

Exploring City Structure from Georeferenced Photos Using Graph Centrality Measures

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Photo sharing websites, such as Panoramio and Flickr, compose a large, free data source. The shared photographs are time- and geo-referenced making it possible to regard users' postings as sequences of visited places over time and treat them as trajectories of their movement.

Visual analytics approach

We propose a visual analytics approach for exploring movement patterns of people in a city and the structure of the city itself. The approach involves:

1. Extraction of trajectories from the sequence of photographed places.
2. Aggregation of trajectories into a graph of moves (edges) between generalized places (vertices).
3. Computation of centrality scores for each vertex (place) of the graph of aggregated moves.
4. Interactive visual analysis of the graph's structural connectivity.



Fig.1: Example of a trajectory created by a sequence of captured photographs across Athens, Greece. (Photographs are downloaded from Flickr)

Aggregation

1. Characteristic points are extracted from trajectories.
2. Spatially bounded density based clustering of the points.
3. Cluster centroids are used for generating Voronoi polygons; the generalized places.
4. Trajectories are aggregated into moves between polygon (place) pairs.



Fig.2: Example of a graph of aggregated moves between places in the centre of Athens, Greece.

Graph of Moves and Place Centrality

The aggregation results are represented using a directed, weighted graph with vertices being the set of extracted places and edges the moves between places weighted by the number of transitions present. The centrality scores computed for each place (vertex) are:

1. Degree centrality (in- & out-, weighted in- & out-degree)
2. Closeness centrality
3. Betweenness centrality
4. Clustering coefficient

Visual analysis of results using:

- Choropleth maps
- Diagrams
- Parallel coordinates
- Time graphs
- Filtering
- Clustering



Fig.3: Choropleth map depicting in-degree per place in Athens, Greece. In-degree reflects the number of visits per place. The central areas of Athens, the harbours (Piraeus, Rafina) and cape Sounio have high in-degree.

Aggregation of trajectories can be performed by arbitrary time intervals making it possible to explore centrality over time.

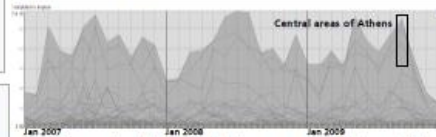


Fig.4: Time graph of the weighted in-degree per month of places in Athens, Greece showing various monthly peaks. Each line represents a distinct place, the lines with highest values correspond to the most central places of Athens.

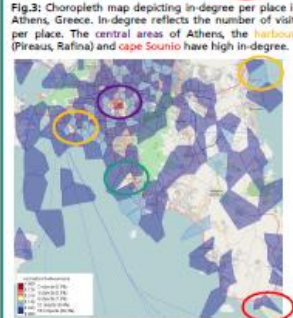


Fig.5: Choropleth map depicting betweenness centrality per place in Athens, Greece. The measure reflects the number of shortest paths passing through a place. The central areas of Athens, the harbours, cape Sounio, and the shopping area of Glyfada seem to be places that are included on most peoples routes.



Fig.6: Choropleth map depicting closeness centrality per place in Athens, Greece. Closeness measures the distance of a place to all others and reflects how well connected a place is. The central areas of Athens, the harbours (Piraeus, Rafina, Lavrion), airport, cape Sounio, the Athens Riviera and the Olympic stadium are all areas with high closeness.

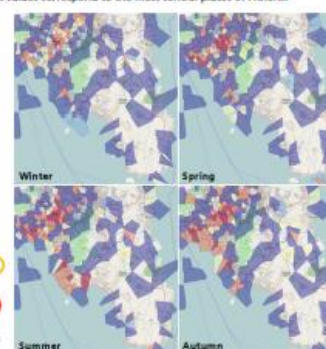


Fig.7: Choropleth maps showing closeness centrality per season of places in Athens, Greece. The images reveal clear seasonal variation especially in the coast areas around Athens.

