Sensor networks

Exposure analysis

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Betreuer: Kay Römer

What’s coming up

What I will try:

- Introduction to sensor networks.
- Exposure problem.
- Algorithms for finding minimal exposure path in a network.

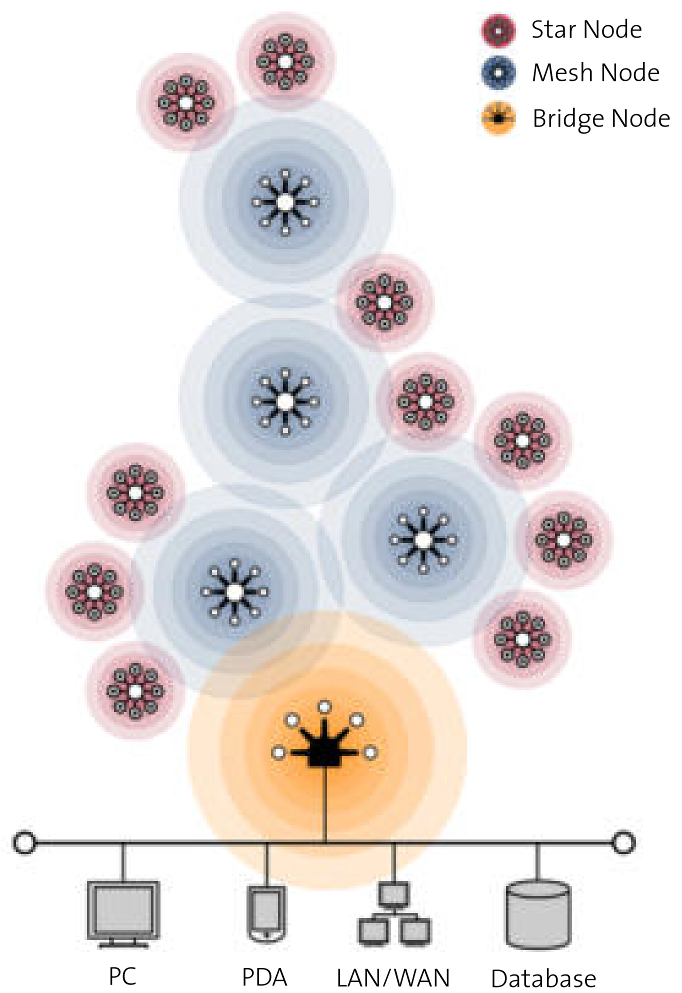
Philippe: Adaptive sampling.

Specs

- No fixed infrastructure.
- Fragile - flexible.
- Low computing power.
- Low battery life.
- Cheap.
- Distributed.

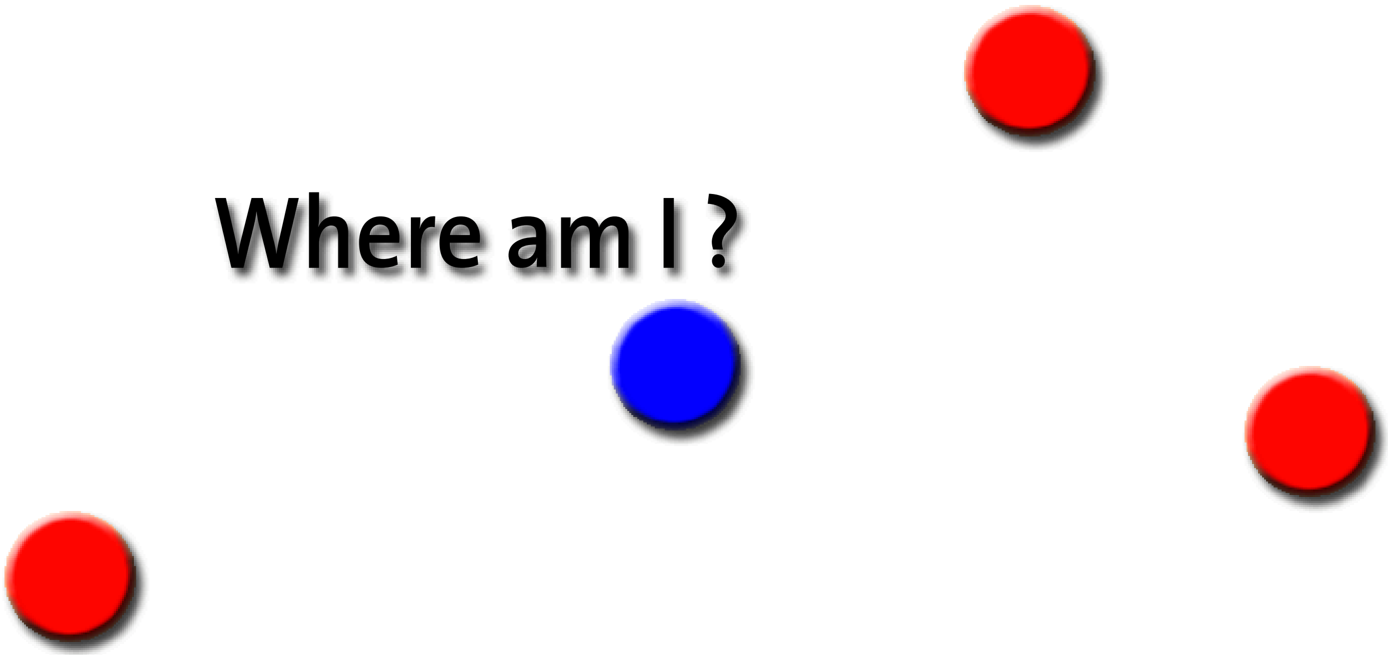
Revolutions:

- Connection to the internet.
- MEMS sensors.



Location discovery

- Dterministic placement.
- GPS.
- Trilateration.



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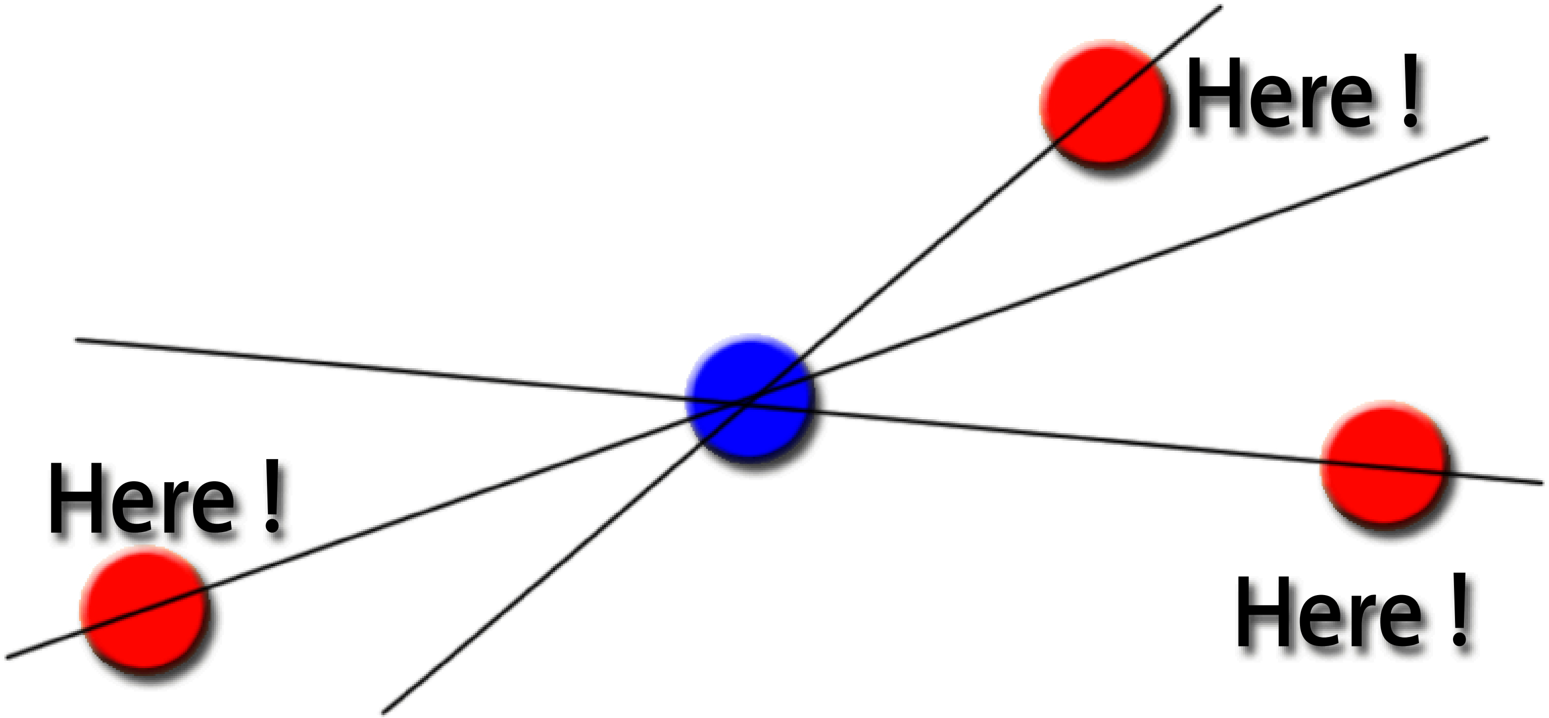
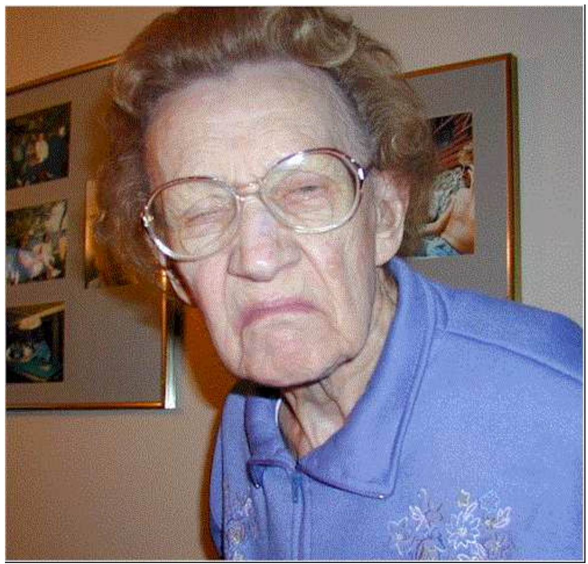


Everyday utility

Real life examples:

- Monitoring (enviromental, ...)
- Robotics.
- Industrial automation.
- Military applications (smart dust).
- Surveillance (mother-in-law detection, ...)

