Effect of Physical Constraints on Spatial Connectivity in Urban Areas

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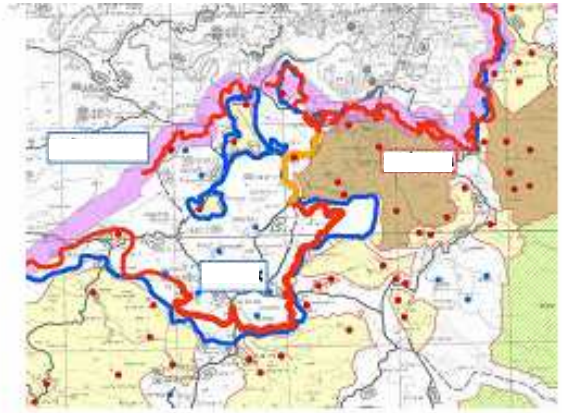
Motivation

- Wide variety of spatial constraints
- Influence connectivity among objects
- Spatial constraints affect our perception of space

Influence of Physical Constraints

Physical entities

Boundaries



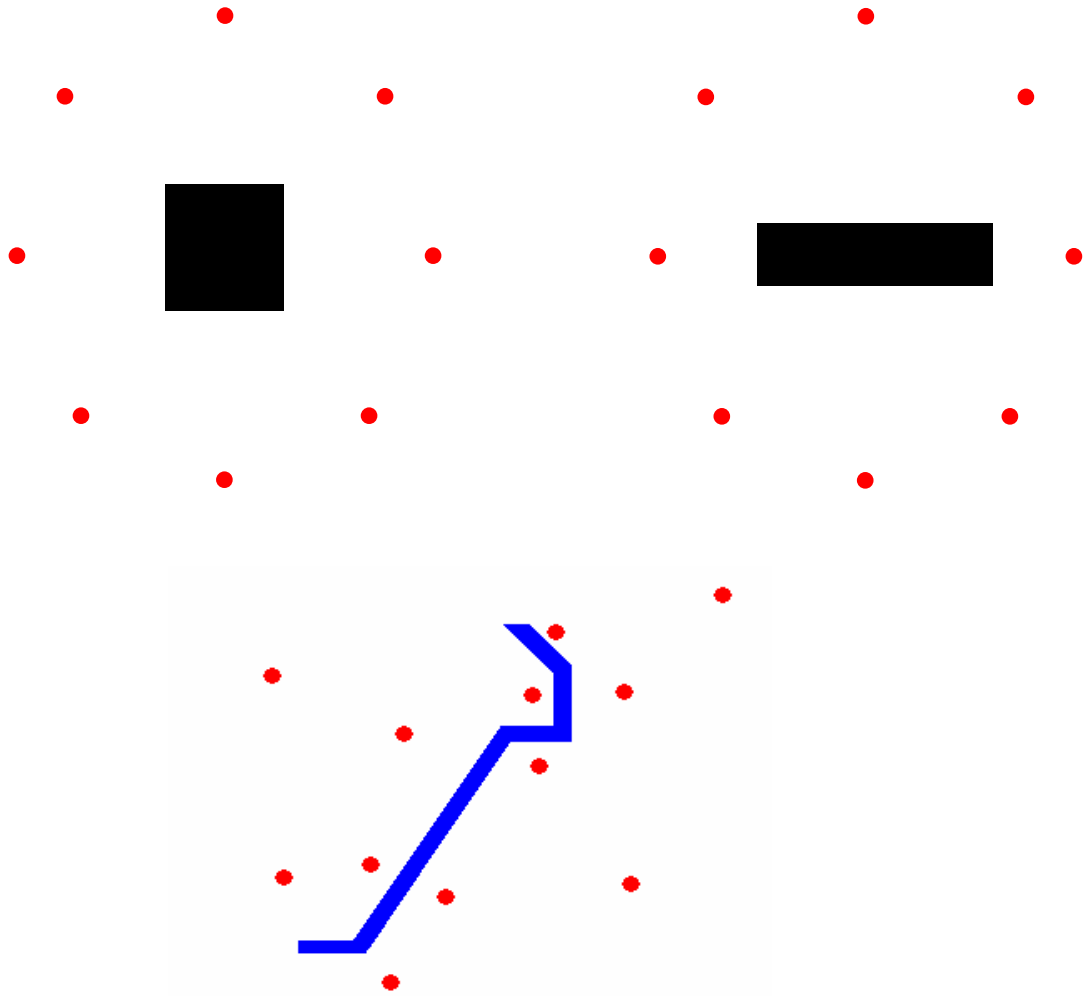
Accidents

Motivation

- Obstacles have direct influence on space
- Obstacles integration wears many forms:
  - Data aggregation, geographic patterns
  - Data interpretation, prediction

Question – how can their effect be quantified

Ranking the effect of obstacles



Objectives

- **Derivation of measures for physical constraints effect**
  - Ranking influence of physical constraints
- **Influence of facilitators - crossings**
- **More complete description of space**
  - Data summary
- **Learn how obstacle effect can be measured**
- **What these measures consist of**

Outline

- Introduction √
- Type of constraints
- Obstruction indices
- Derivation of measures
- Demonstration

Type of Constraints

- *Object constraints* – selection of a subset based on attributes of the objects
- *Physical* – objects (stream, lakes, accidents) interfere with connectivity
- *Aggregation Constraints* – imposition of constraints on the aggregation of the data.