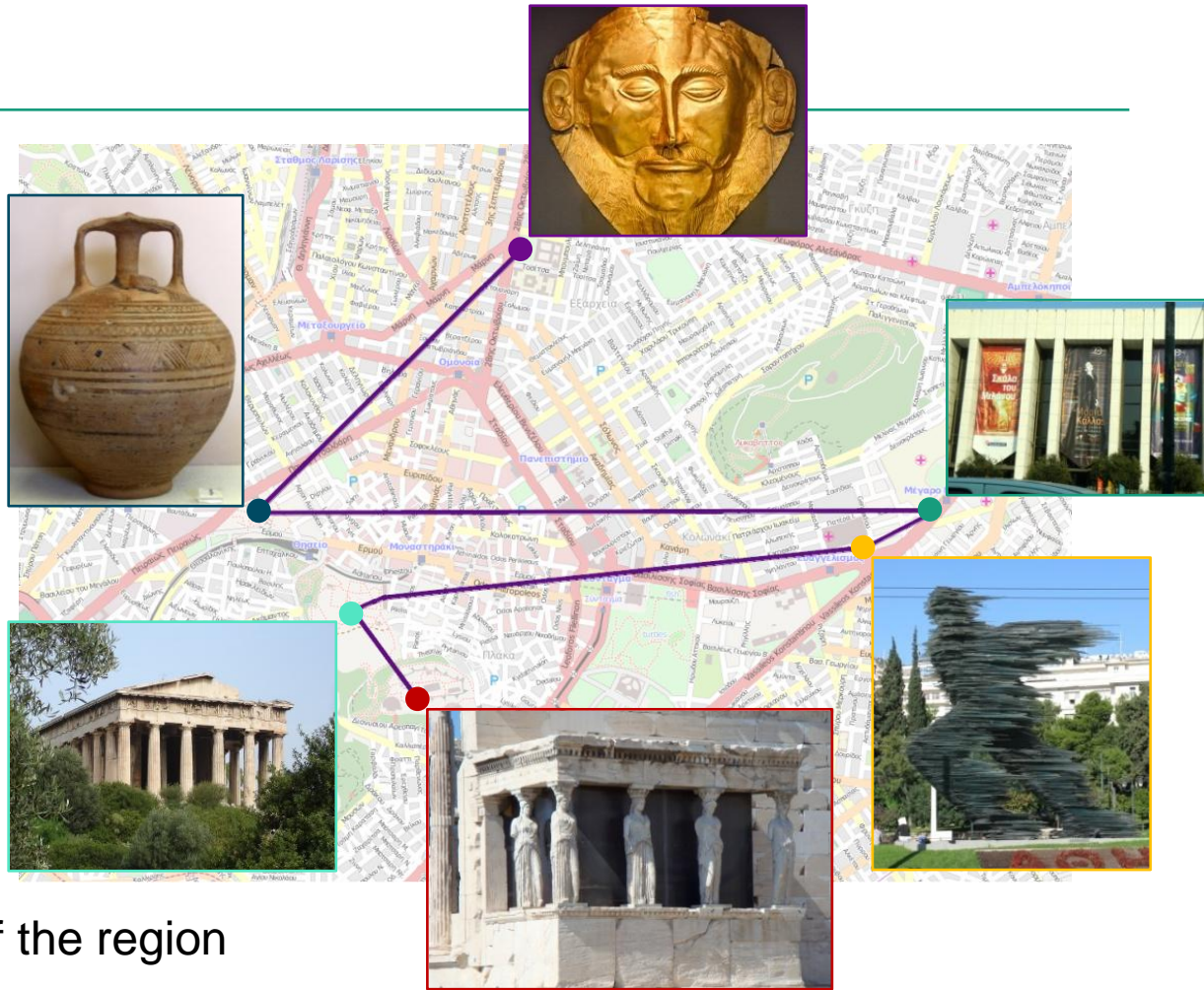
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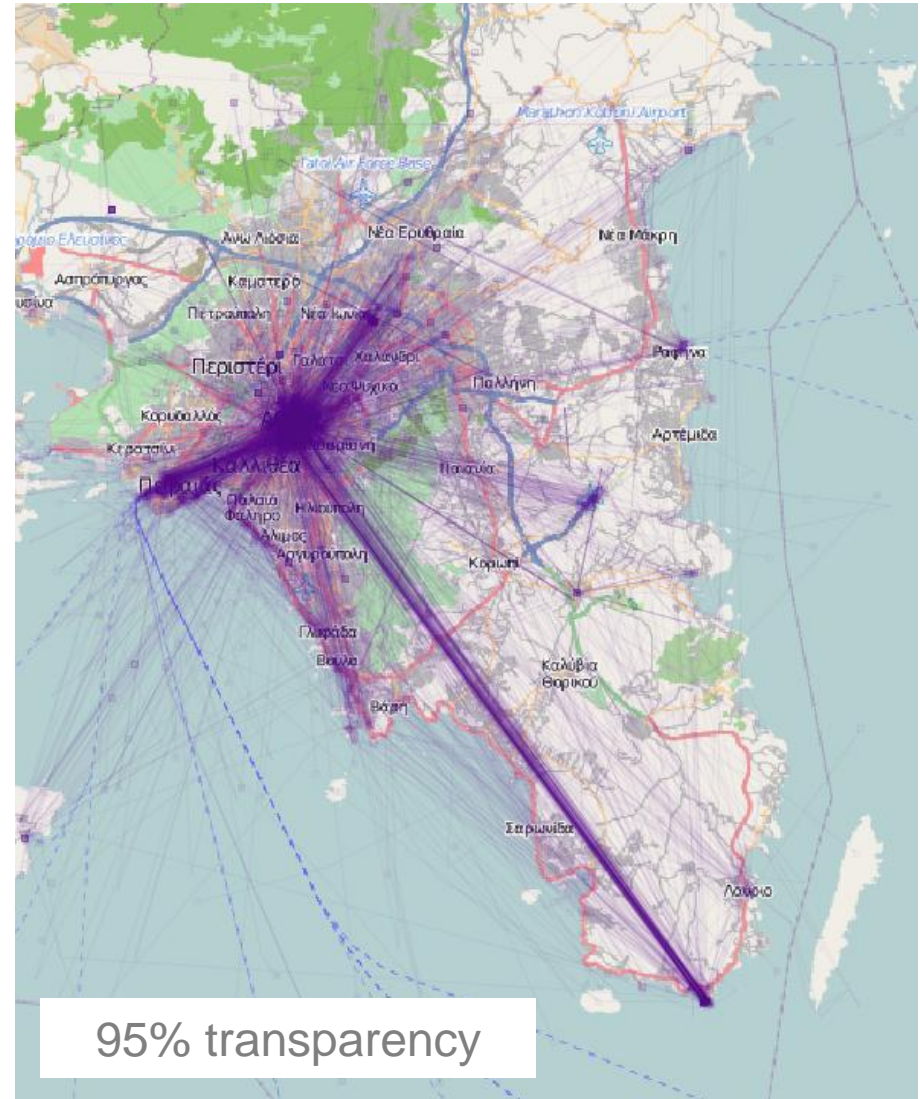