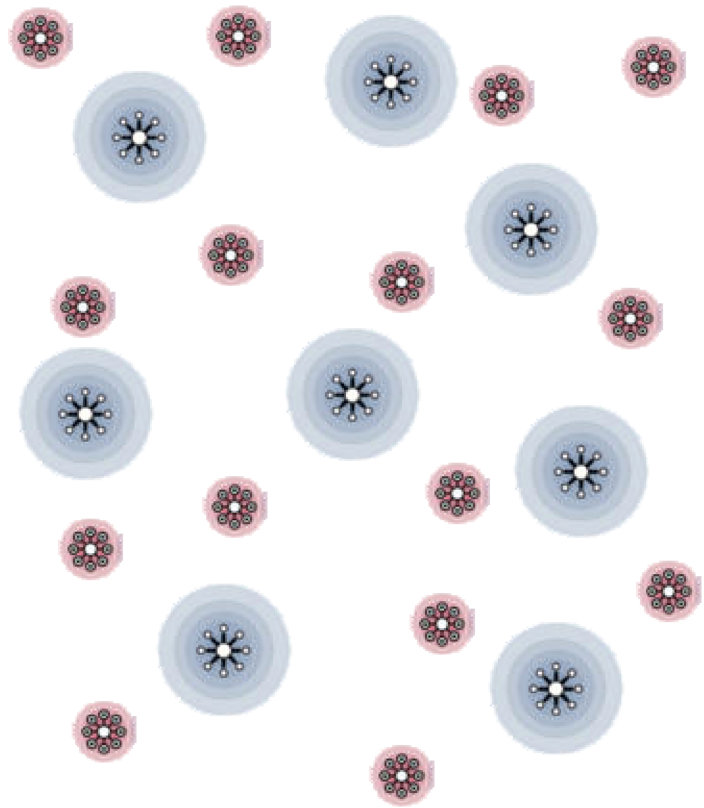


The problem

Let's say we have deployed a sensor network.

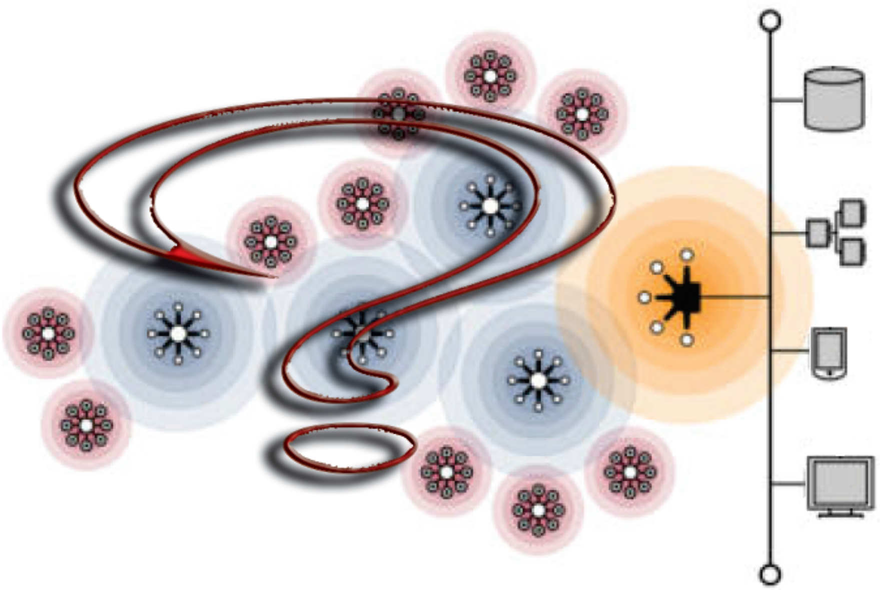
- How good is it?
- Efficient correction?
  - adding least sensors
  - getting best result

Exposure helps us answer such questions.



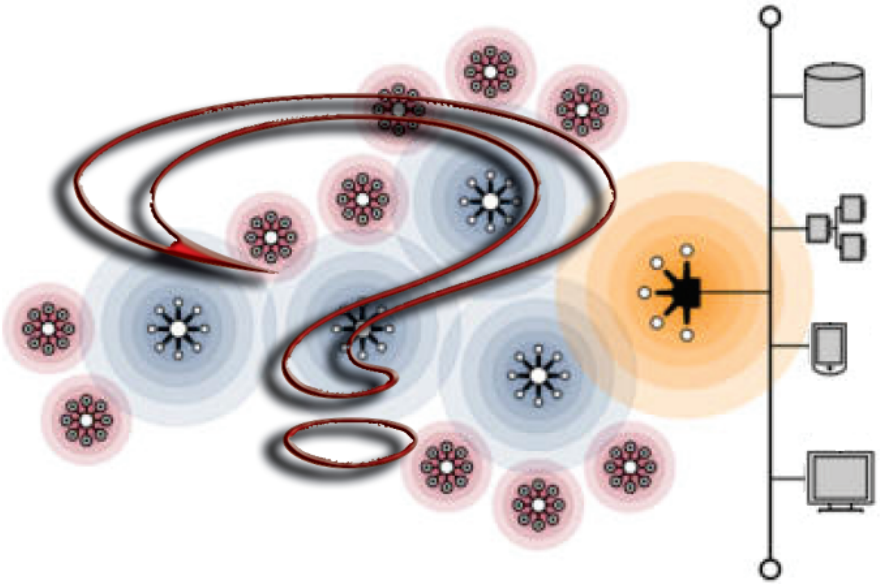
Why?

Exposure is directly related to coverage in that it is an integral measure of how well the sensor network can observe an object, moving on an arbitrary path, over a period of time.



Why?

The minimal exposure path provides valuable information about the worst case exposure-based coverage in sensor networks.



Voronoi diagram

Intuition:
if sensors can sense you then stay away!

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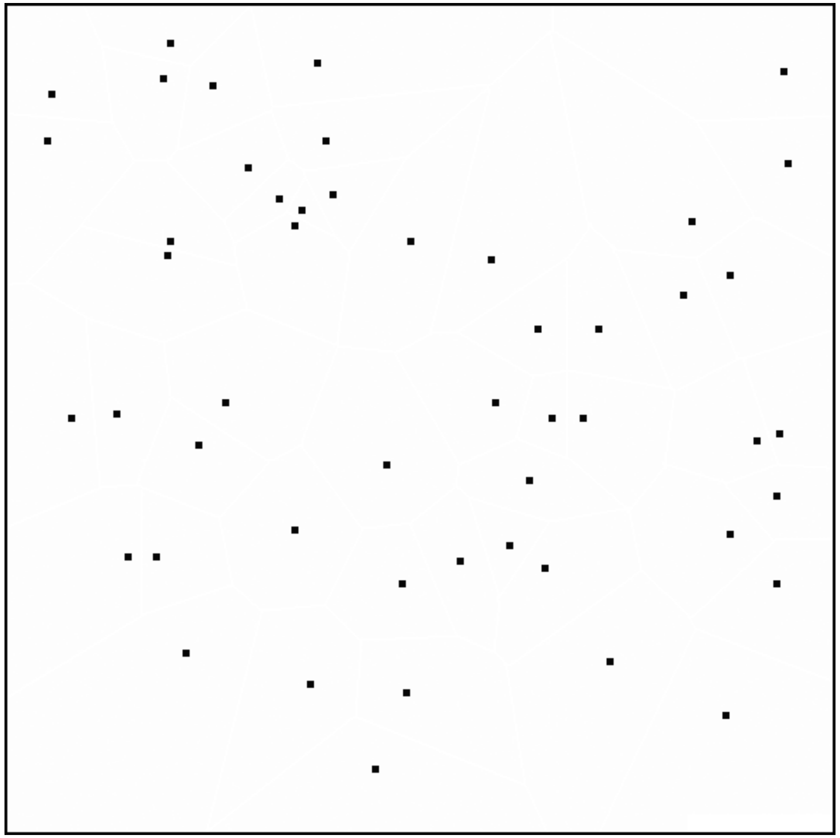
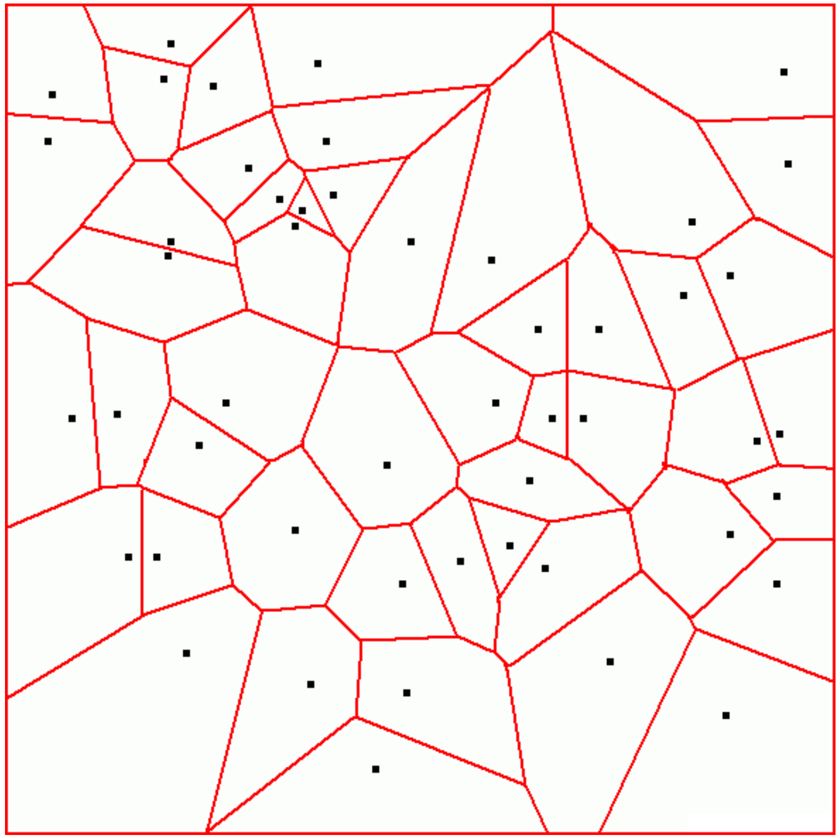
if sensors can sense you then stay away!

In 2D, the Voronoi diagram of a set of discrete sites (points) partitions the plane into a set of convex polygons such that all points inside a polygon are closest to only one site.

