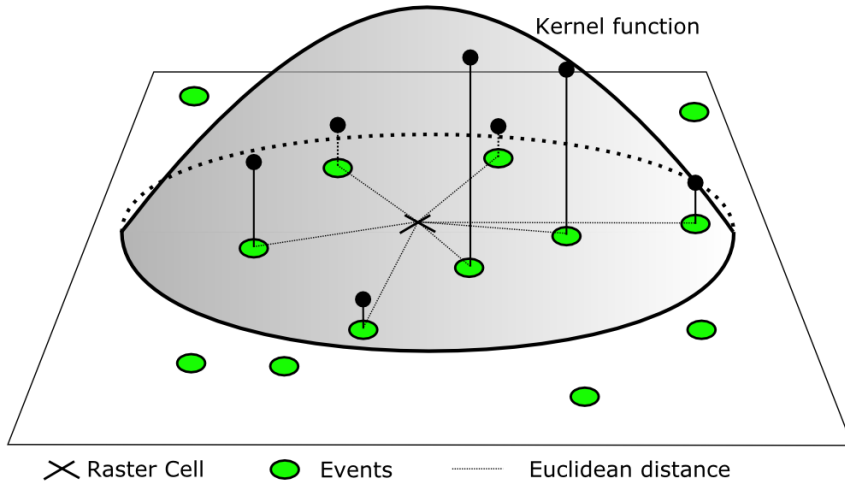


X Raster Cell ● Proj. event — Network
----- Bandwidth — Short. Path Tree

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



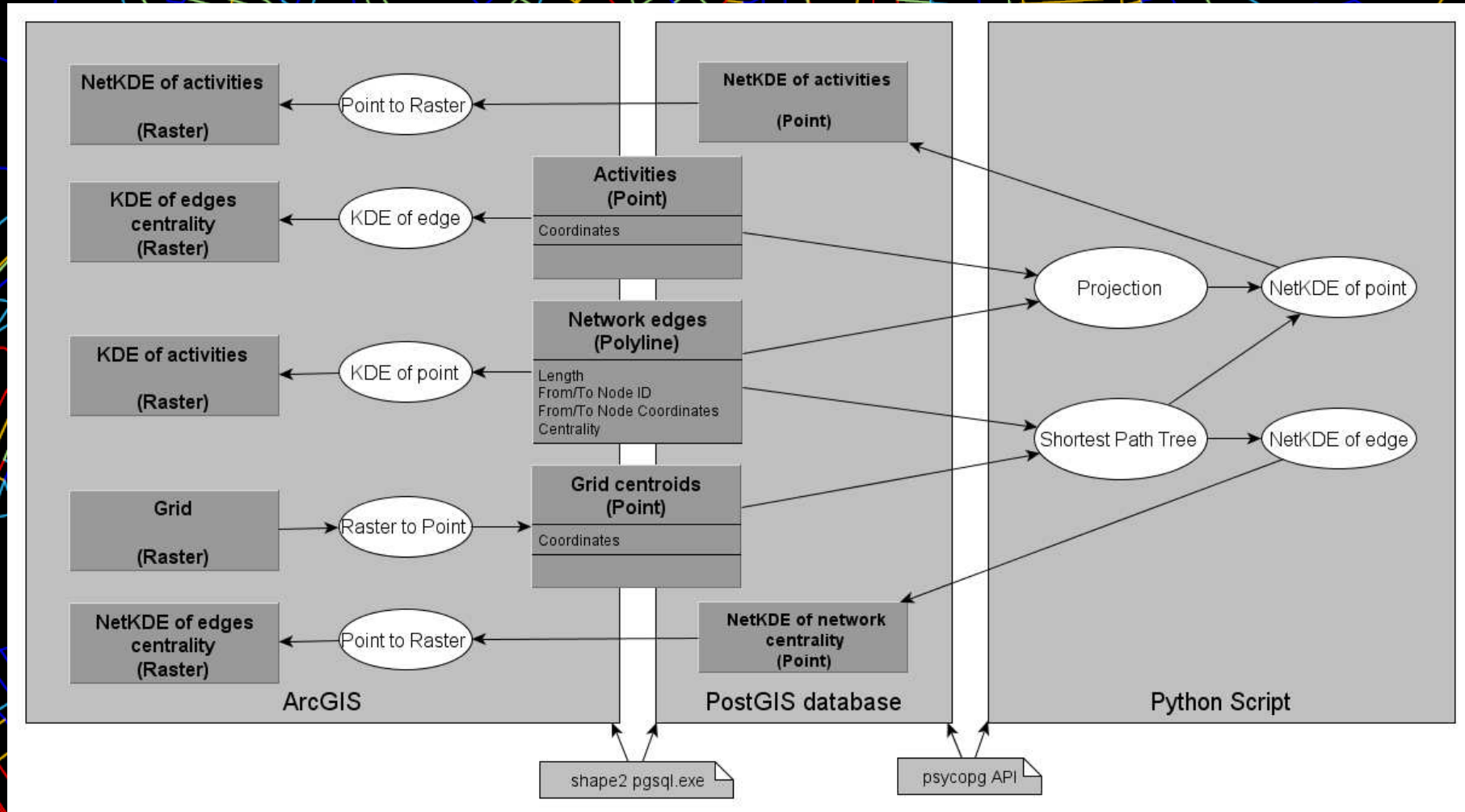
$$\hat{f}_h(x_j) = \sum_{i=1}^n \frac{1}{h^2} K\left(\frac{x_j - x_i}{h}\right)$$