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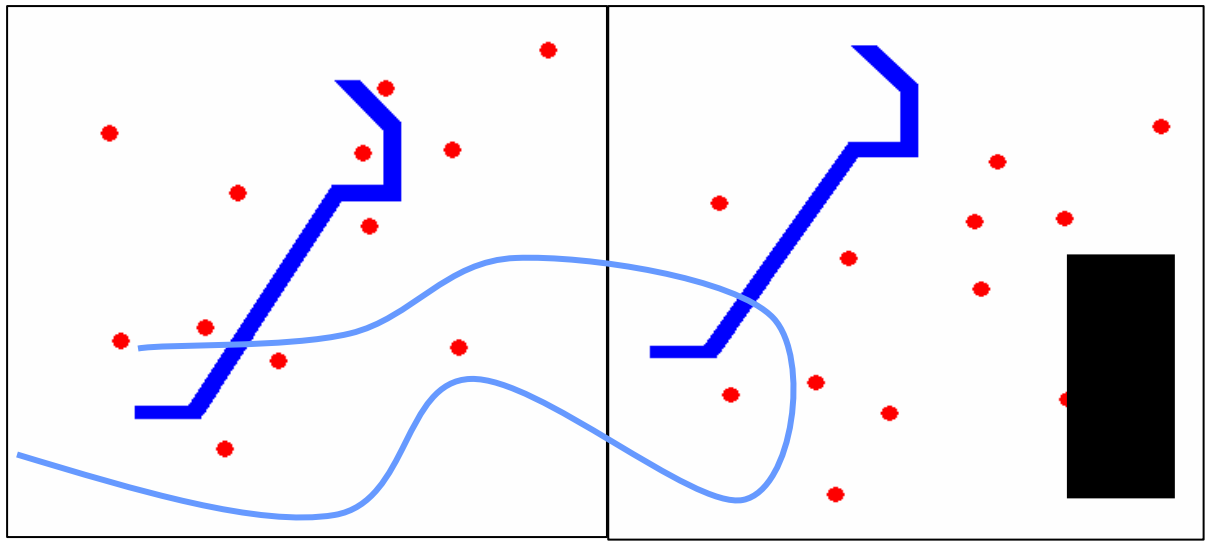
Obstruction measures

- **Shape properties –obstacle geometry**



Obstruction measures

- **Shape properties –obstacle geometry**
- **Distance obstruction measures**

  Quantify the change in distances among points as a result of obstacles presence.
- **Aggregation obstruction measures**

  Quantify changes in the data aggregation (clusters) derived from the points as a result of obstacles presence.
- **Connectivity obstruction measures**

  Quantify the obstacles influence on the choice of routes.

We analyze here the distance and aggregation indices

Metrics – requirements

- Measures are with respect to the reference state
- Same measures apply to both states
- Obstructions cannot improve connectvity

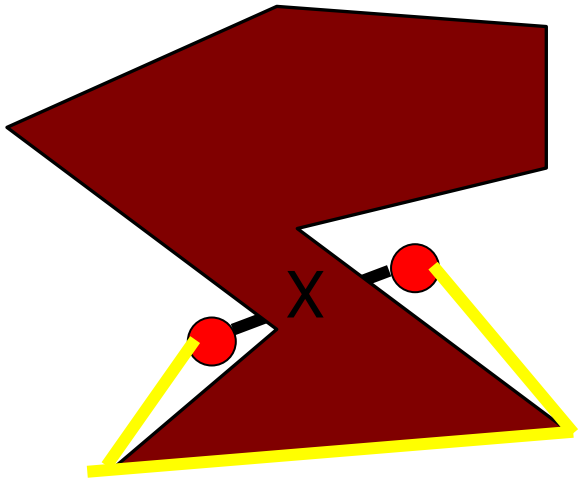
Metrics - requirements

- **Normalized**
  - Ranges between 0 (no interference) to 1 maximal interference
- **Provide measures for**
  - Whole set
  - Subset
  - Individual entity
- **Uninfluenced by quantification of obstruction effect**

Distance Obstruction Index

- Distance increases in the presence of obstacles
- Obstructed paths must circumvent obstacles

- Obstructed paths must be part of the visibility graph



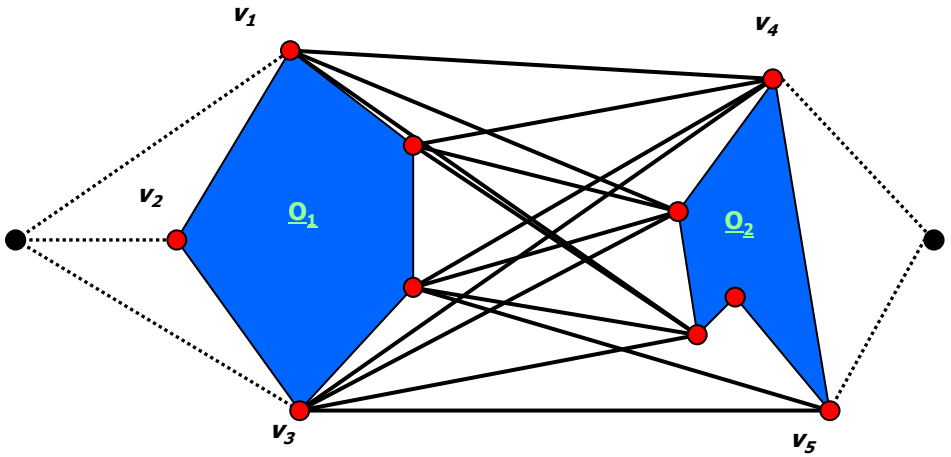
Visibility graph

- Visibility Graph G=(V, E)

- Each vertex of obstacles is included in V
- Edges in E are only ones between visible nodes

A shortest path computation problem

- Visibility graph between 2 points with 2 obstacles



Distance obstruction Index (ctd.)

- Evaluation of a distances between point pairs.
- Based on distance comparison with (Da) and without (Db) obstacles

$$Dr_{ij} = \begin{cases} 0 & i = j \\ \dfrac{Da_{ij} - Db_{ij}}{Da_{ij}} & i \neq j \end{cases}$$

(unitless)

$$0 \leq Dr_{ij} \leq 1$$

Distance obstruction Index (ctd.)