Voronoi diagram



Voronoi diagram

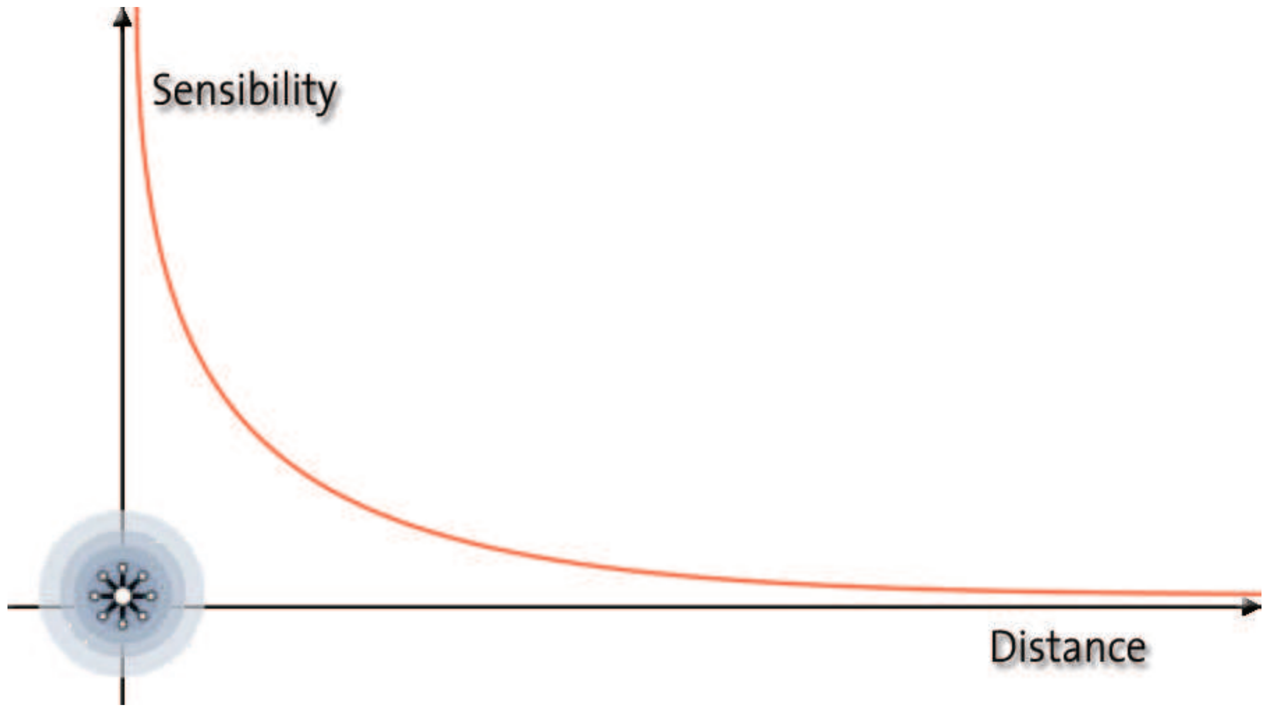


Sensibility

Definition:

$$S(s,p) = \frac{\lambda}{[d(s,p)]^k}$$

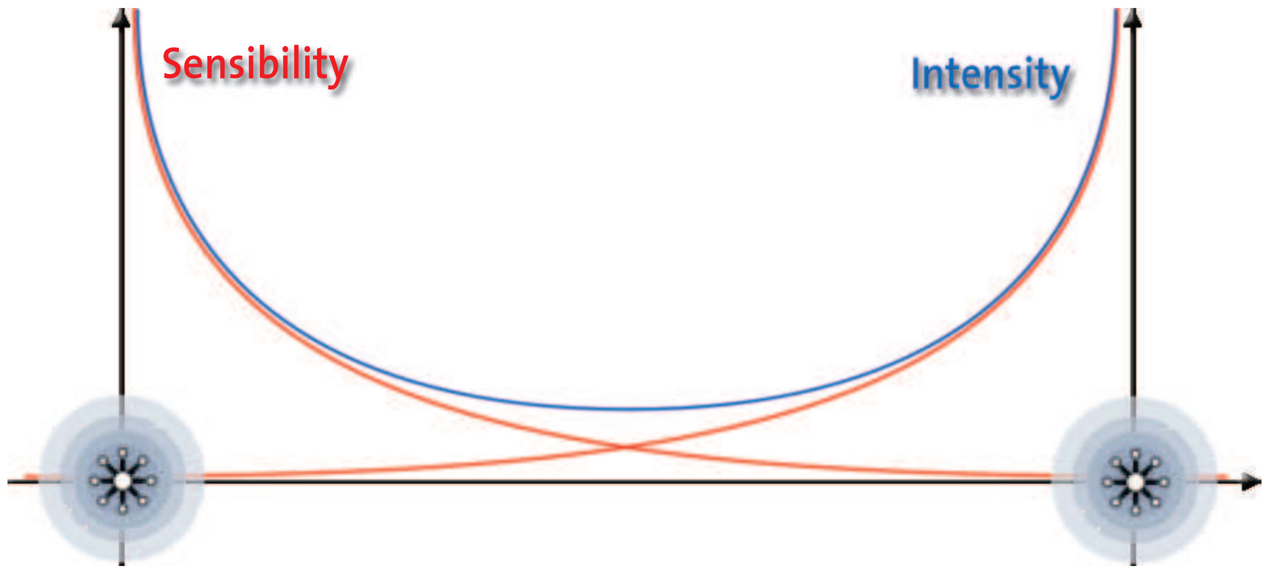
- Point p
- Sensor s
- $d(s,p)$ Euclidean distance
- λ and k sensor parameters



Intensity

Definition: All-Sensor Field Intensity $I_A(F, p)$ for a point p in the field F is defined as the effective sensing measures at point p from all sensors in F.

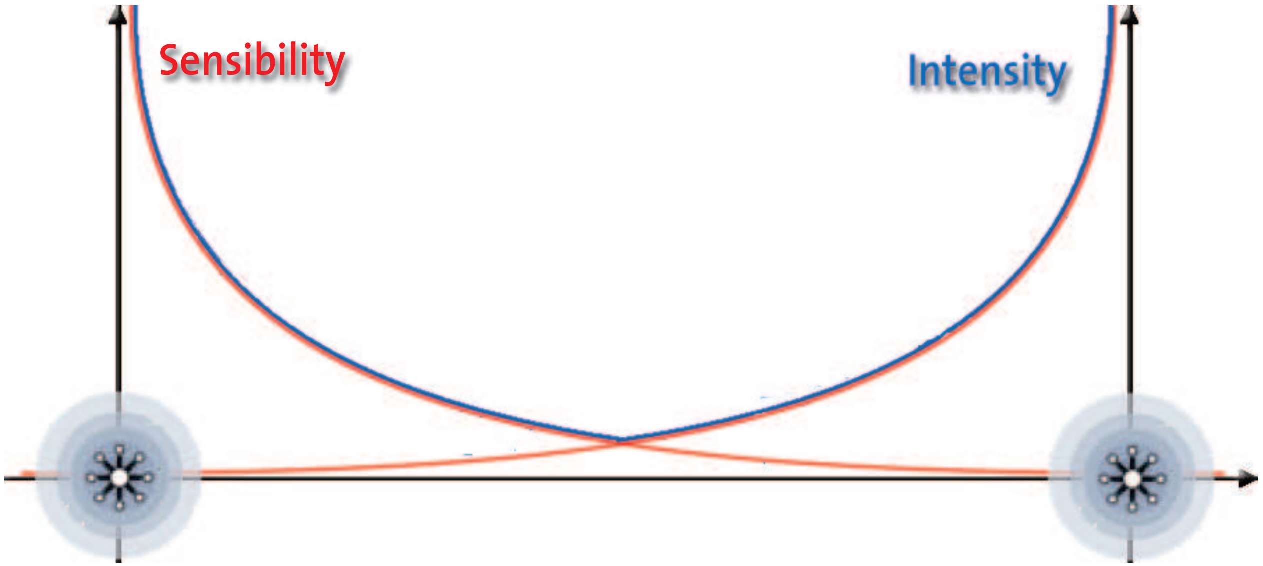
$$I_A(F, p) = \sum_{i=1}^{n} S(s_i, p)$$



Intensity

Definition: Closest-Sensor Field Intensity $I_C(F,p)$ for a point p in the field F is defined as the sensing measure at point p from the closest sensor in F, i.e. the sensor that has the smallest Euclidean distance from point p.

$$I_C(F,p) = S(s_{min}, p)$$



Exposure

Definition: The exposure for an object in the sensor field during the interval $[t1, t2]$ along the path $p(t)$ is defined as

$$E(p(t), t1, t2) = \int_{t1}^{t2} I(F, p(t)) \left| \frac{dp(t)}{dt} \right| dp$$

where the sensor field intensity $I(F, p(t))$ can either be $I_A(F, p(t))$ or $I_C(F, p(t))$ and $\left| \frac{dp(t)}{dt} \right|$ is the element of arc length.

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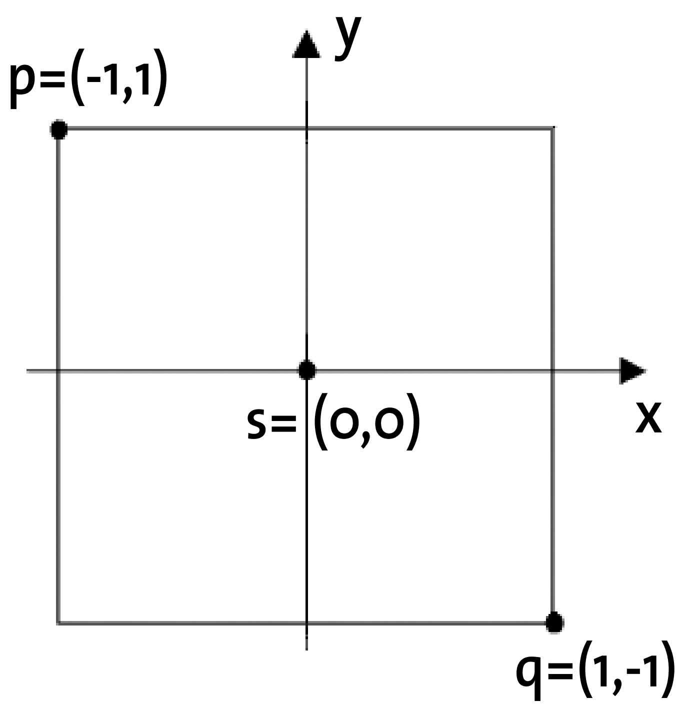
Simple example

How *simple* is the Exposure?

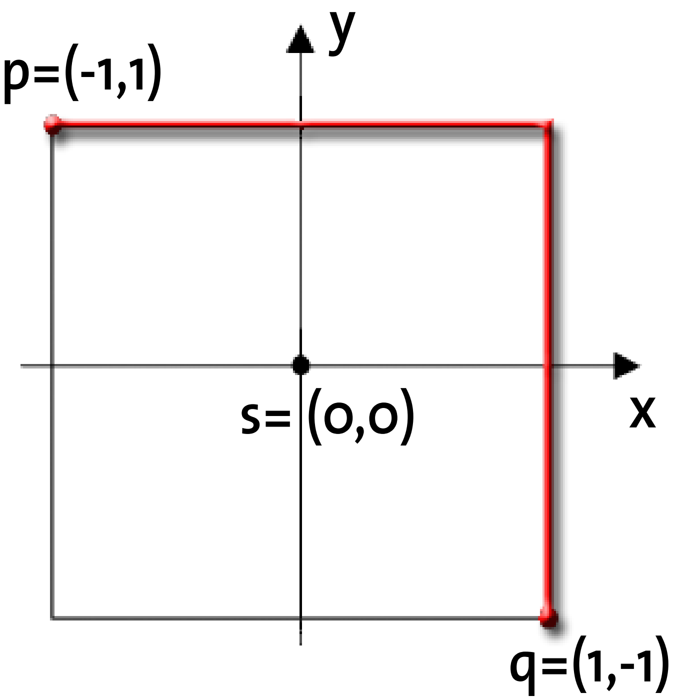
What is the minimal exposure path from p to q?

Let us test if the Voronoi diagram approach is sufficient.