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

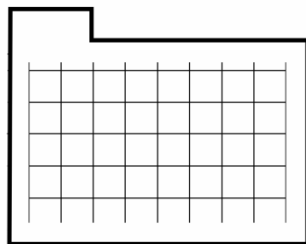
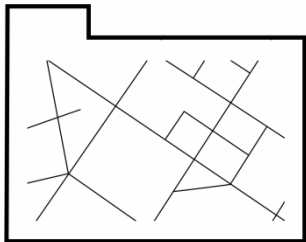
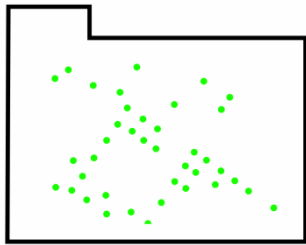
KDE: The Kernel function weights events according to their radial distance

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

Methodology



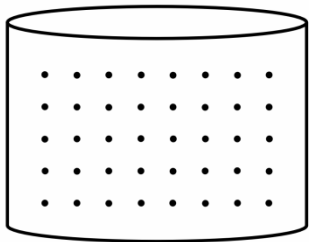
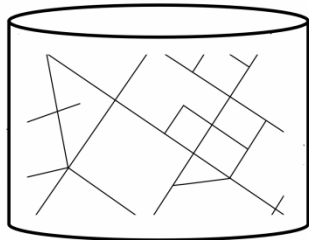
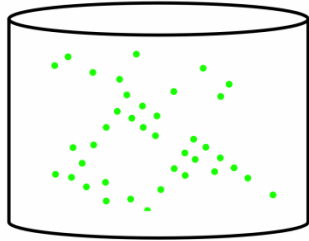
Input data