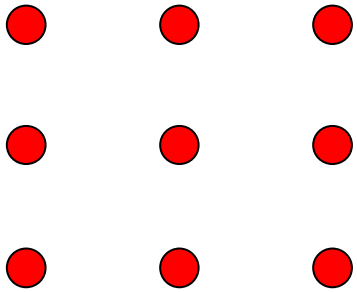
- **DOI –averaging the individual entries**

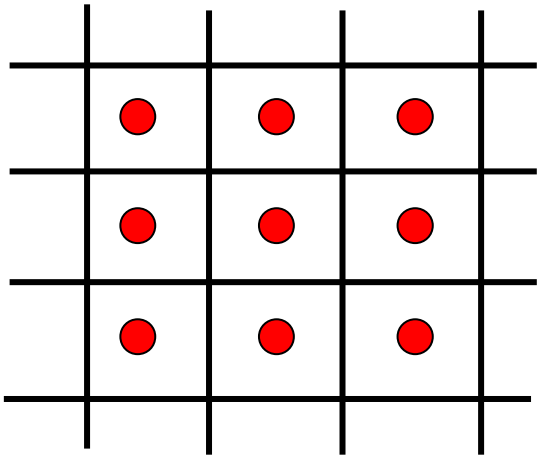
$$DOI = \frac{2\sum_{i=1}^{n}\sum_{j=i}^{n} Dr_{ij}}{(n-1)^2}$$

$$0 \le DOI \le 1$$

- **Influence on a point – column in the matrix**

- **Simple measure**
- **Normalized measure**
  - No interference – Da=Db
  - Max interference Da→ ∞





Influence of Physical Constraints

- **Obstacles – data aggregation**

Clustering Obstruction Index

- **Obstacles alter spatial connectivity**
- **Questions raised:**
  - What measures reflect change in aggregation
  - Is change in number of clusters sufficient?
  - Should noise be treated and if so how?
  - How to cluster?

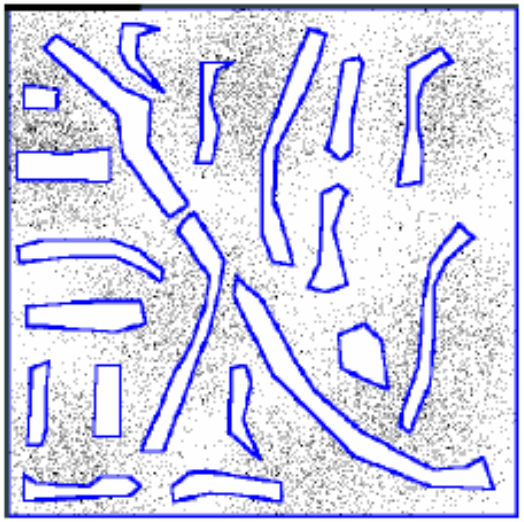
Requirements

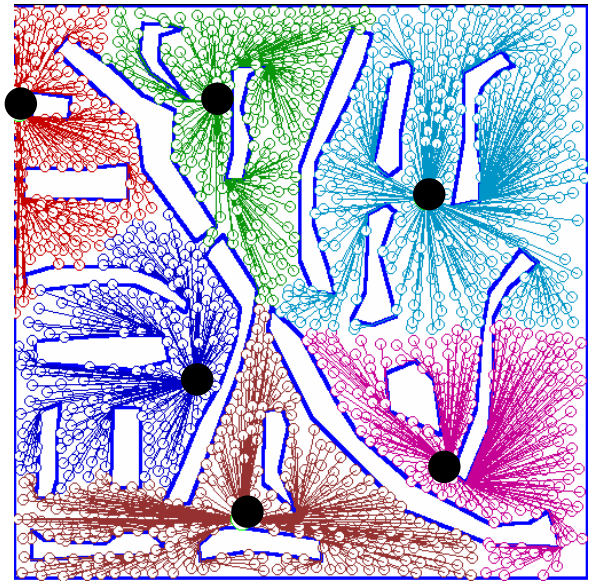
- General metric – not method related
- Same metric for before and after states
- Little relation to distance measures
- Reflect changes in object association between states
- Support the existence of noise

Clustering with obstructed distances

20 polygonal obstacles
64,000 entities

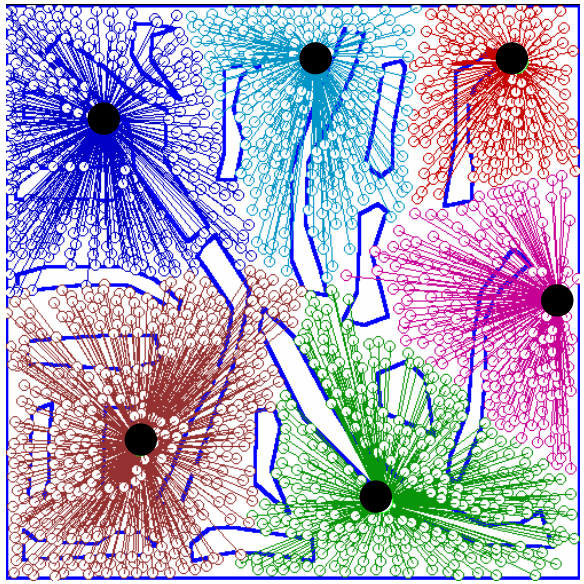
Data partitioning into 6 zones (e.g., 6 ATMs)