Simple example

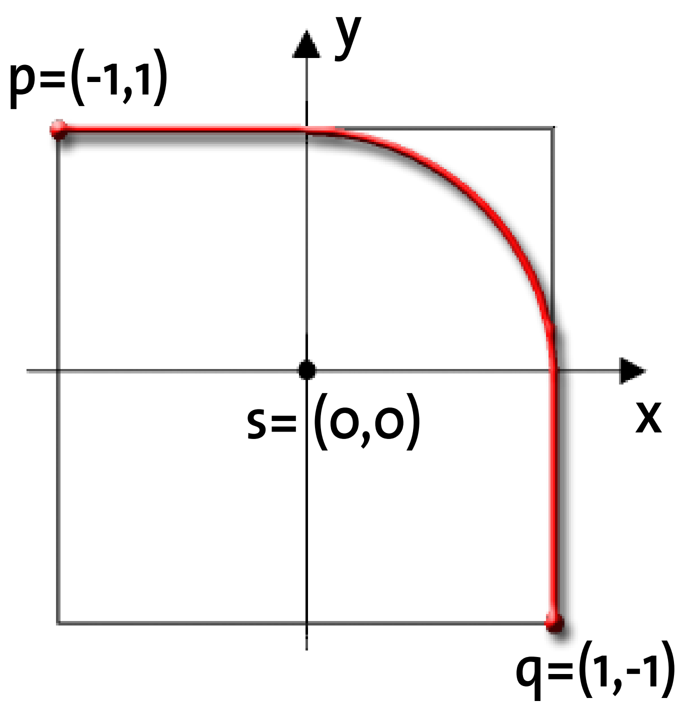
The Voronoi diagram approach would suggest sticking to the edges of the graph.



Simple example

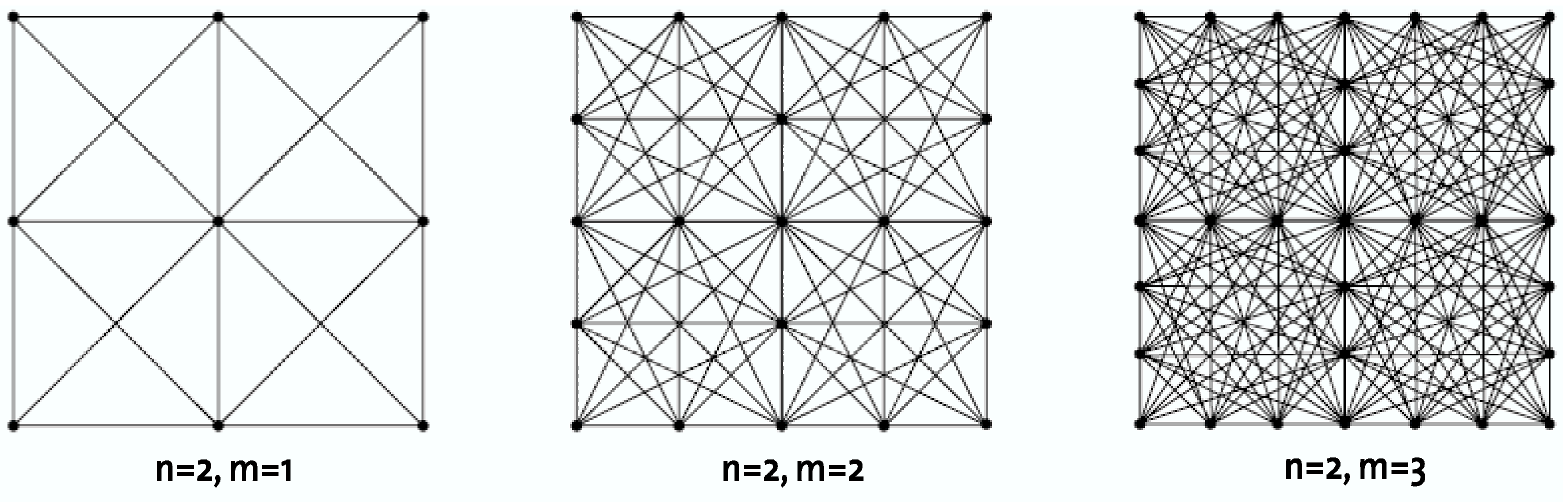
- step closer to sensor

  BUT
- reduced sensing time
- reduced path length
- overall exposure reduced



First algorithm

- Generate grid.
- Transfrom grid into edge-weighted graph.
- Find minimal exposure path using Dijkstra's Single-Source-Shortest-Path algorithm.



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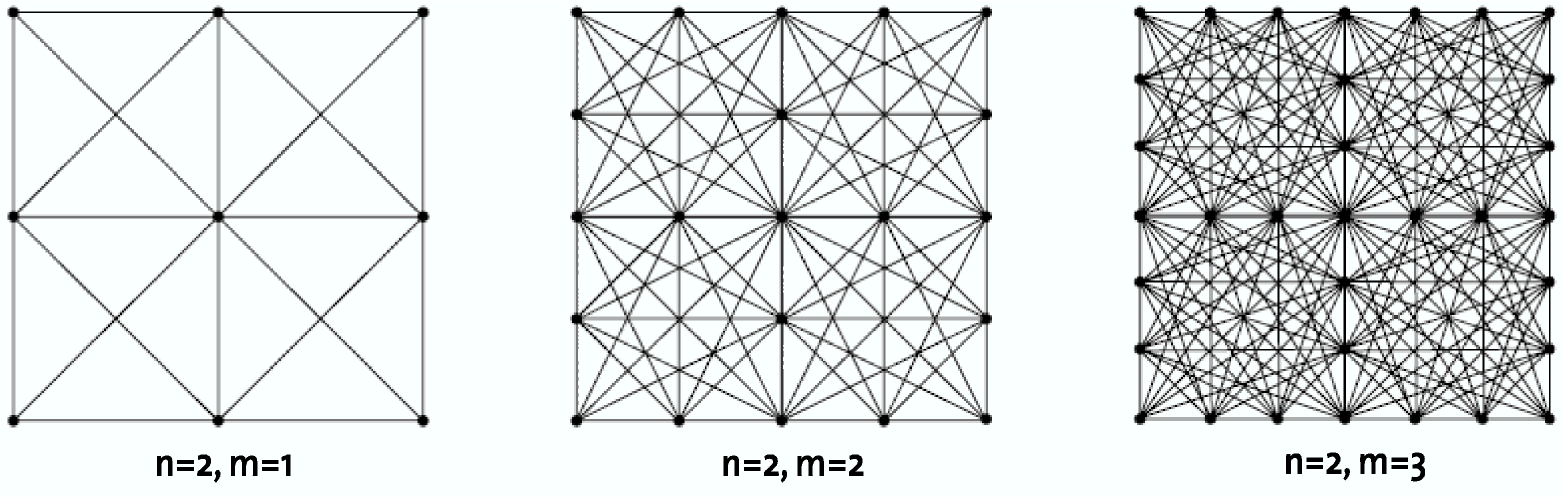

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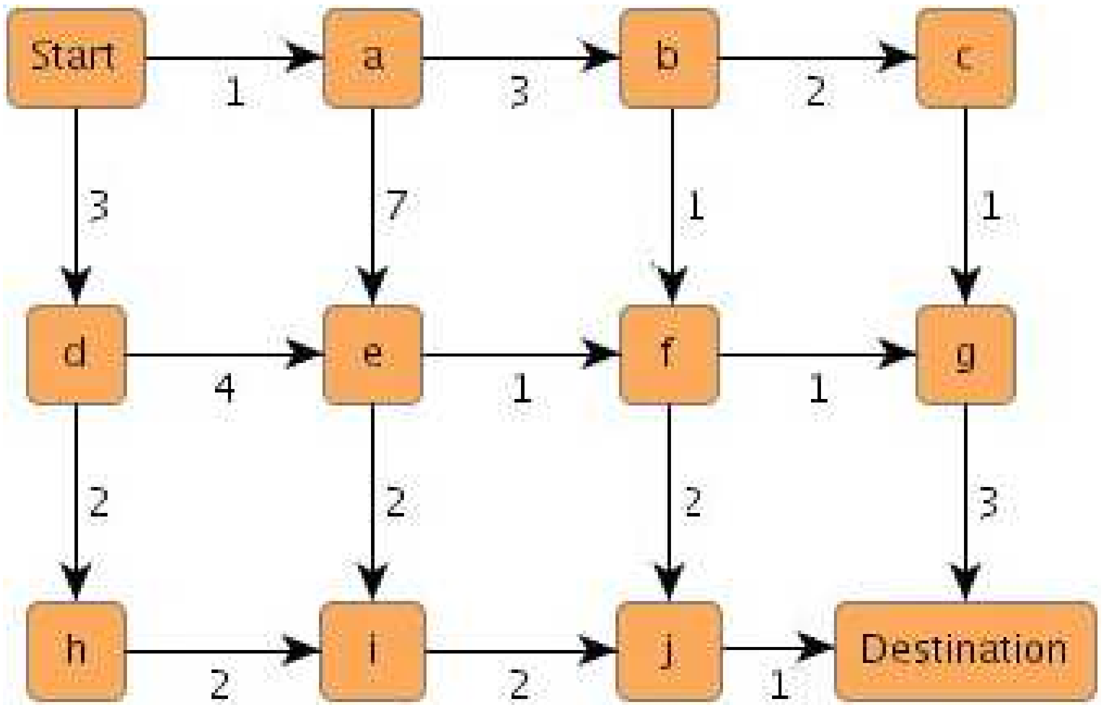

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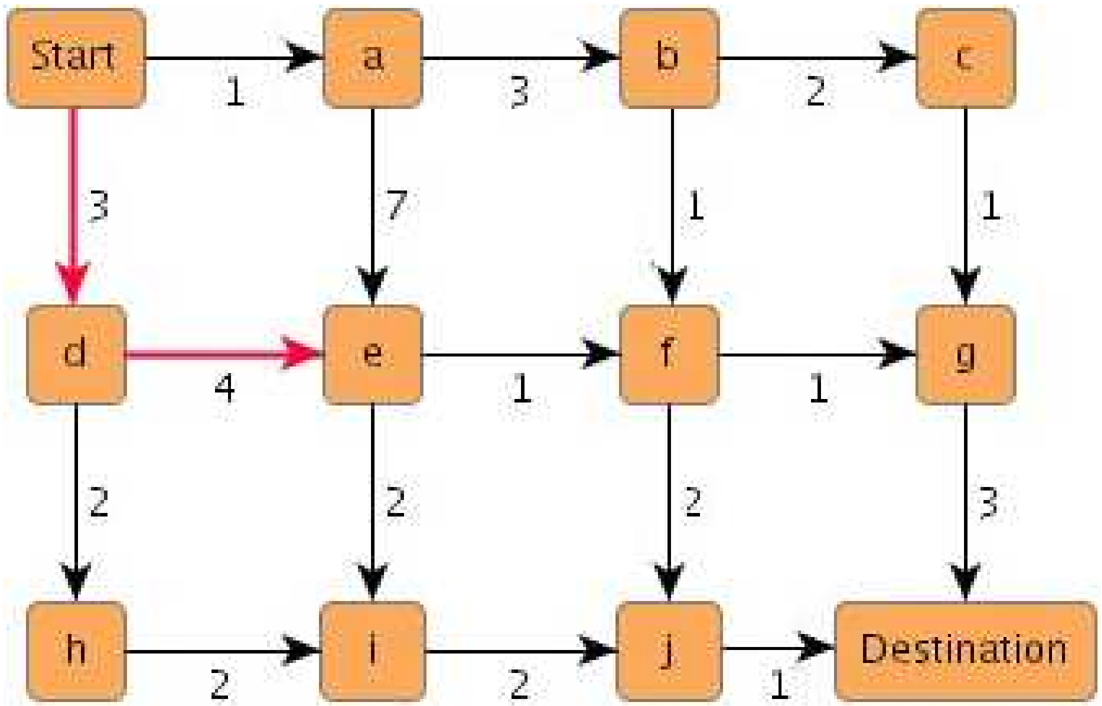