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

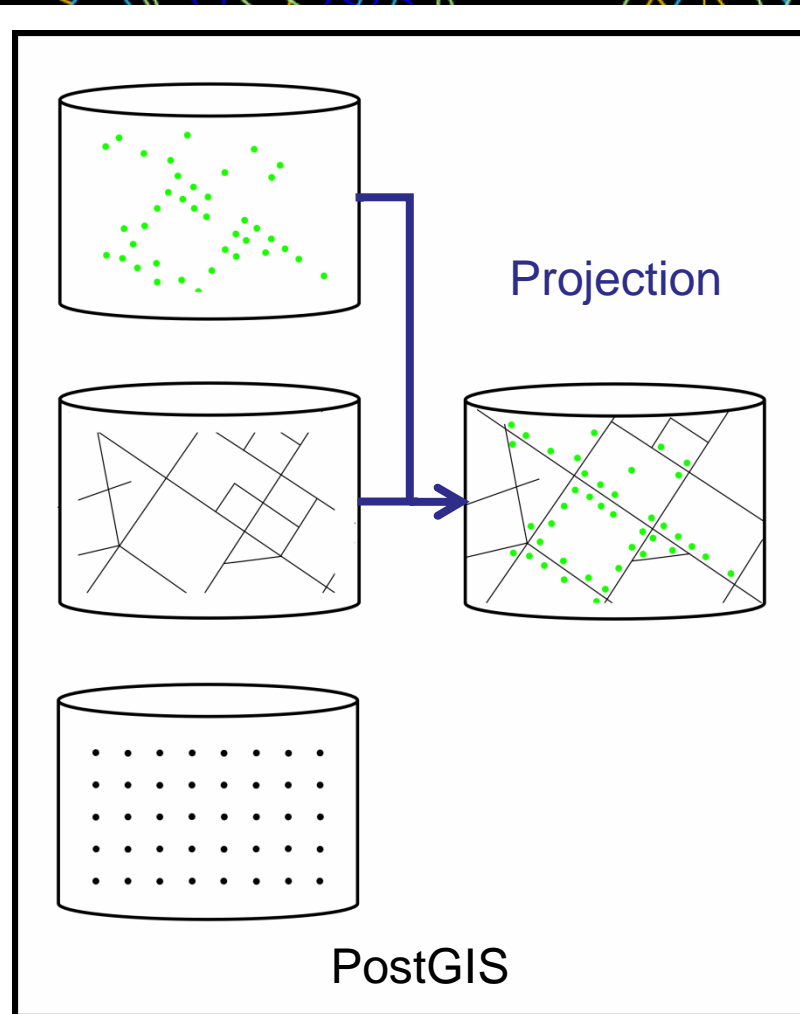
Conversion



PostGIS

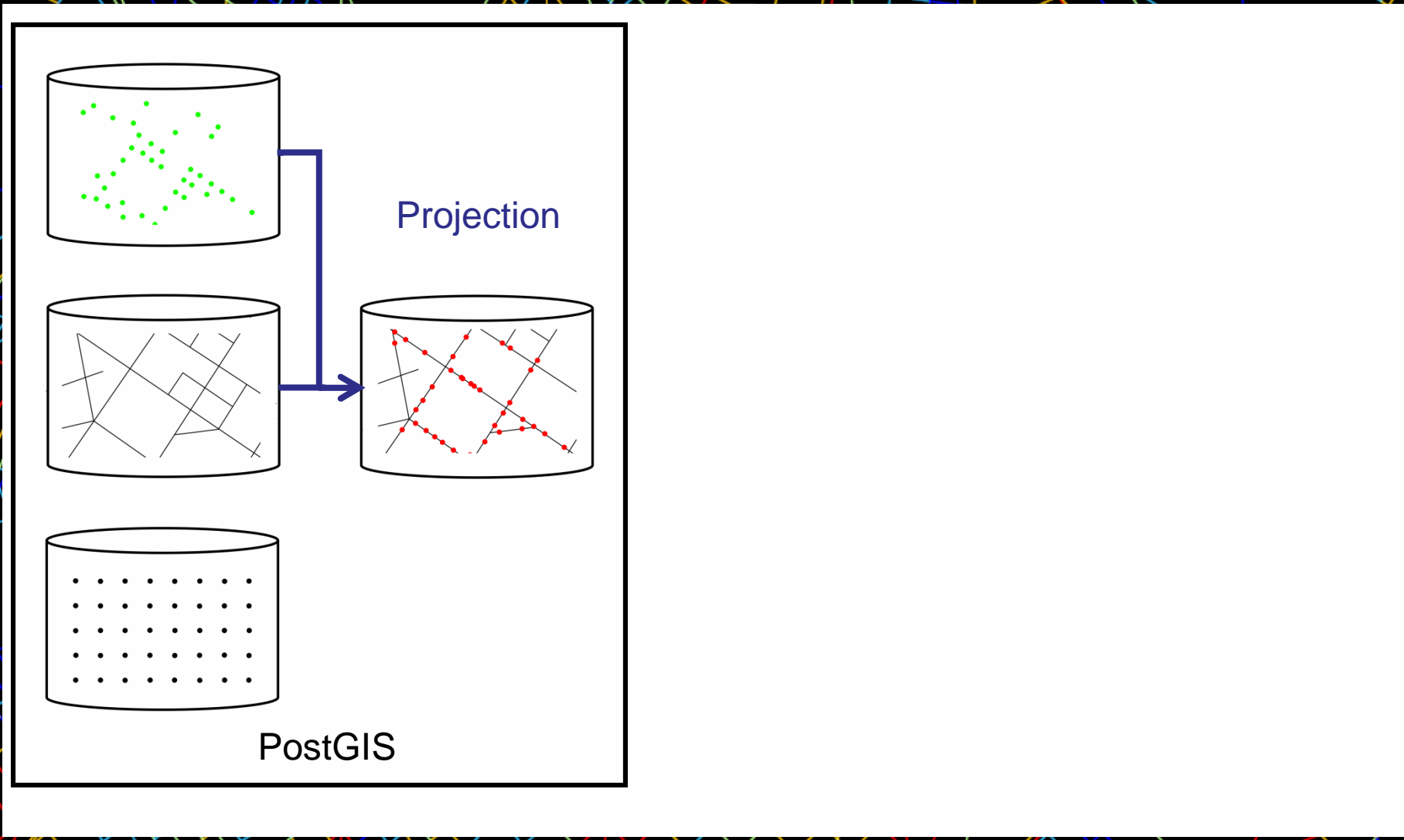
- » Files are exported into a PostGIS database
- » The raster grid is converted into points