COD

Ordinary clustering

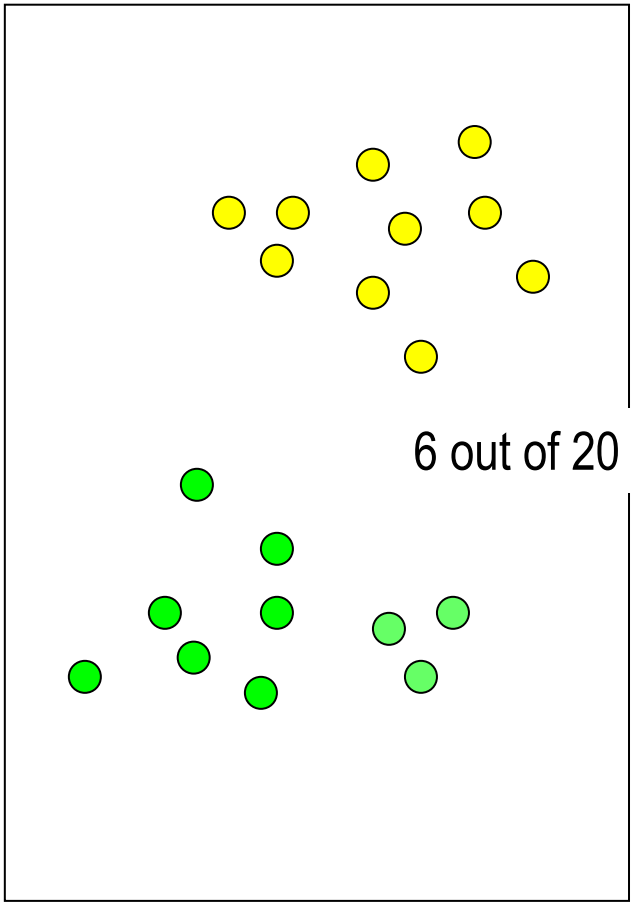


Clustering measures

- **Existing measures**
  - Scatter density based
  - Assumption of same reference setup
  - Essentially distance measures
- **Proposed**
  - Dispersion → association matrix
  - Maps resulting clusters to the original ones
  - Has no distance elements

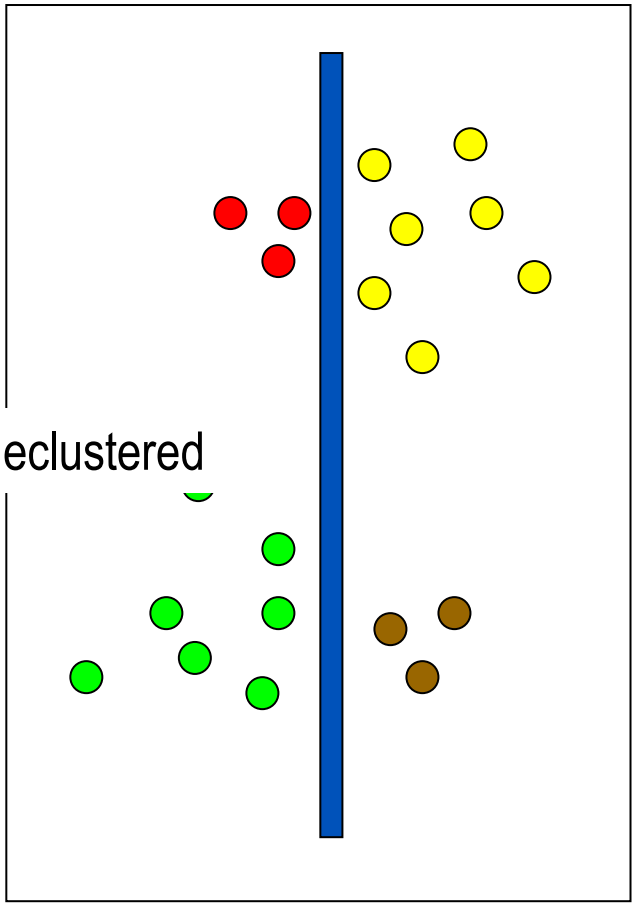
Clustering structure effect

Without obstacle:



2 Clusters (10 points each)

With obstacle:



4 Clusters

6 out of 20 points are declustered

Clustering Obstruction Index (ctd.)