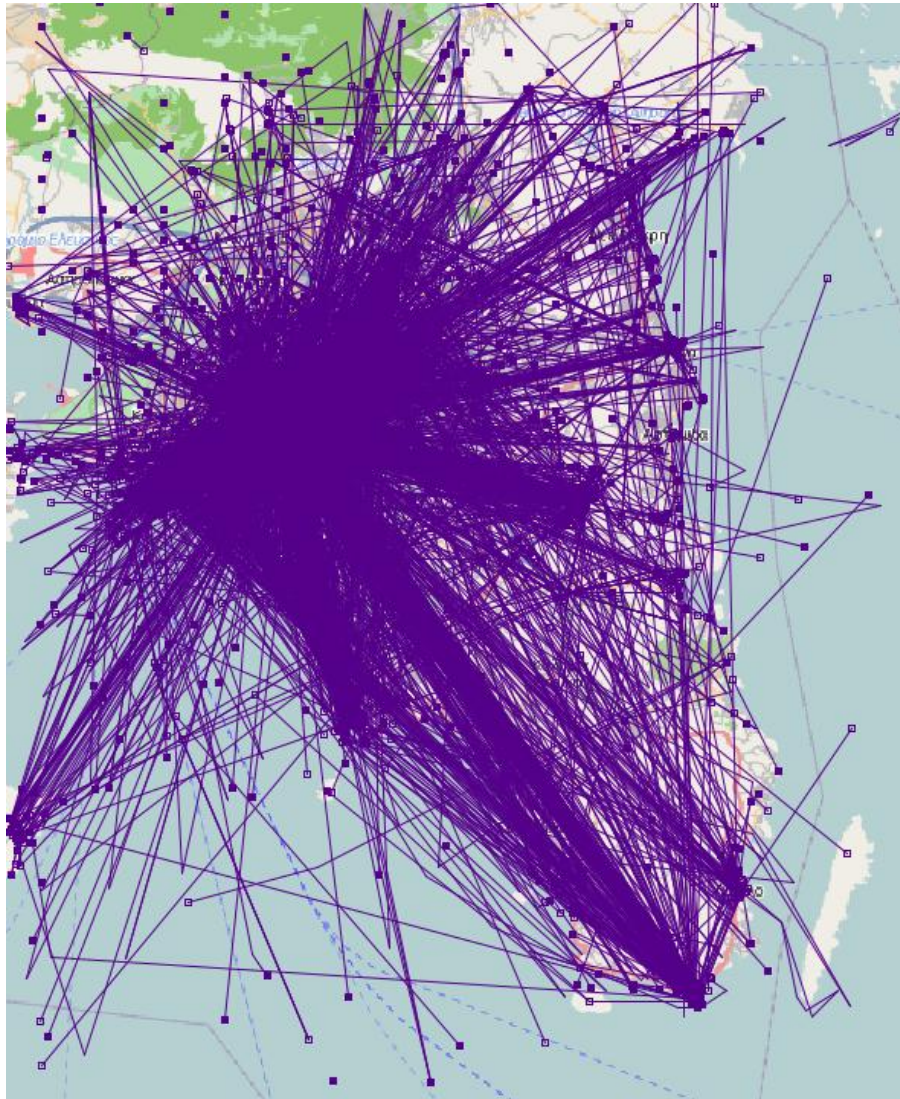
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Geo-temporally referenced photos