Activities projection

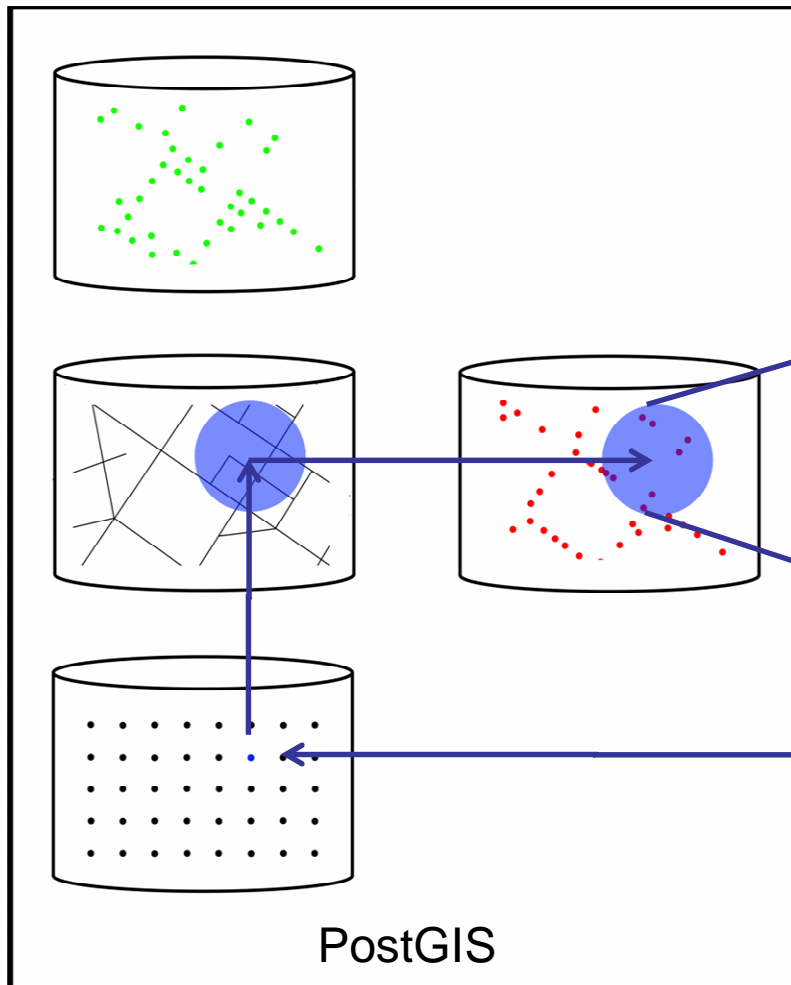


- » Activities are projected on the nearest edge

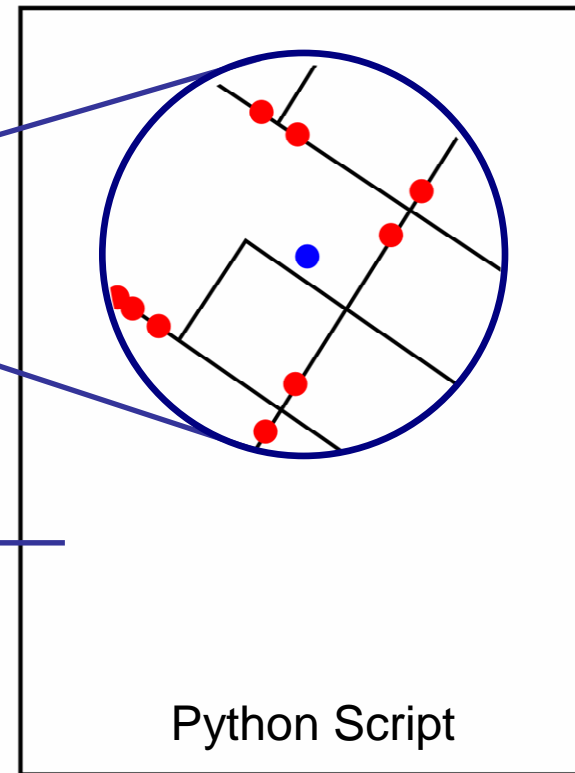
Activities projection



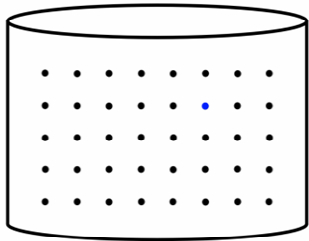
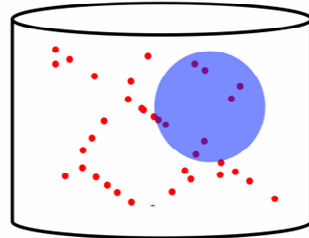
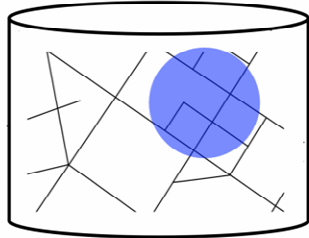
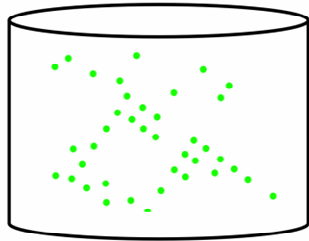
Calculation