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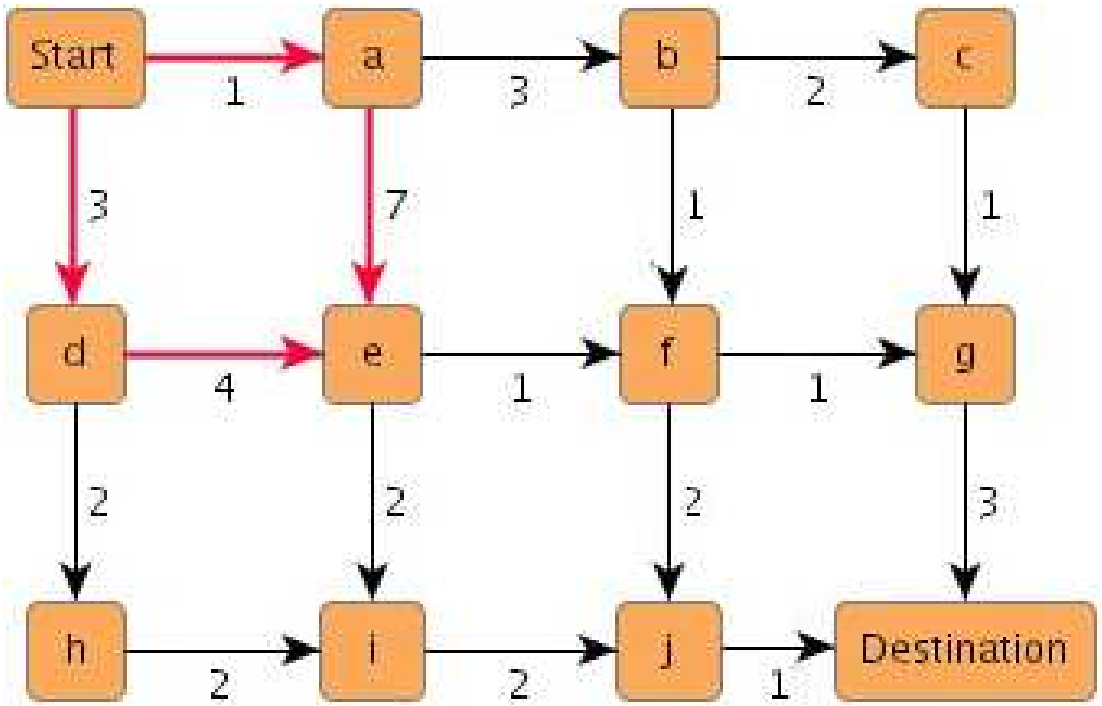

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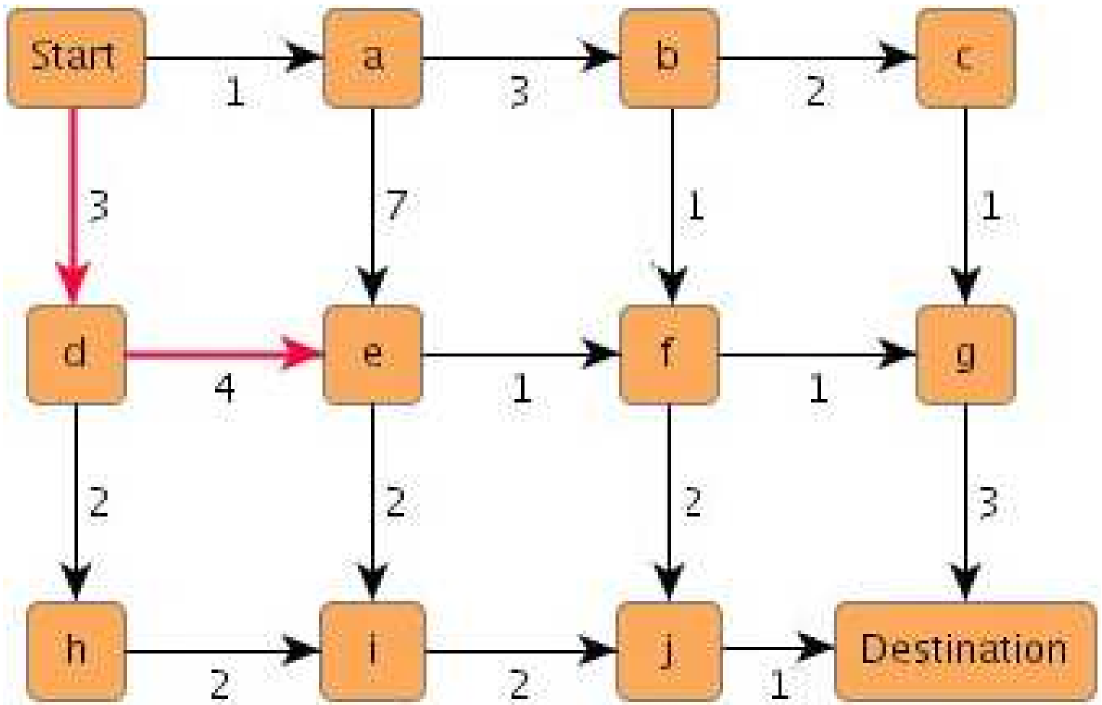

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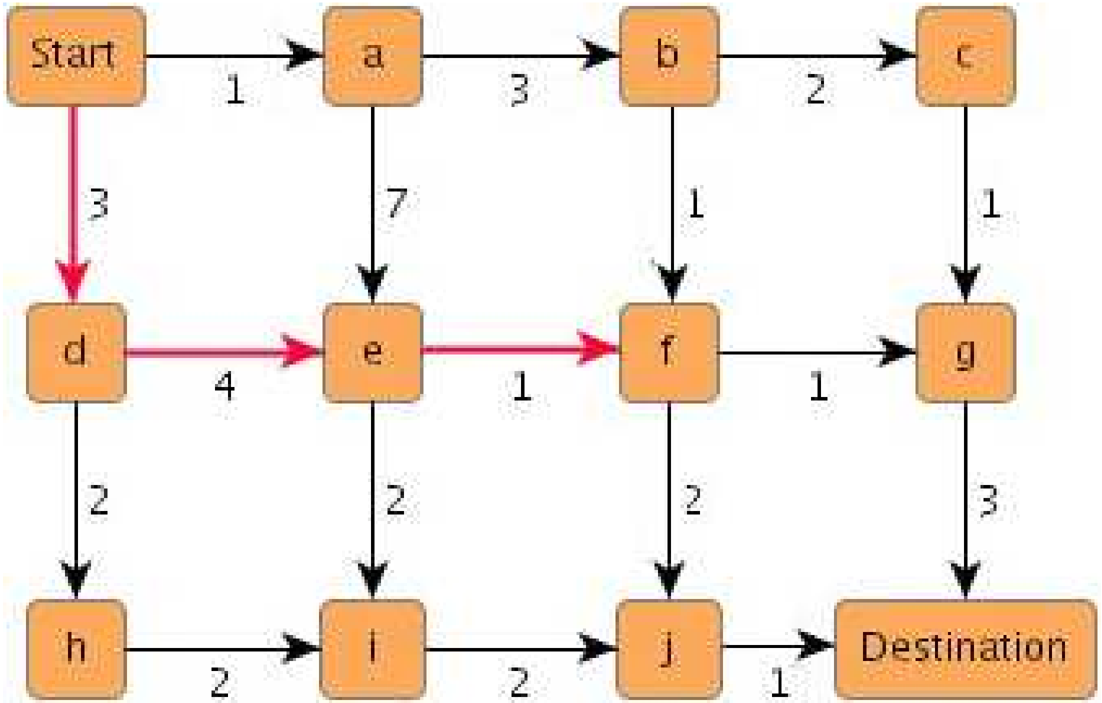

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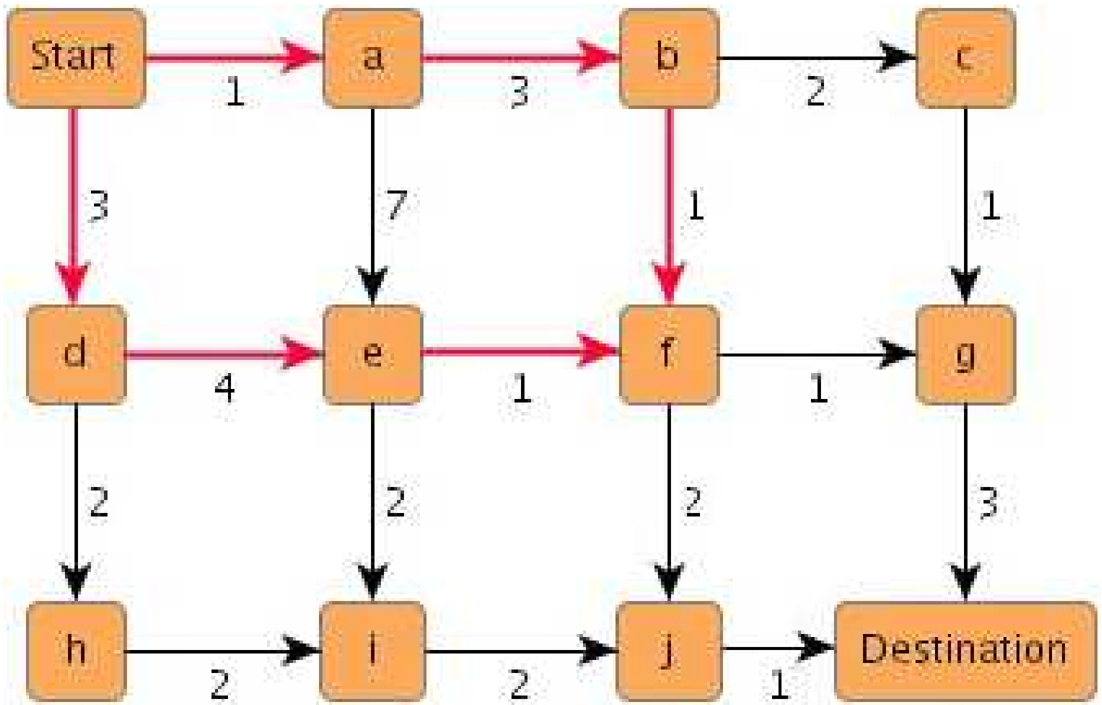