- Changes in the structure of the clusters

$$COI = \frac{N - \sum_{i=1}^{n} \max(c_i)}{N}$$

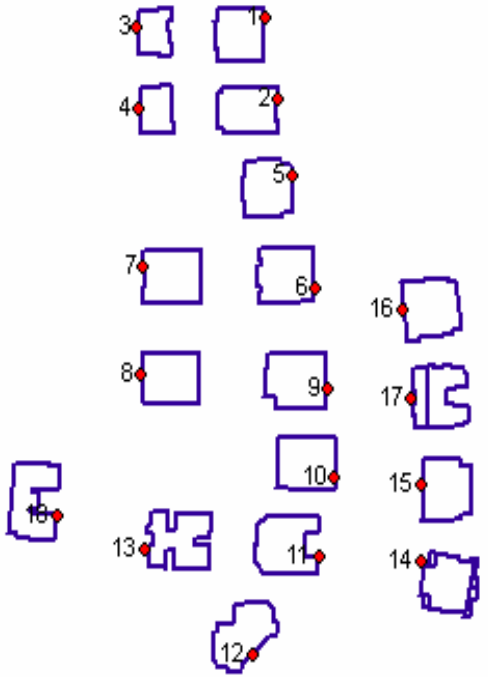
$$0 \leq COI \leq 1$$

- COI measures deviation from original structure
- Normalized measure

Application

Residential Neighborhood

- Apparent arrangement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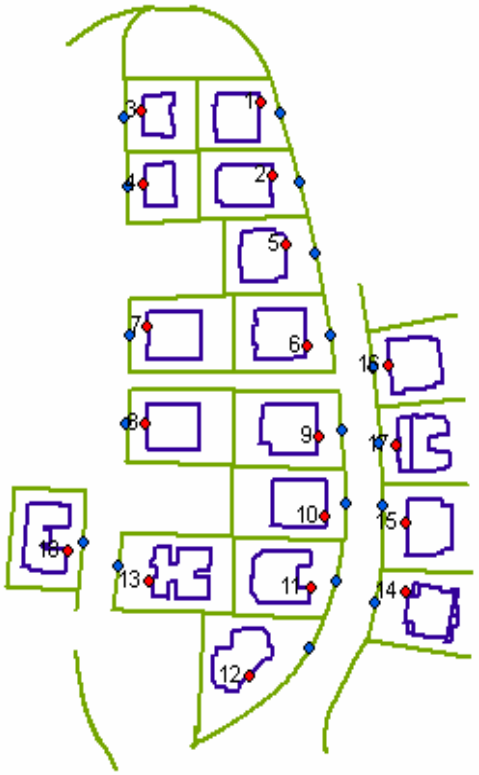
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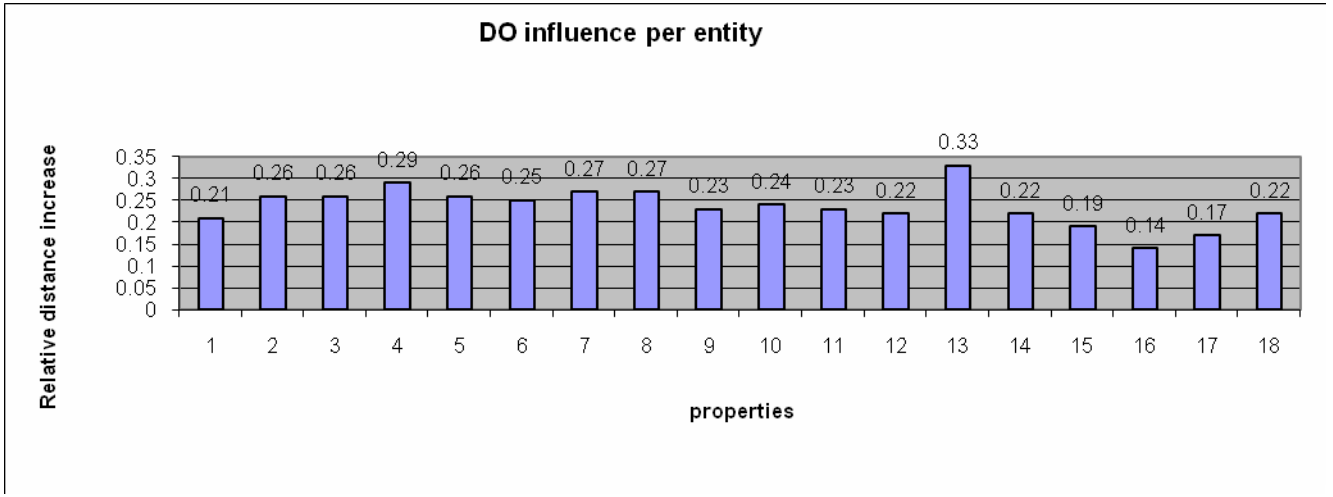
DOI

- **Global measure – 0.25**
  - Average increase of 25% in paths
- **Distribution**
- **Analysis per location**