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

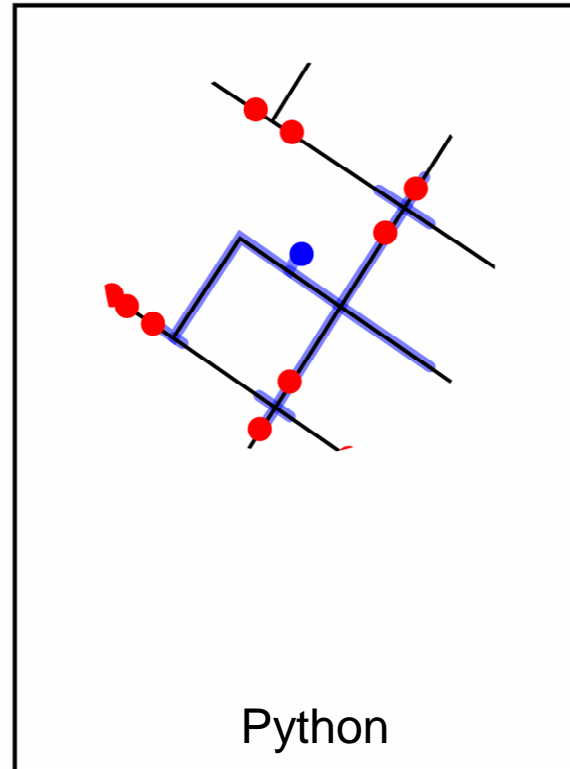


Calculation



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**

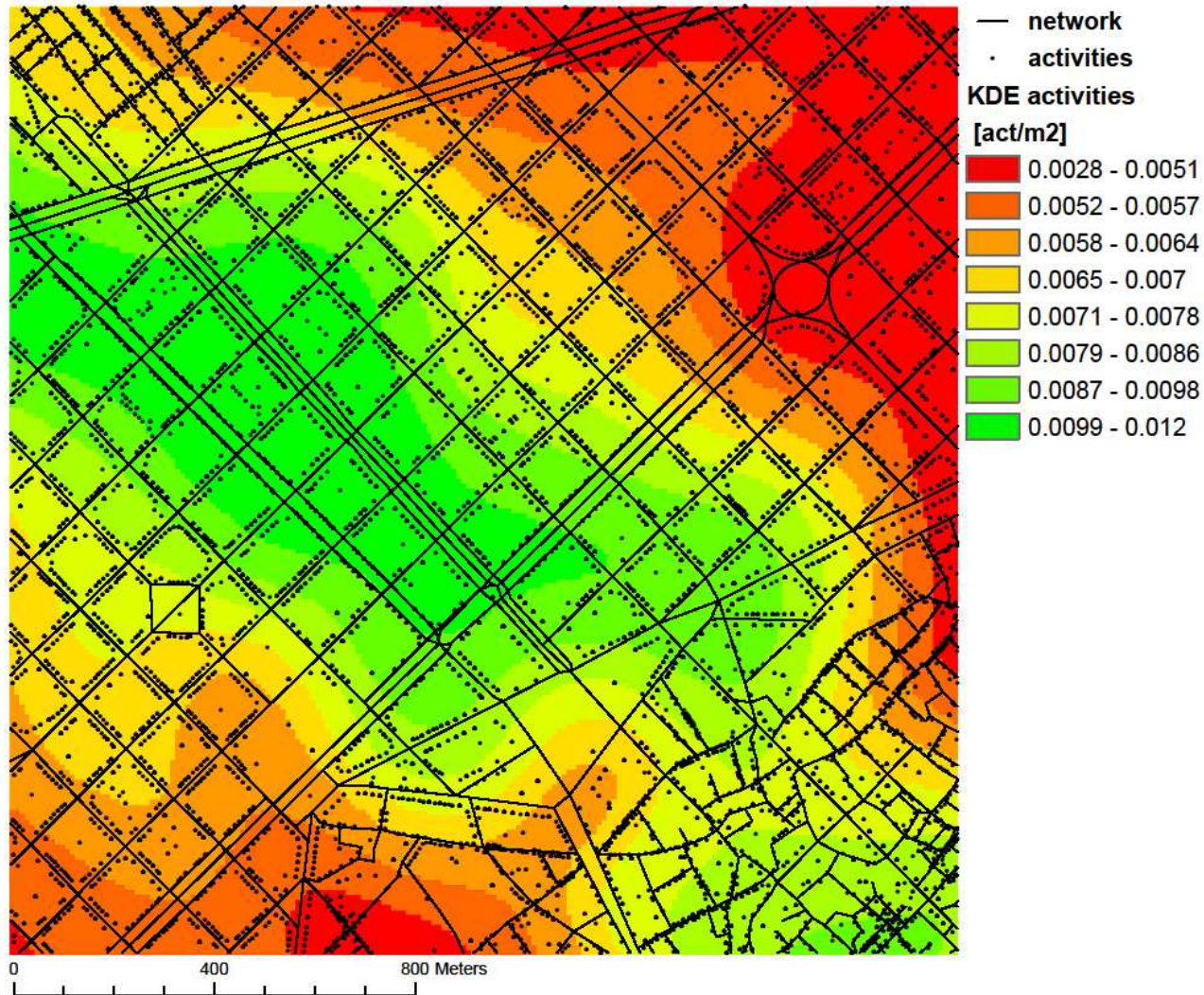
- **Network:** 11,000 edges
- **Activities:** 166,000 economic activities listed by the *Agencia de Ecologia Urbana* in 2002