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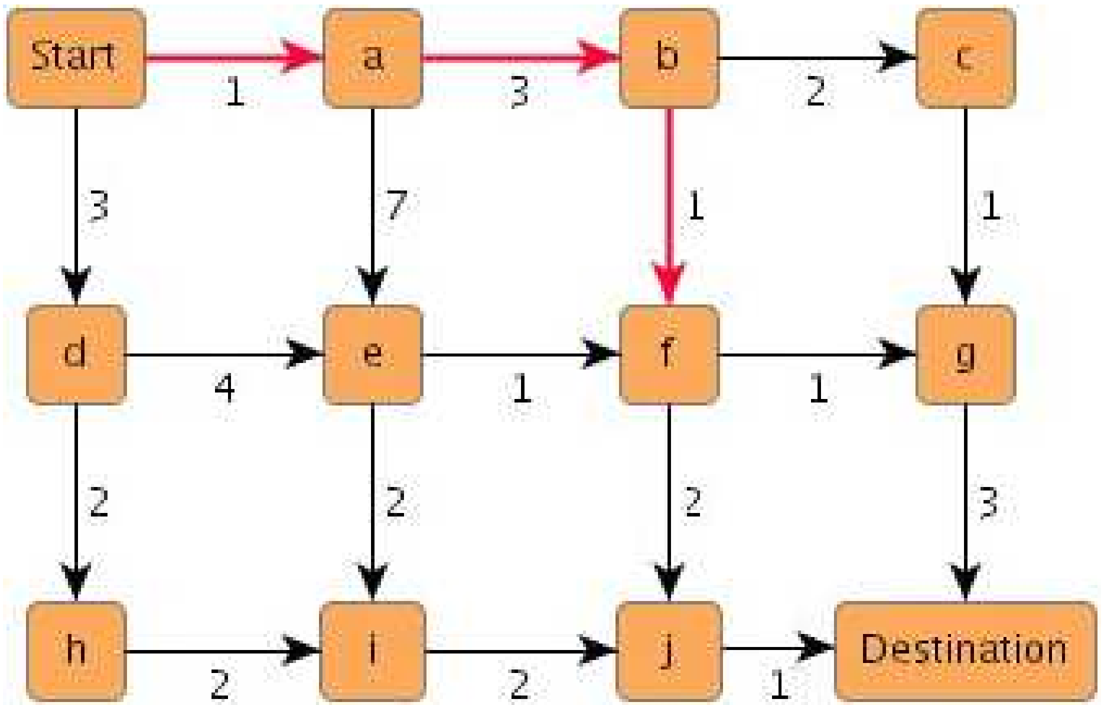

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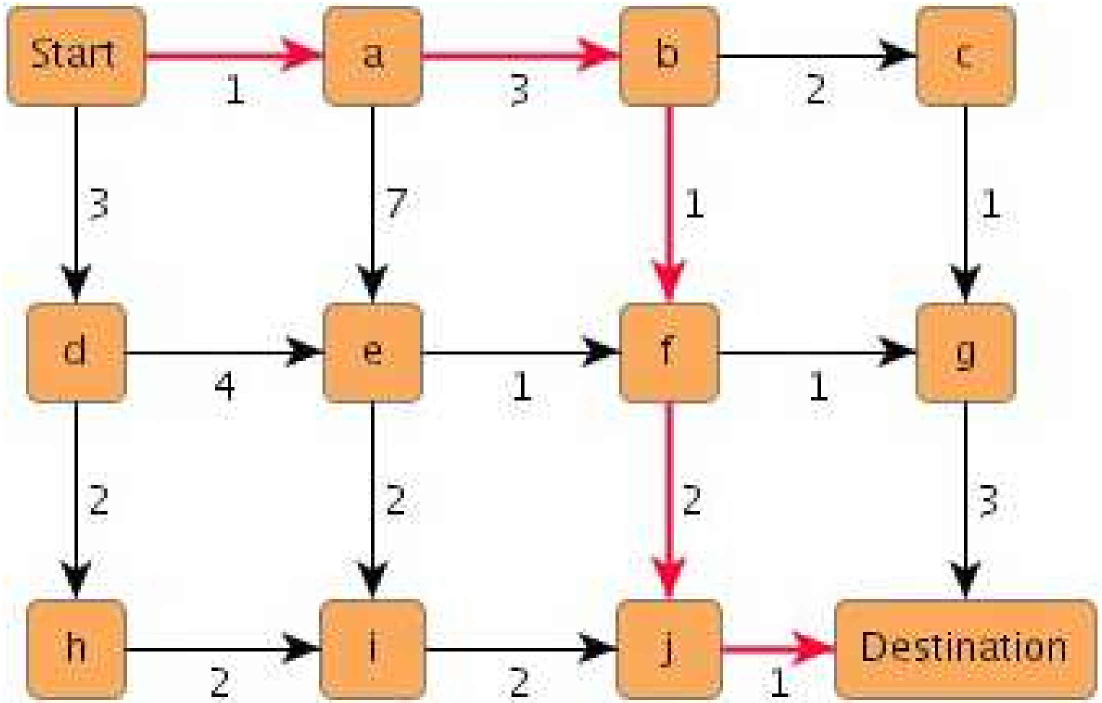

A few examples

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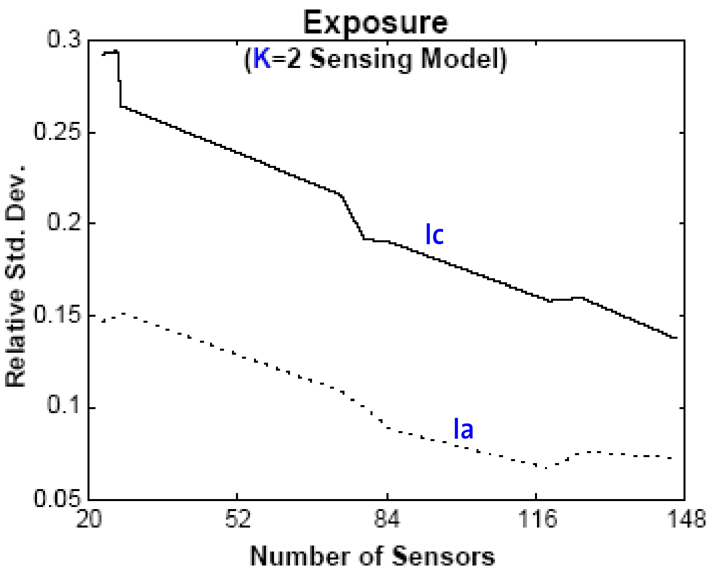

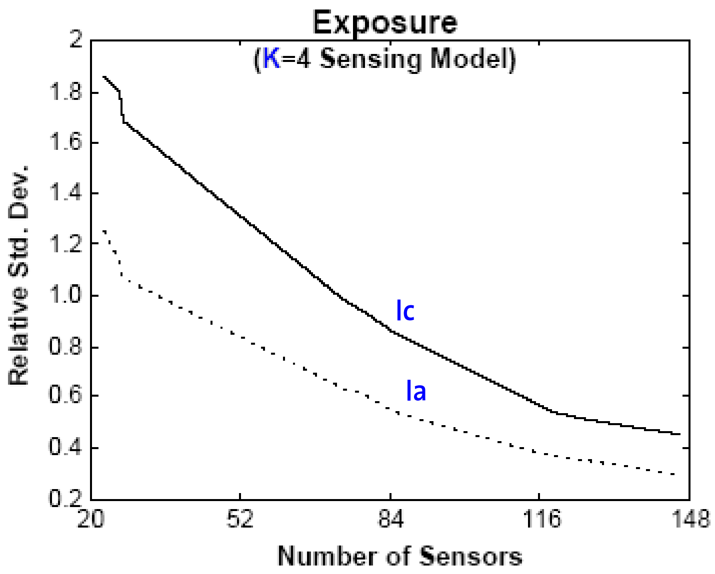

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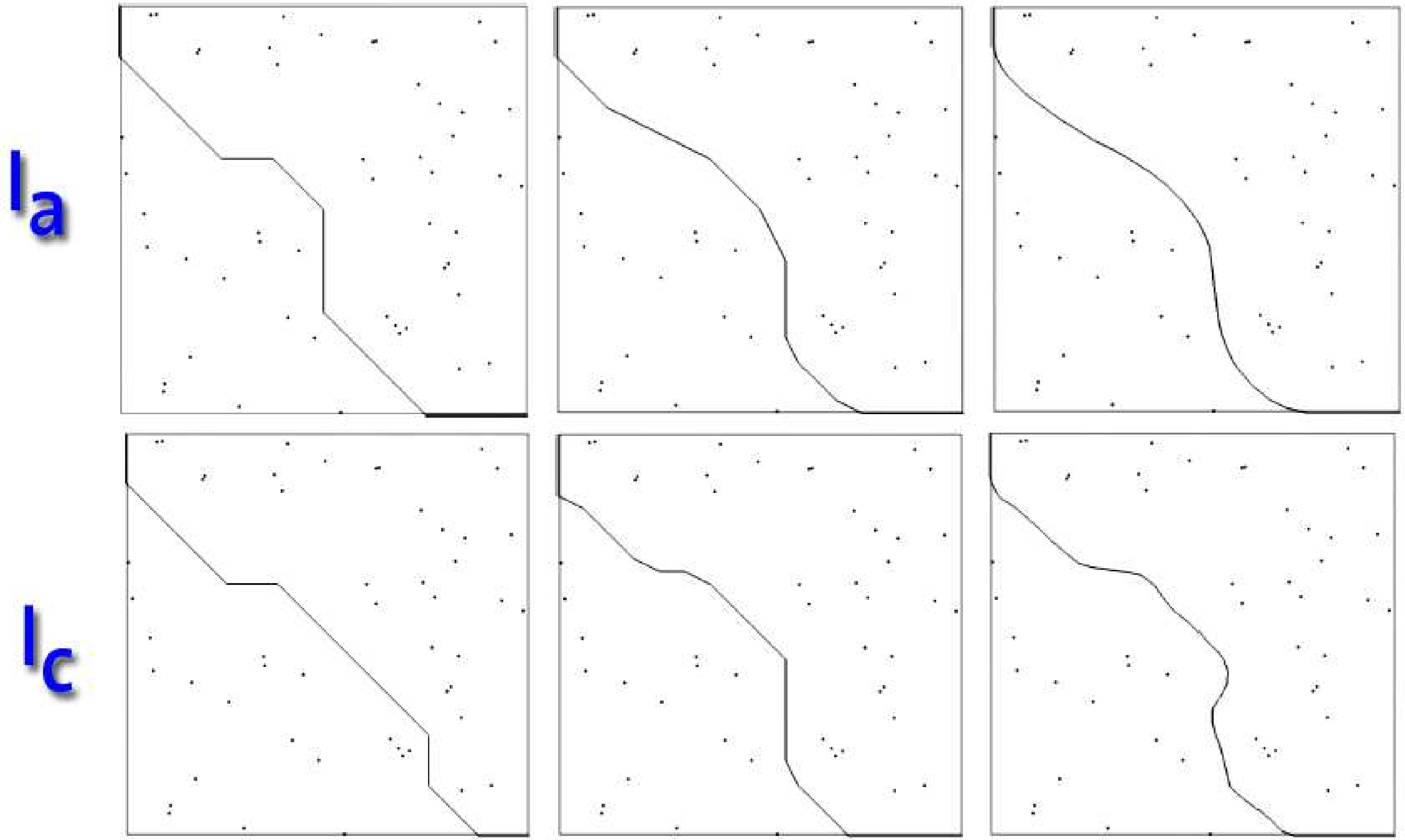