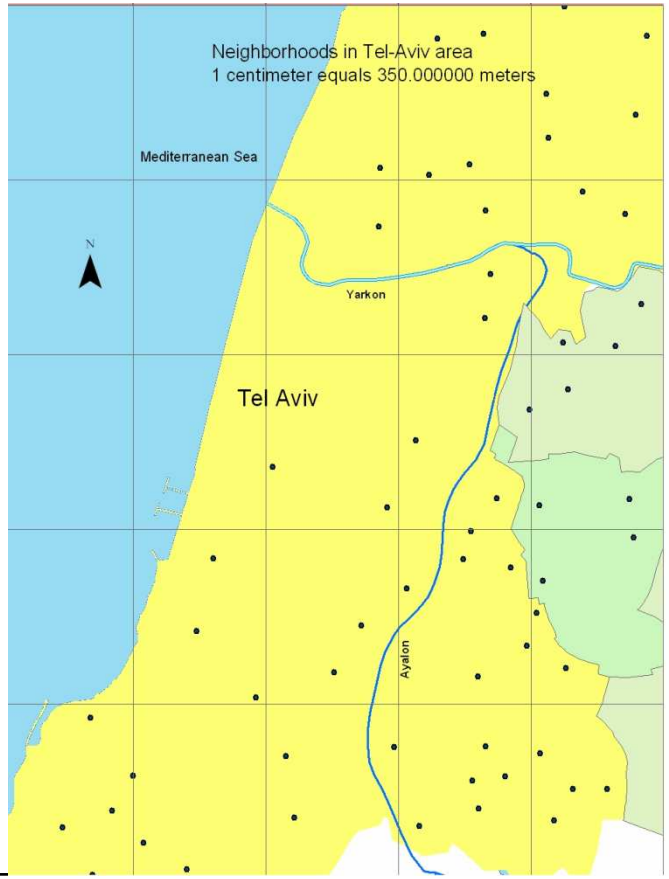


Effect on clustering

General COI index – 0.33

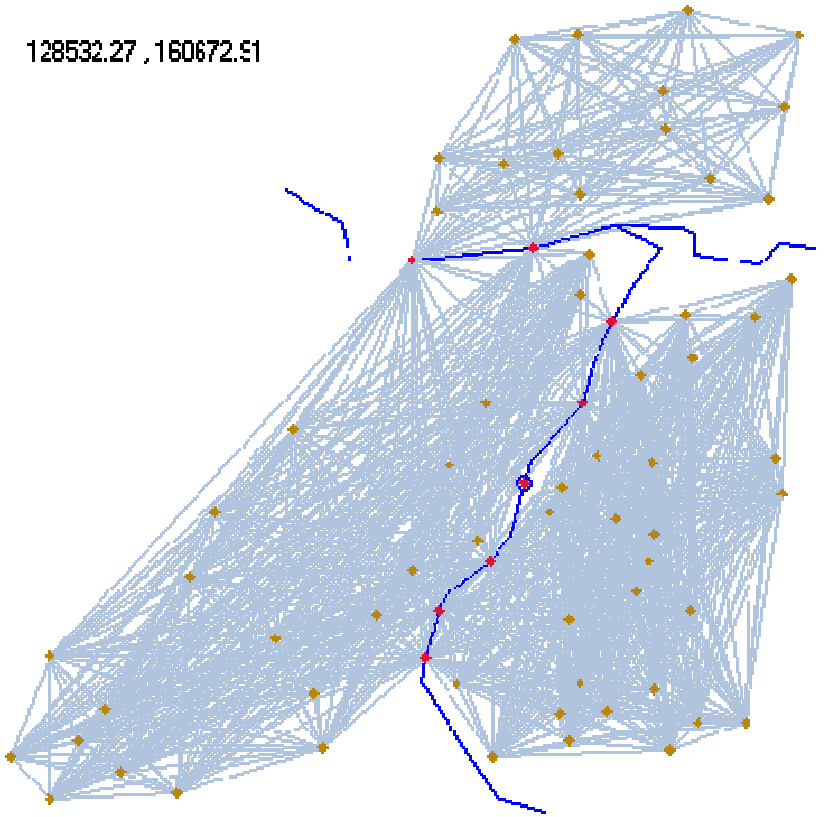
Example

- Analyzing the influence of streams and crossings on spatial connectivity among 61 neighborhoods in a metropolitan area
- Bridges – crossings among obstacles
- With the crossings a set of polygonal obstacles are created

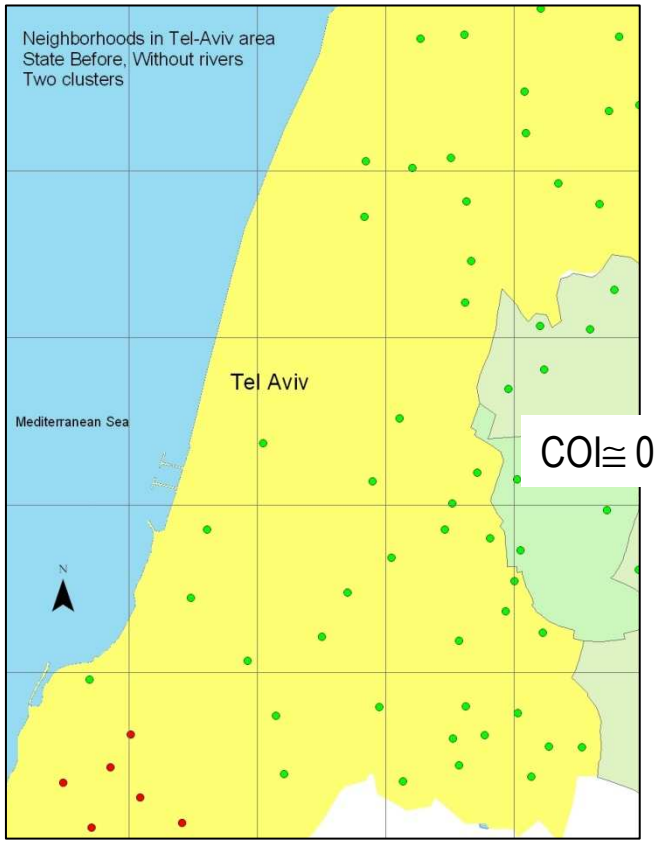


Example (ctd.)

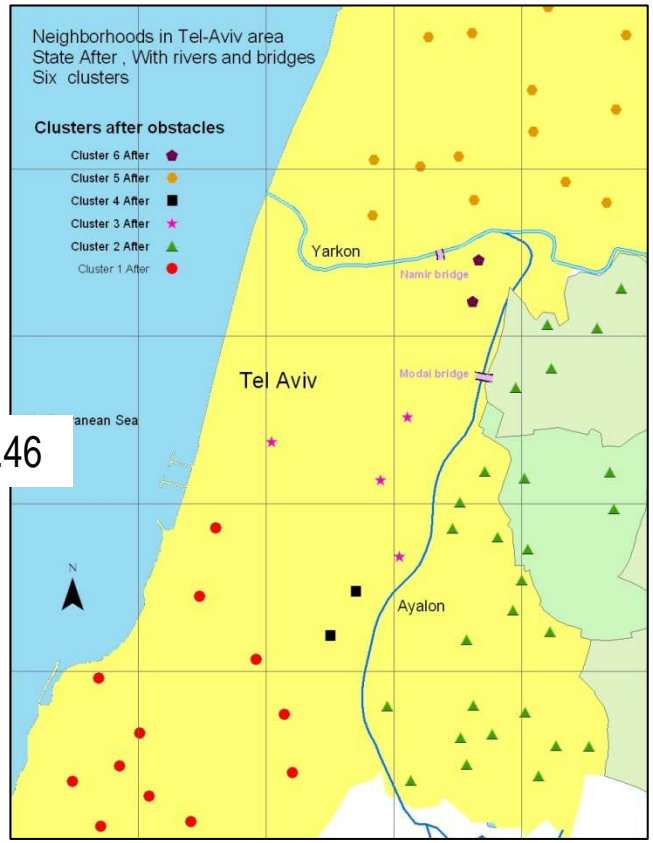
- Formation of the visibility graph among entities
- DOI – 0.1



COI computation



COI≅ 0.46



Original\Resulting		1	2	3	4	5	6	Max(c_j)
C^t=	1	6	0	0	0	0	0	6
	2	6	27	4	2	14	2	27

Conclusions

- Physical constraints affect spatial data in several ways.
- Deriving measures to quantify their influence – not performed so far.
- Different types of interferences.
- Analysis shows that they reflect well the obstacle effect on space.
- Measures to the distance and cluster obstructions were derived.
- Useful for planers and decision makers

Neighborhoods in Tel-Aviv area
1 centimeter equals 350.000000 meters
Mediterranean Sea
N
Bridge Namir
Yarkon
Tel Aviv
Bridge Modai
ThankYou
Ayalon

Data clustering/COD problem

- Clustering – finding patterns (aggregates in the data).
- Well treated methodology in spatial data mining.
- Clustering with Obstructed Distances (COD) – data aggregation in the presence of constraints.

Less treaded.

AutoClust+

➢ Clustering based on Graph-Partitioning (Estivill-Castro, et al. 2000)

AutoClust+ steps:

Construct Delaunay diagram - irrespective of obstacles

Classify Delaunay edges into: Long, Short and Others.