- **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

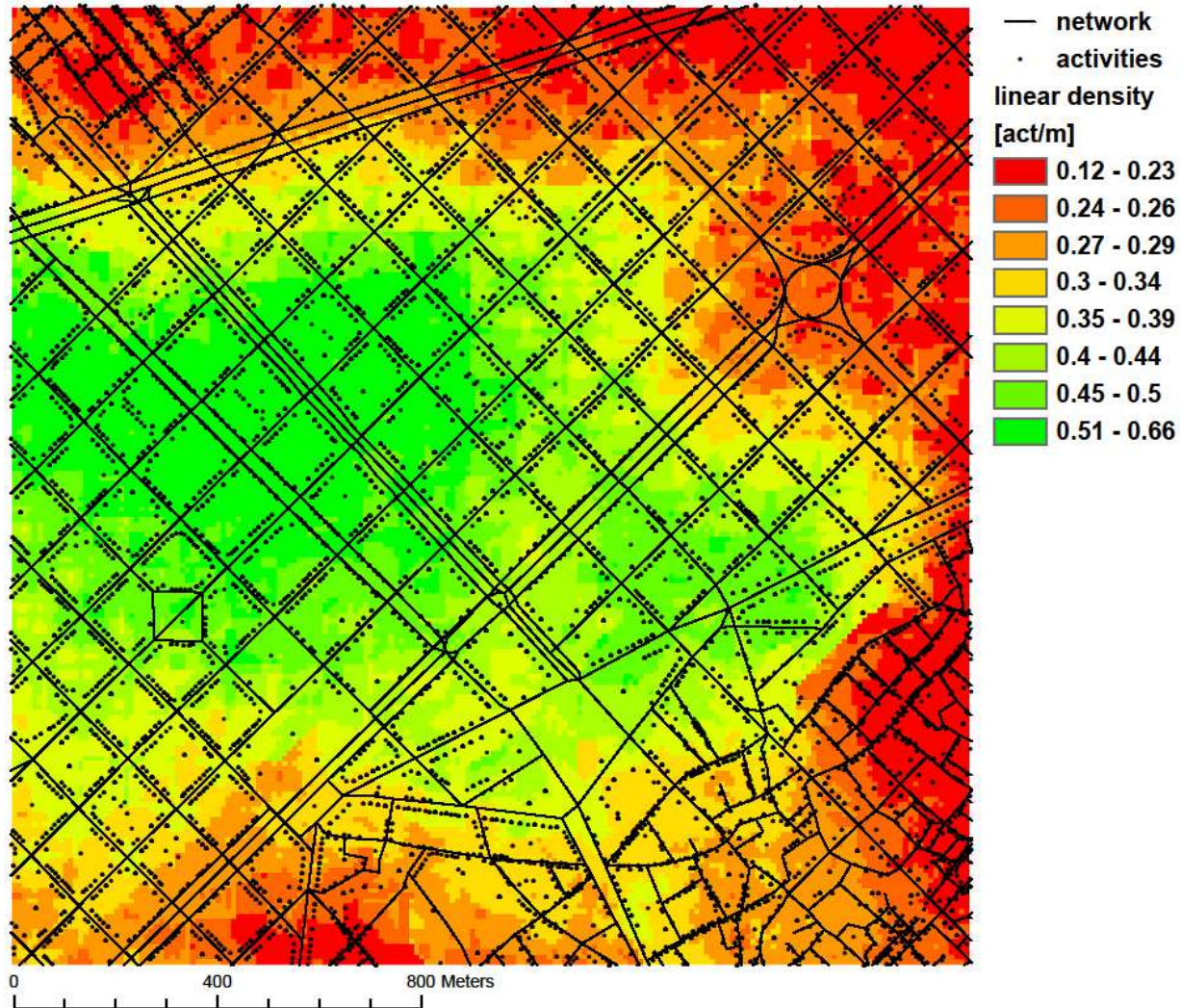


Several activities
can be located at
the same place

Bandwith = 400m

Computed with
ArcGIS

Linear Density

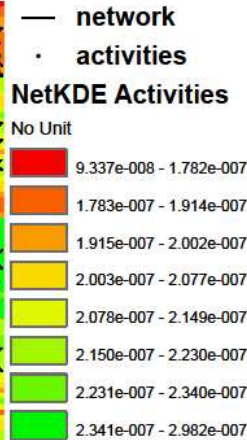
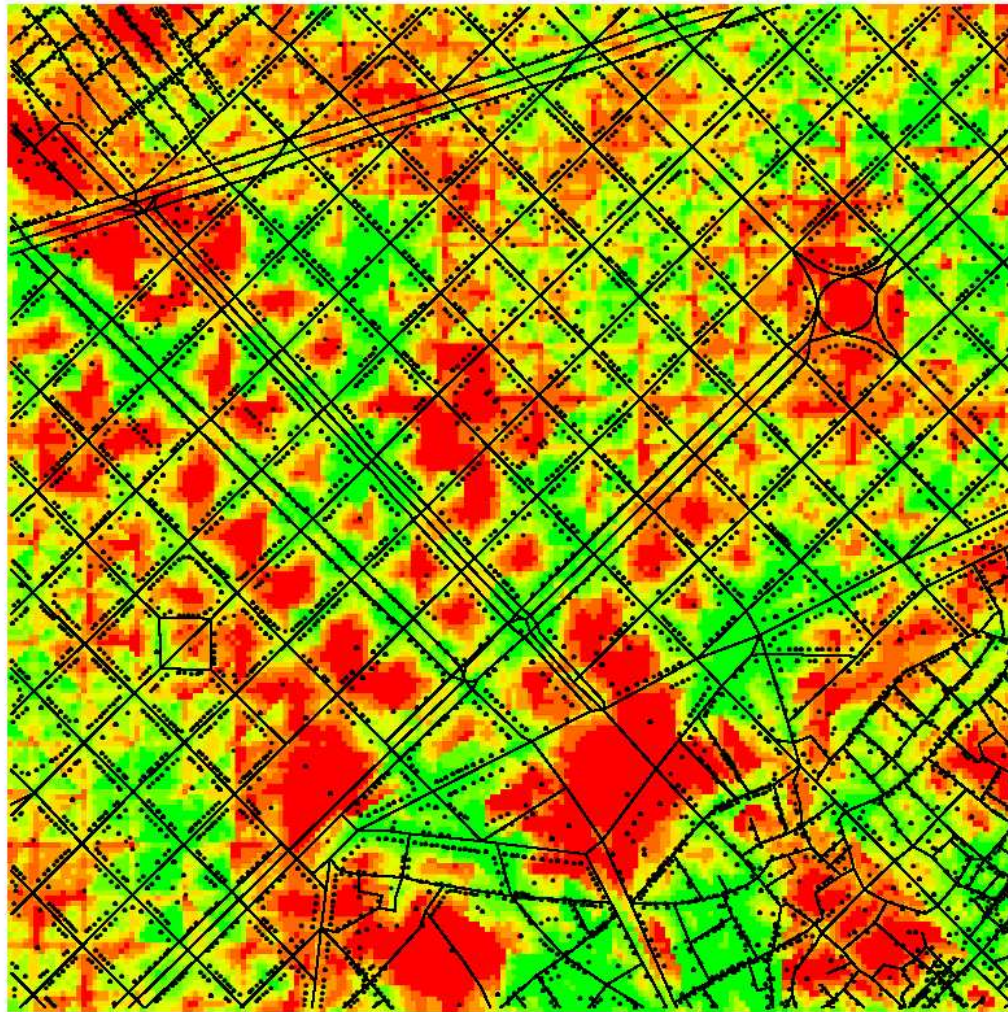