- Photo-sharing websites
- Large free data source
- Photographs
 - Time- and geo-referenced
 - Photographer ID
 - Trajectories
- Browse photo-activity of a region over time
- Explore the spatio-temporal characteristics of the region

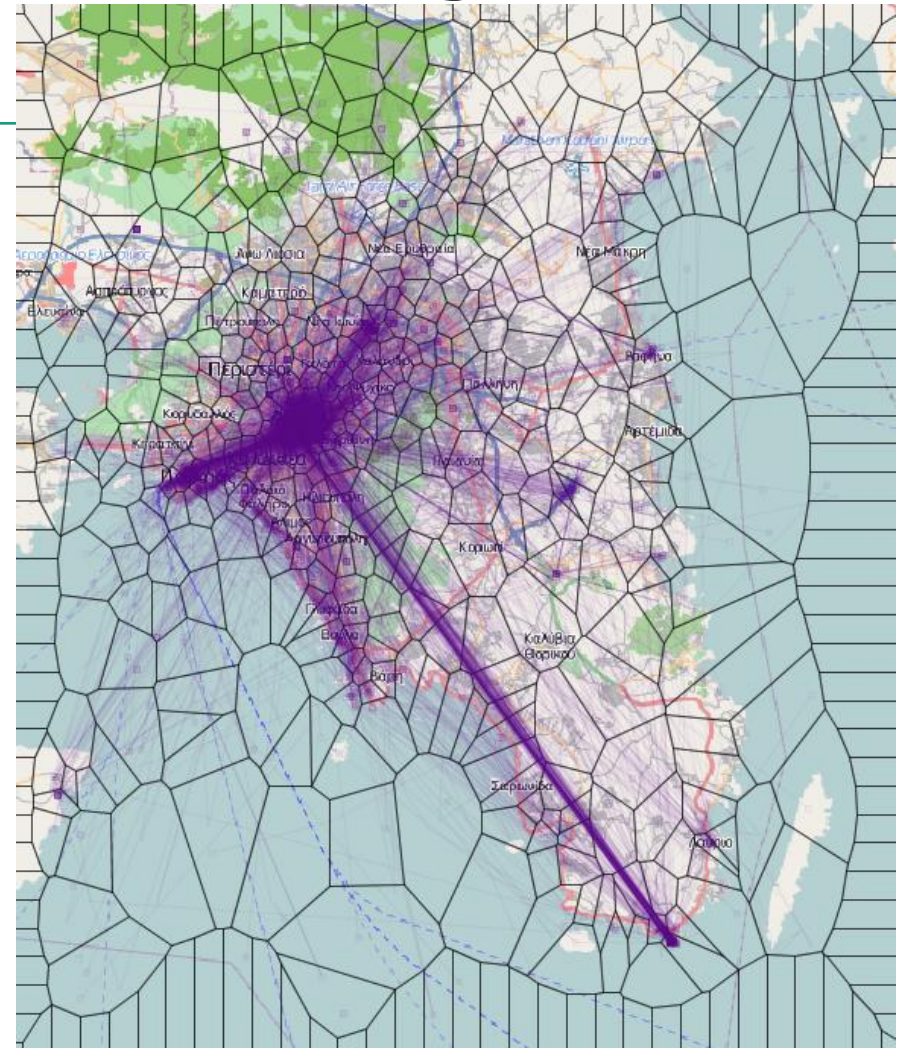


Trajectories from sequences of photographed places

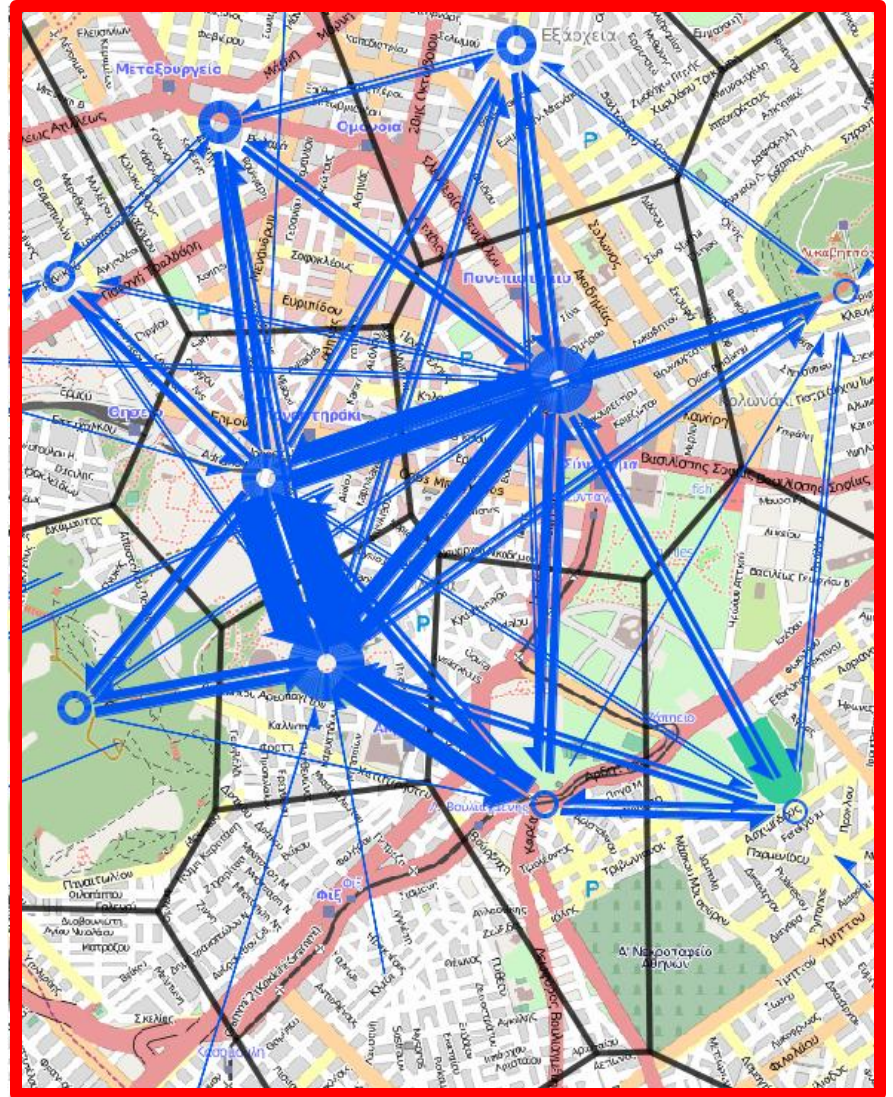
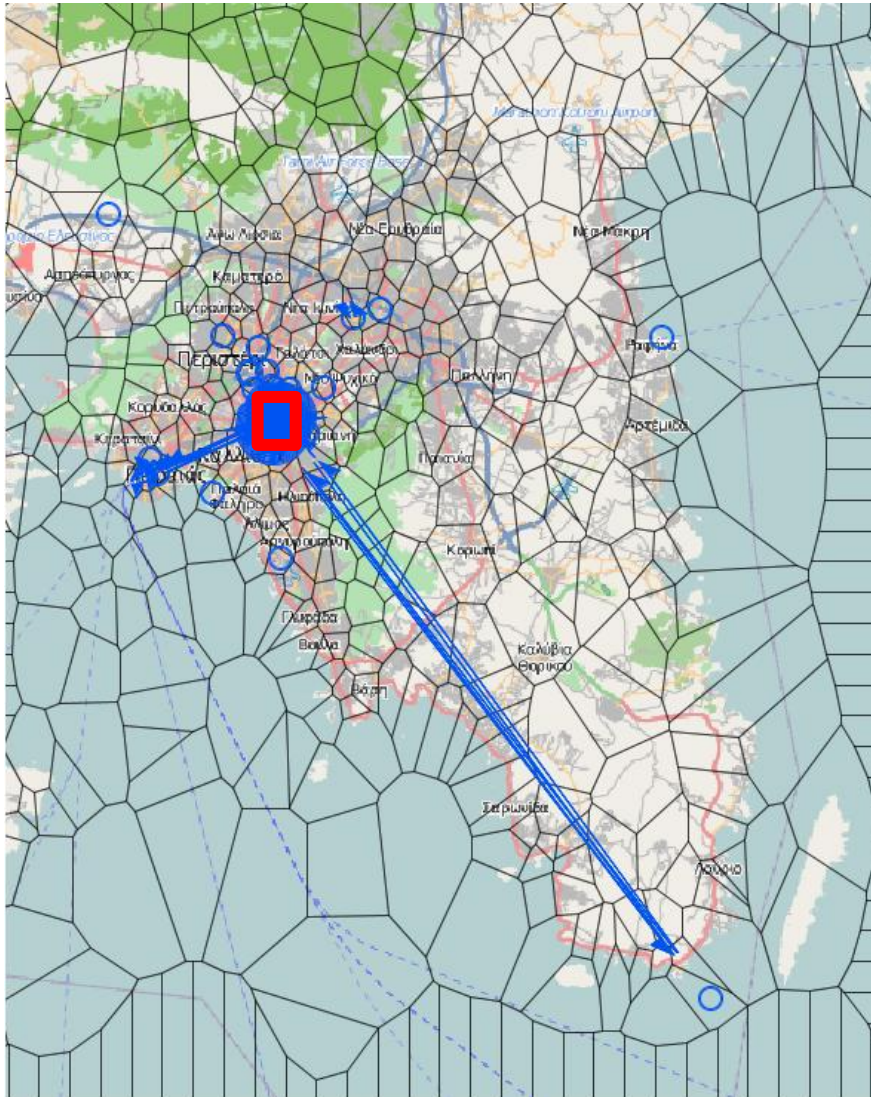