Remove edges intersecting with obstacles

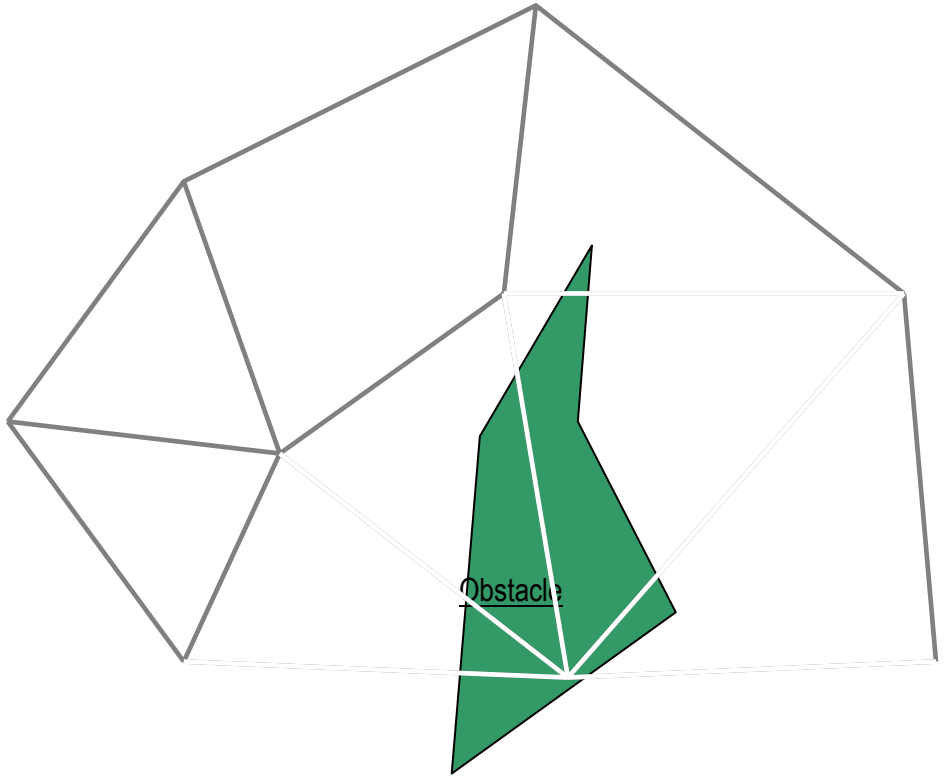
Create initial clusters by removing long and short edges

Create final clusters (fine-tuning the initial clusters) :

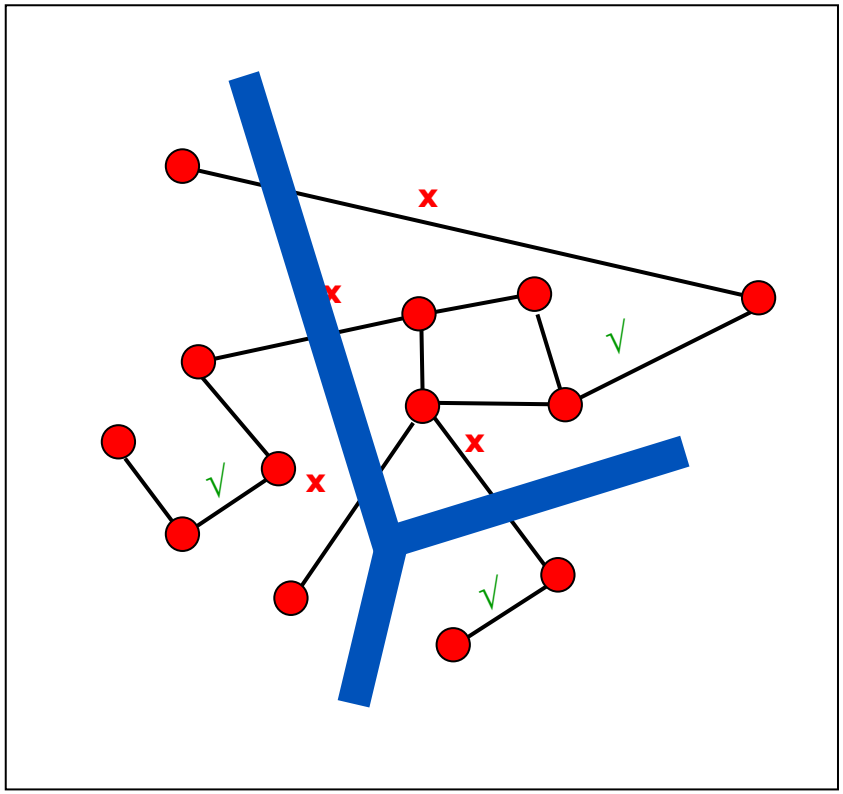
* Return short edges connecting two points from the same cluster
* Remove edges intersecting clusters borders