Linear density of activities =

Nbr. Act./ Length of SPT

Same scale

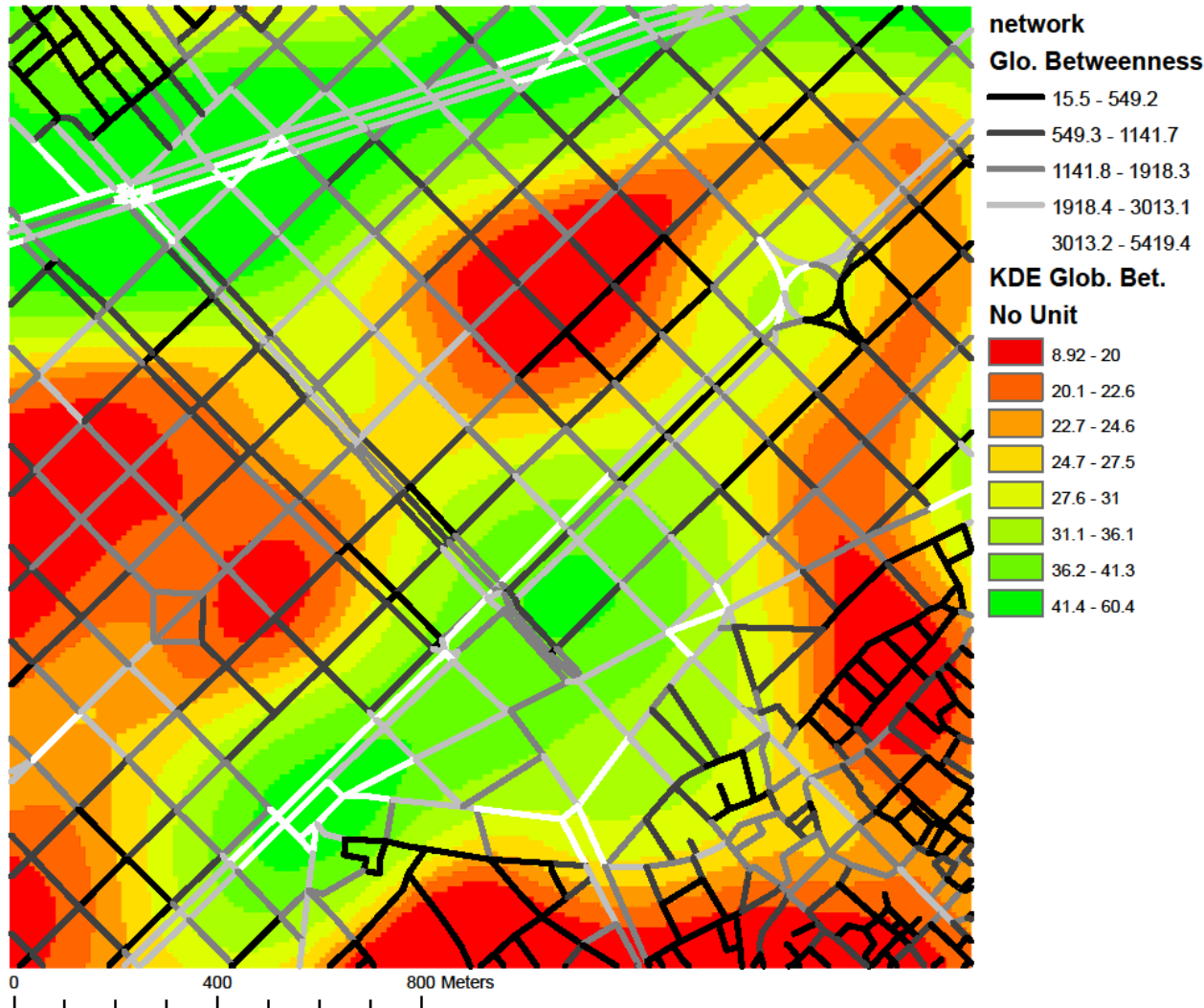
NetKDE of activities



Kernel formula
applied to activities
projected on the
network,

Smaller patterns