Aggregation of trajectories into graph

- Characteristic points extracted from trajectories
- Spatially bounded density based clustering
- Voronoi polygons
- Moves between polygons



Aggregate trajectories to graph of moves between places



Graph of movements between places

- Graph centrality scores for each node
 - Degree centrality
 - In-/Out-degree
 - Weighted in-/out-degree
 - Closeness
 - Betweenness
 - Clustering coefficient

Interactive exploration of city structure

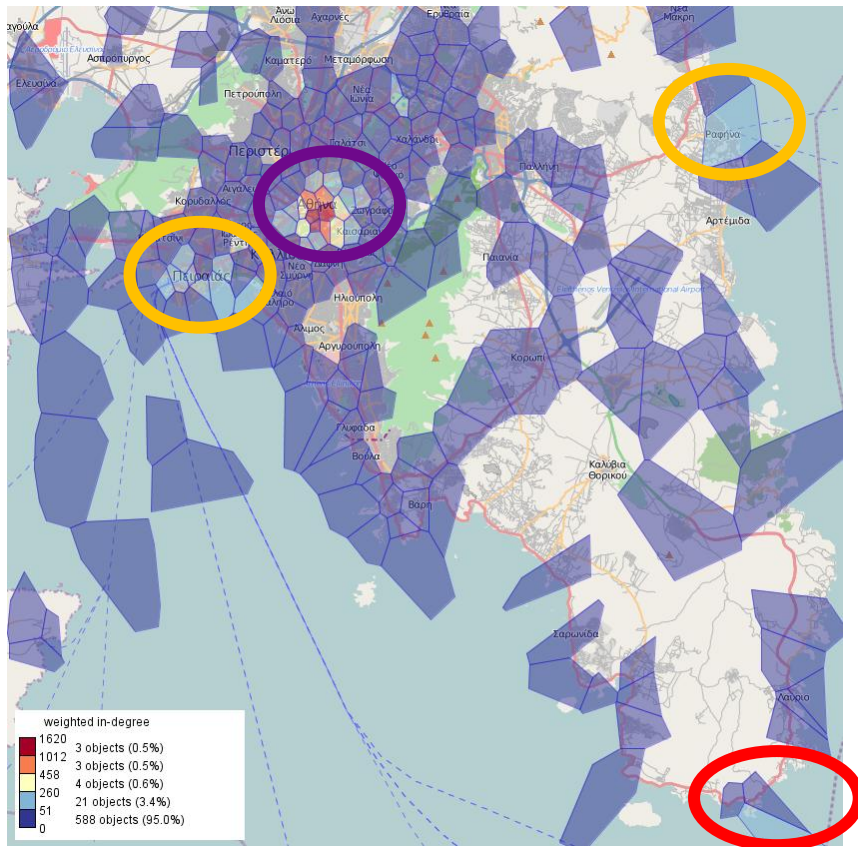


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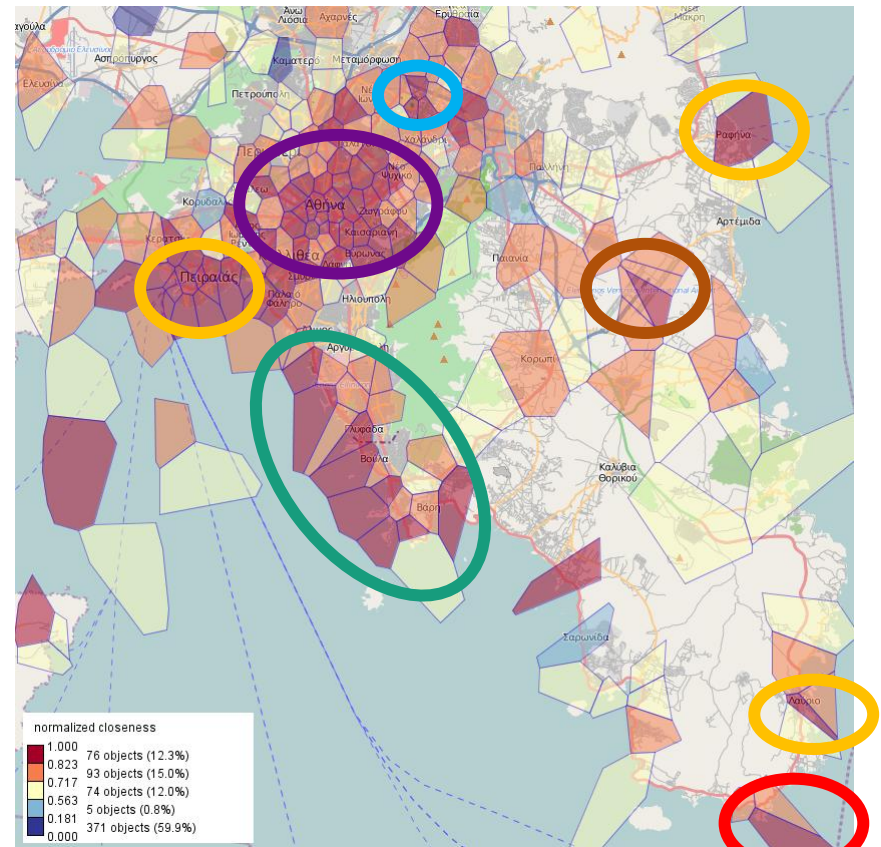
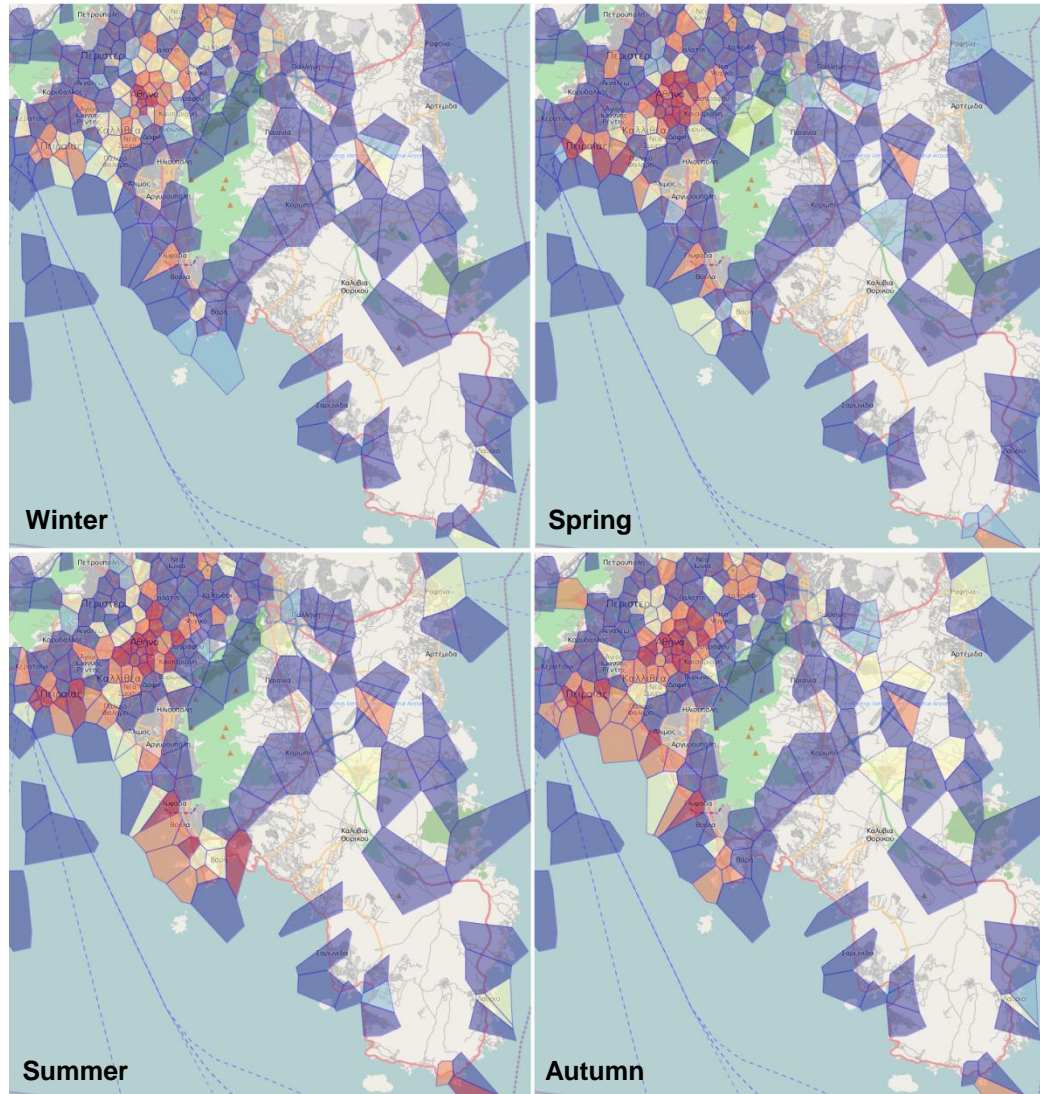