Delaunay diagram with obstacle

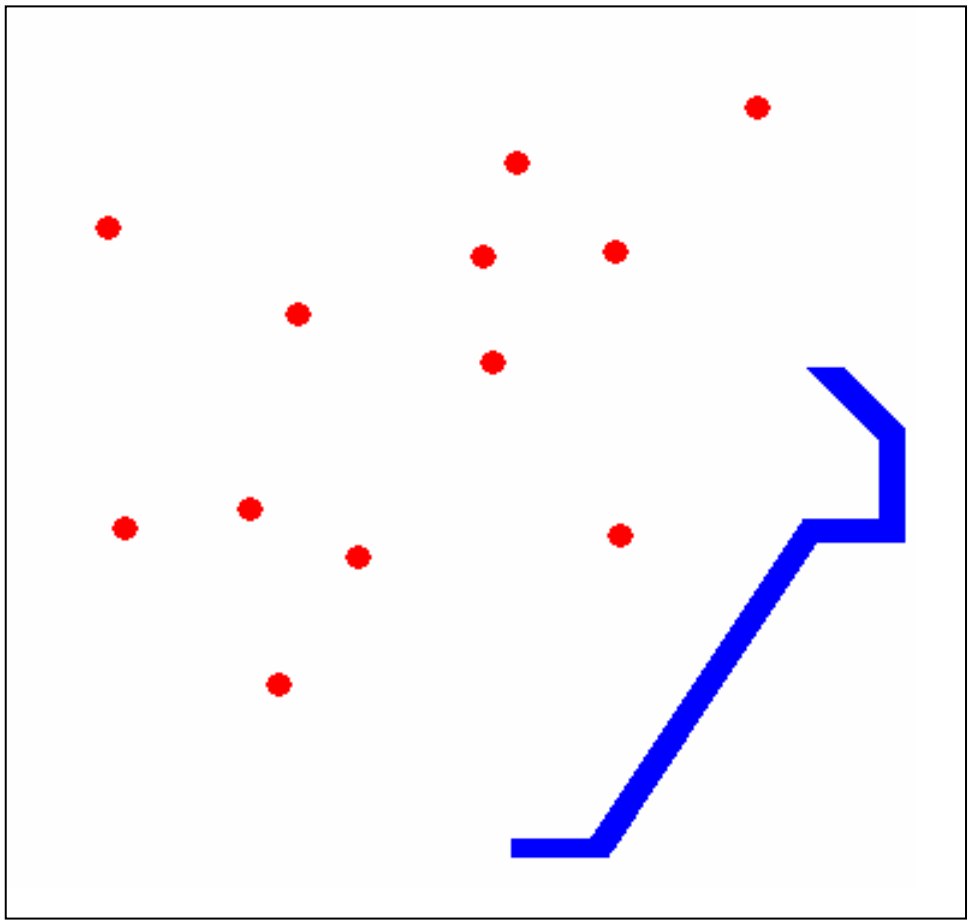
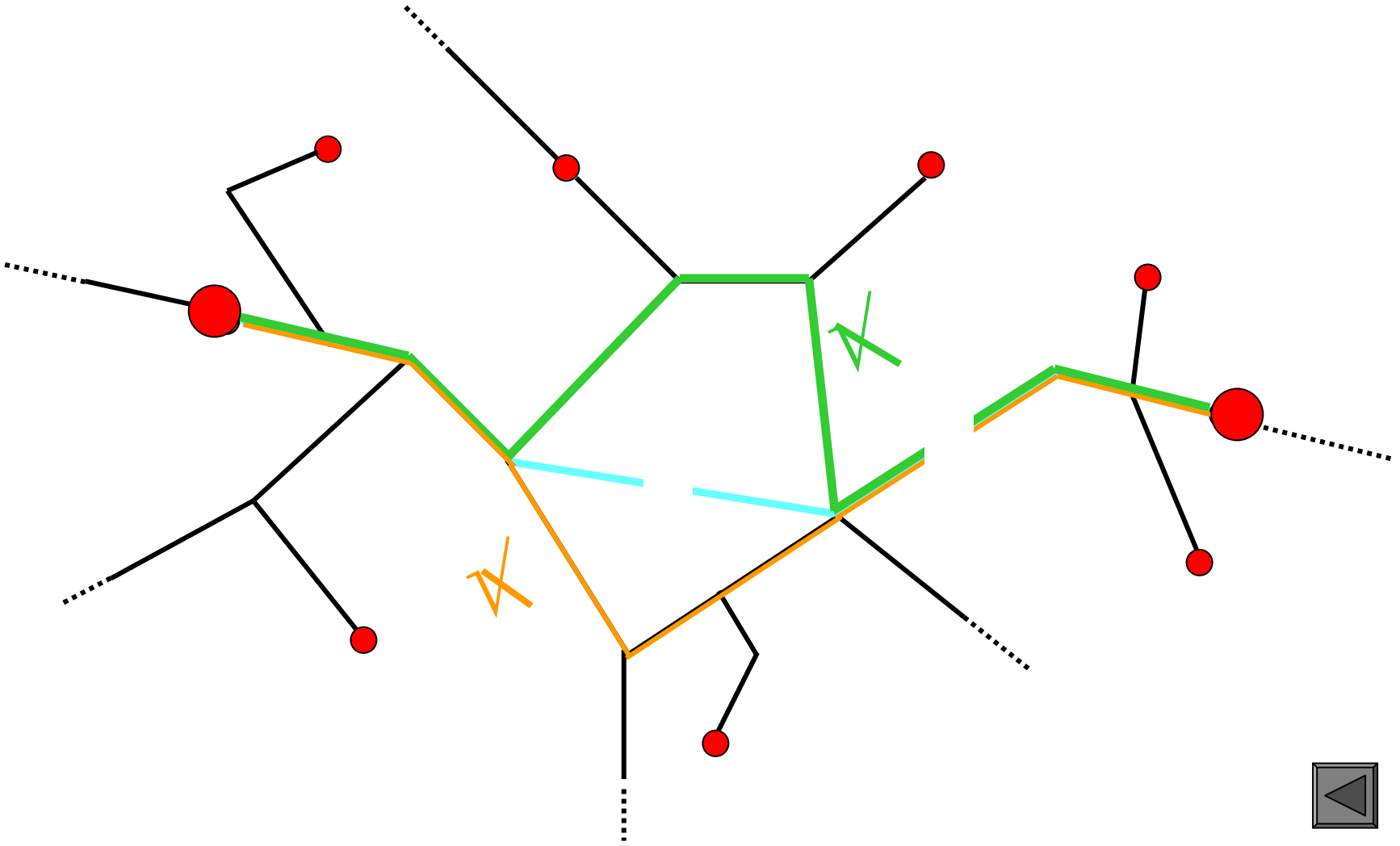
All edges intersecting the obstacle are removed from Delaunay diagram



Influence of Physical Constraints



Clustering Obstruction Index



Influence on Routes