KDE of global betweenness

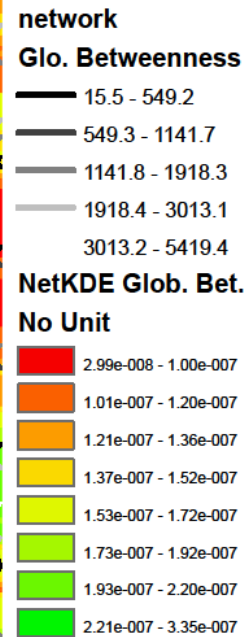
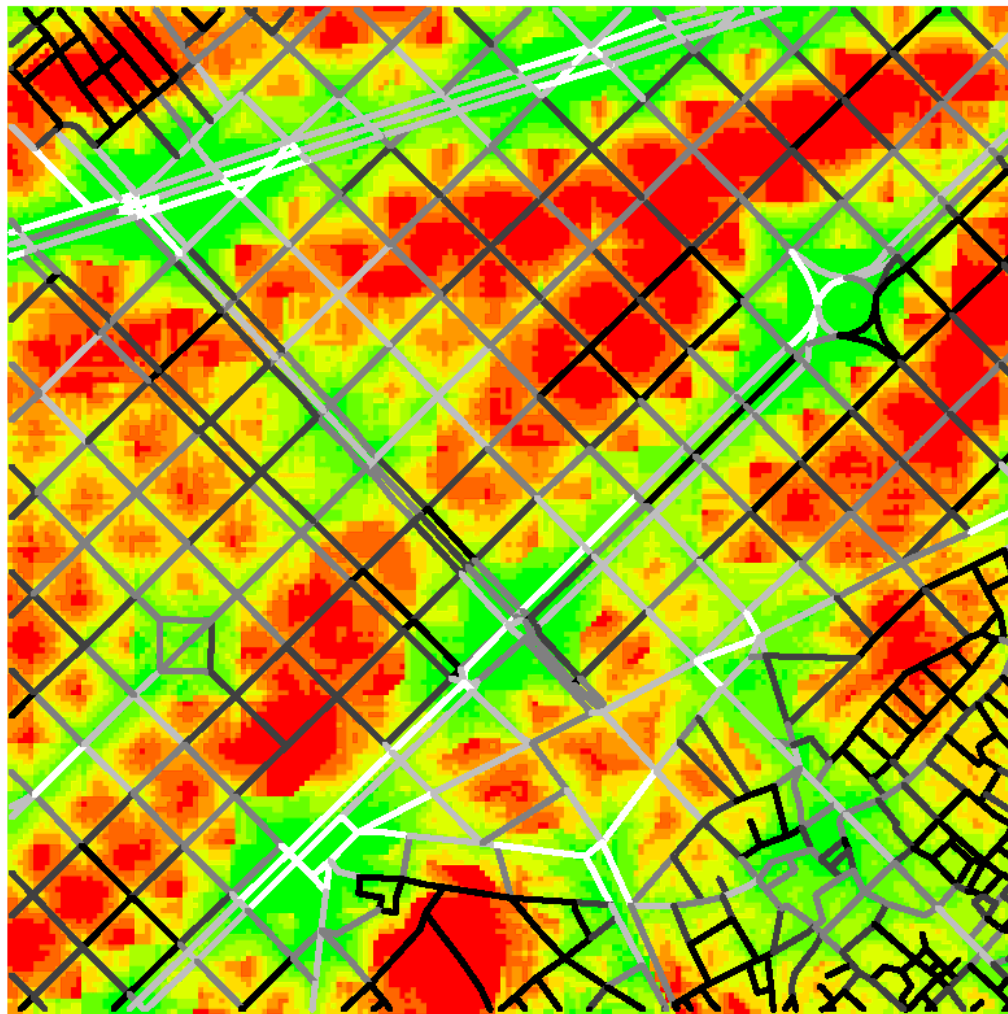


Global betweenness is an indicator characterizing the centrality of an edge.

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