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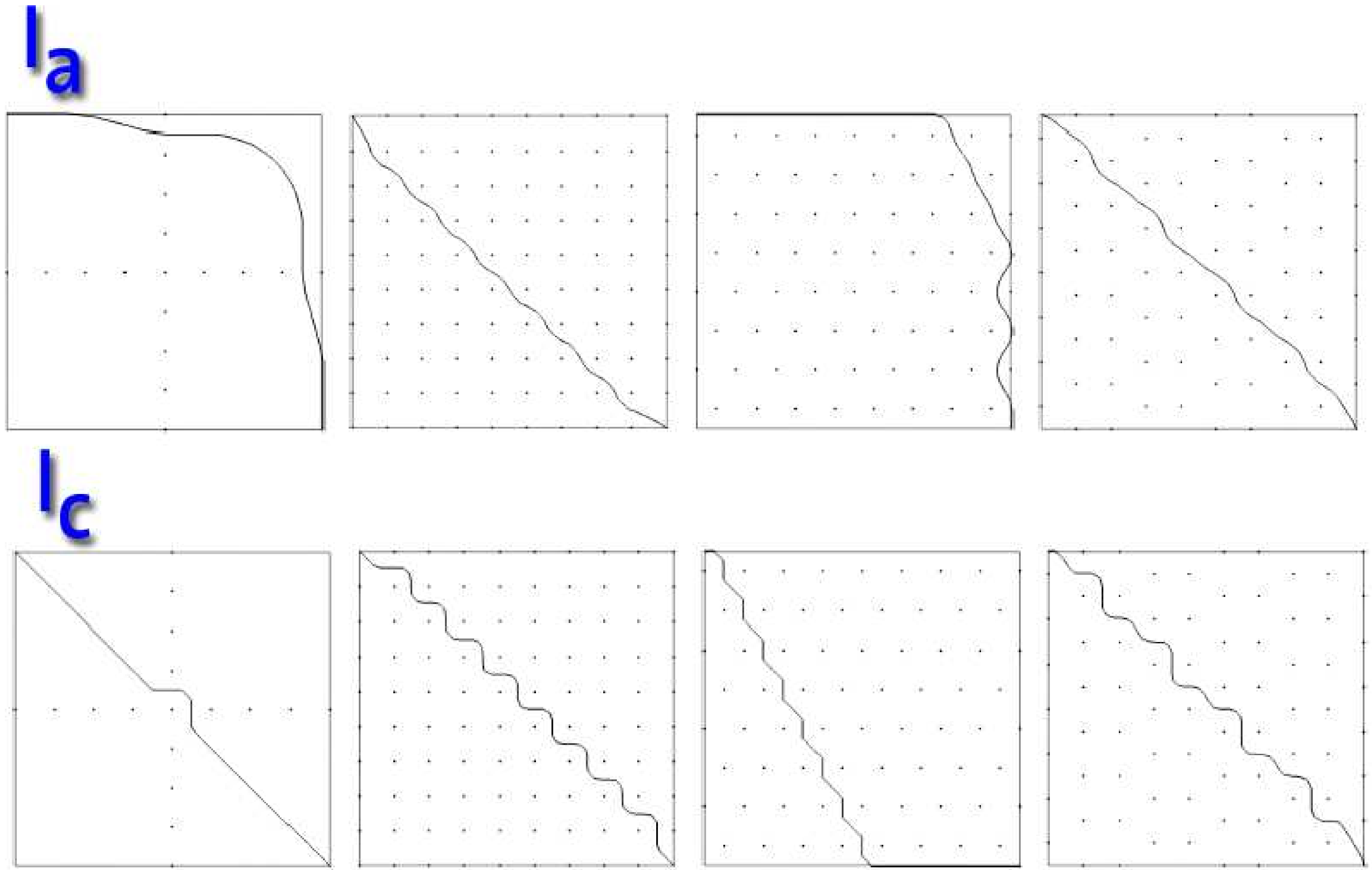
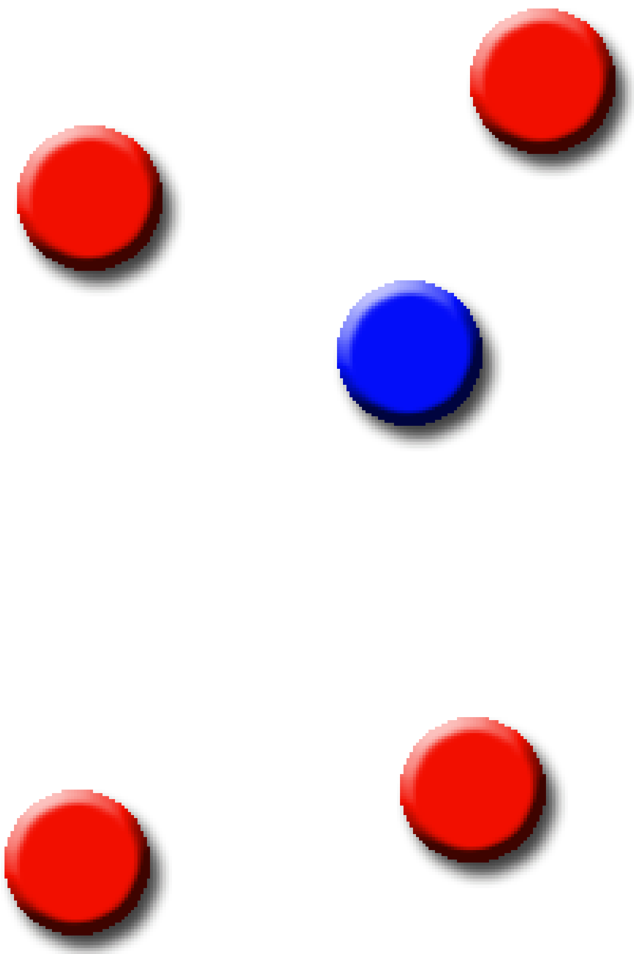


Local knowledge

Assumptions:
- Location knowledge.
- Neighbour knowledge.
- Can compute Voronoi cells.

Specialities:
- Minimal communication.
- Minimize power consumption.

VERSUS
- Response time.



Flooding

- Agent starts algorithm at point p.
- Sensor closest to p computes initial exposure profile (EP).
- Forwards exposures to neighbouring sensors.
- If update smaller:
  - compute new values
  - send updates to concerned sensors
  - update parent
- else
  - send abort back
- Backtrack for solution.

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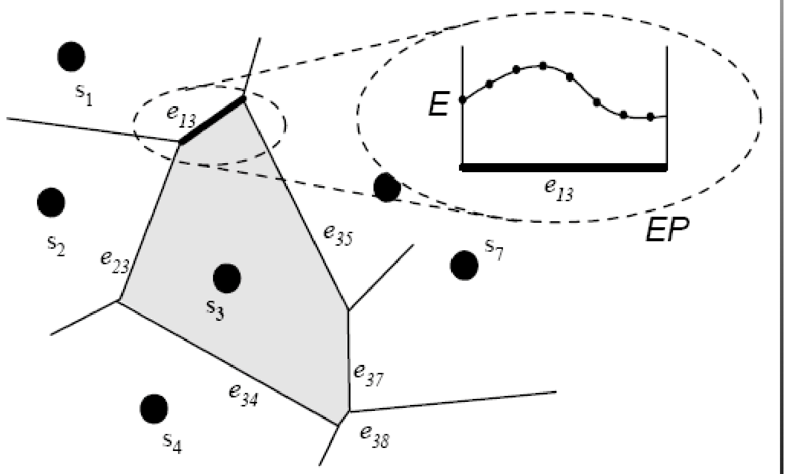

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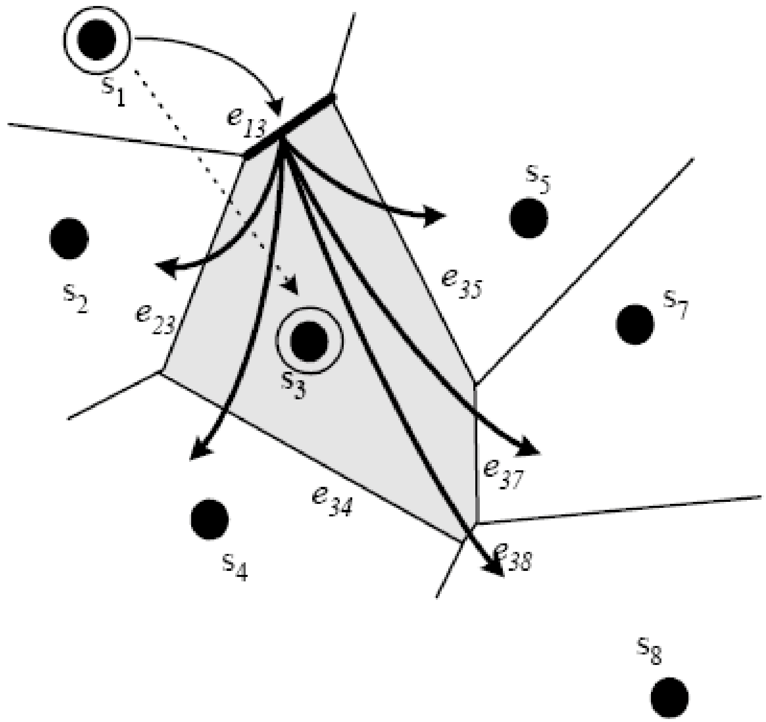

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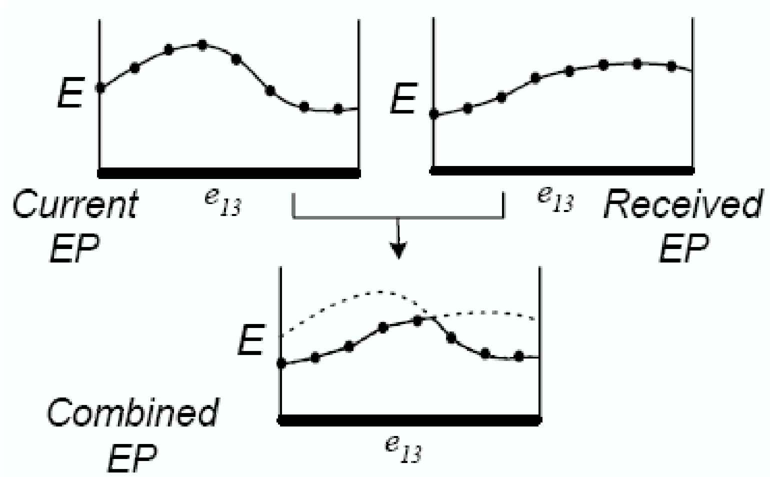