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Interactive exploration of city structure



Interactive exploration of city structure

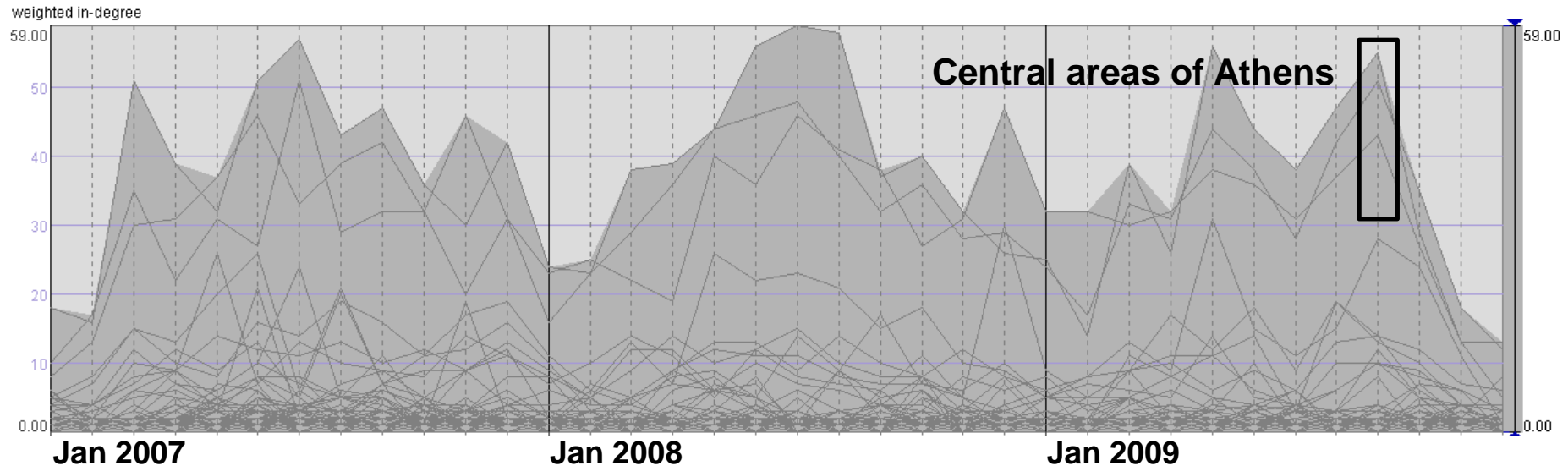


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Thank you!