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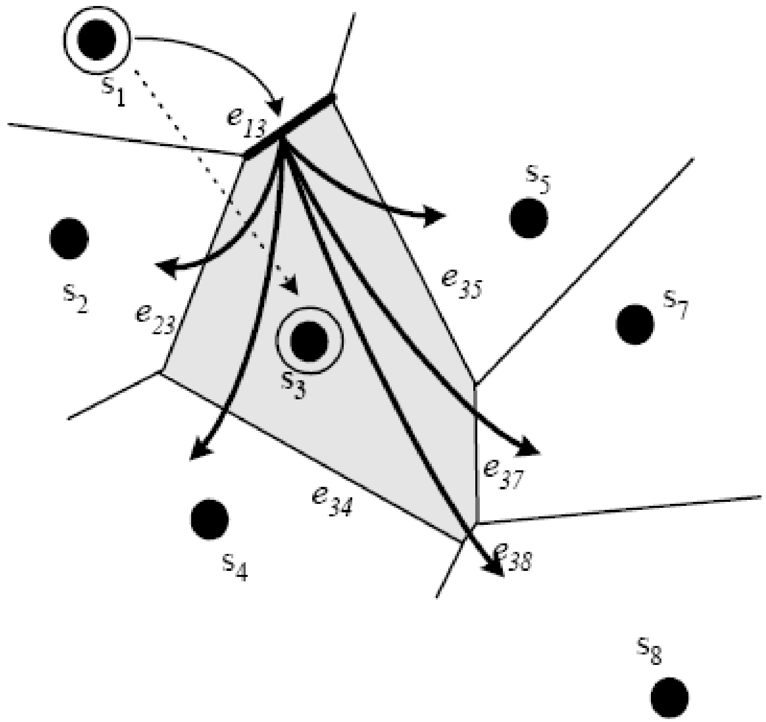
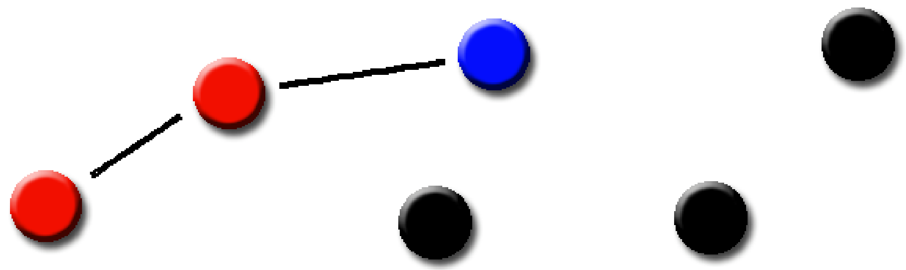


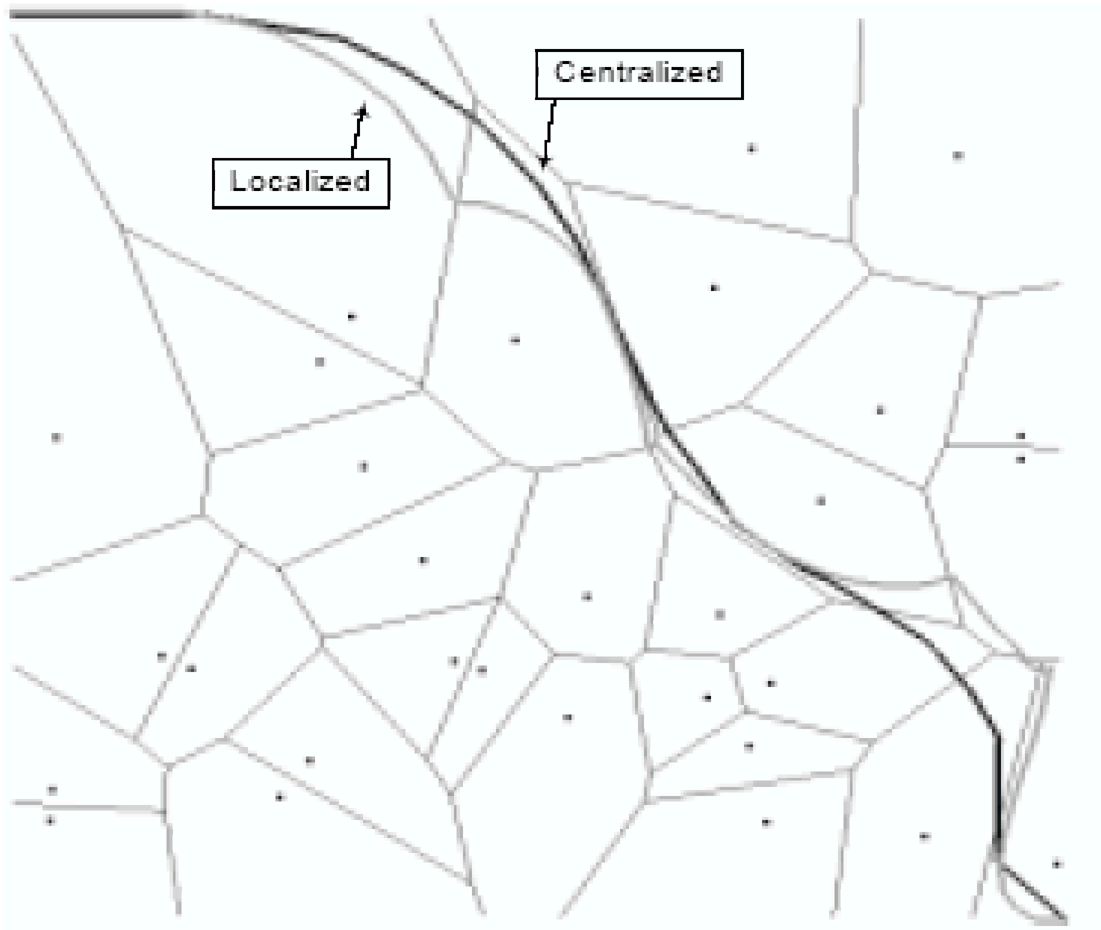
Greedy

- Agent starts algorithm at point p.
- Sensor closest to p computes node exposures in Voronoi cell.
- Forward search message to sensor of most promising node.
- Sensor computes new path portion.
- Returns results.
- Maybe updates parent.
- Recompute most interesting node.



More examples

Flooding:



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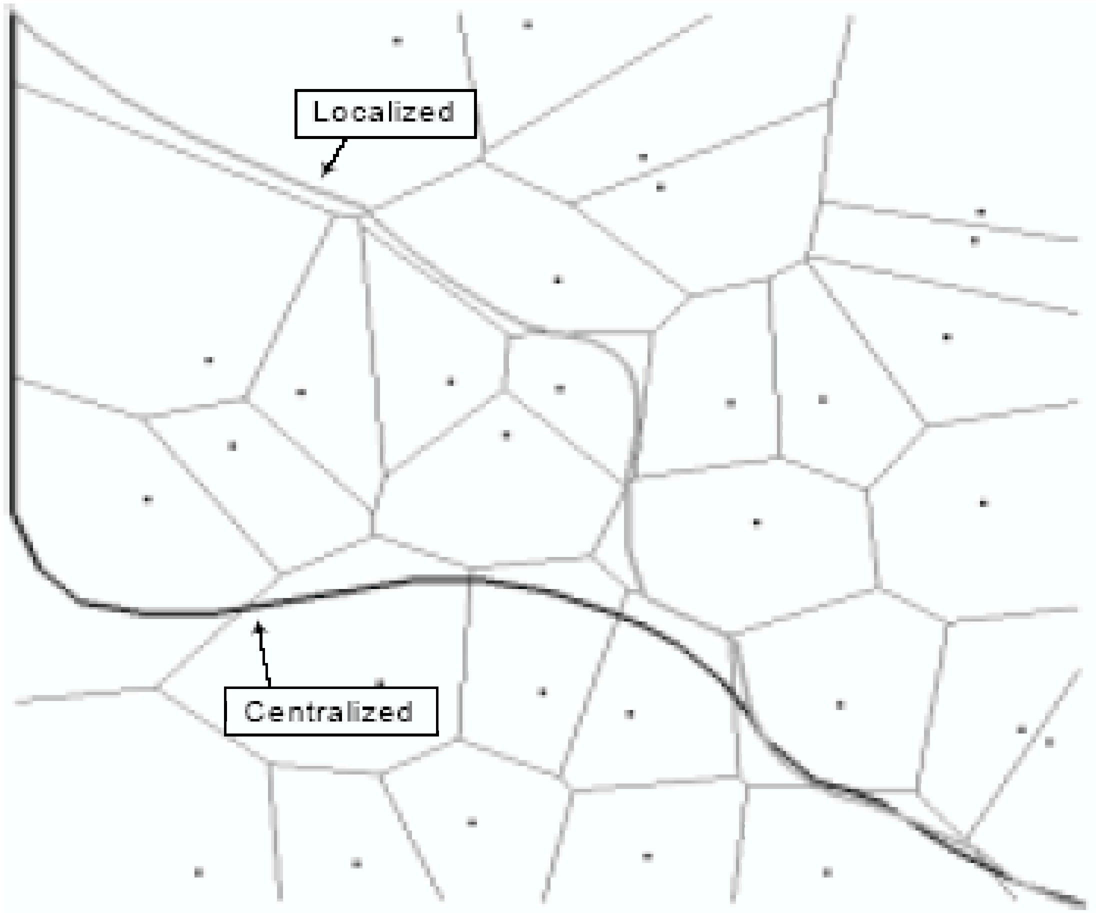
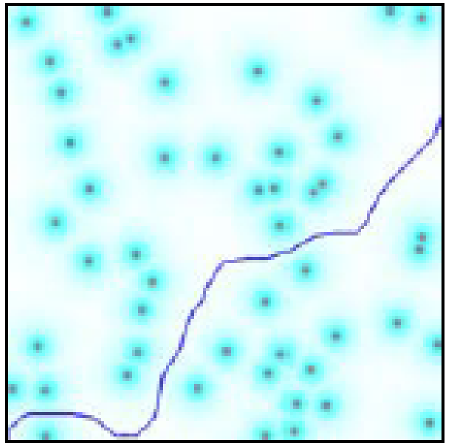


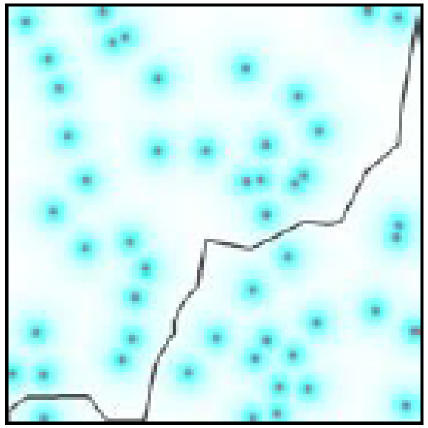
More examples

Greedy:

Centralized algorithm.



Localized algorithm.



More local algorithms?

- Simultated annealing.
- Swarm approach.
- Simplex.
- Genetic algorithms.
- Random-restart hill climbing.
- ...

Recap

What we saw:

- Introduction to sensor networks (location discovery...)
- Introduction to exposure problem.
  - Voronoi diagram
  - mathematical models
- Algorithms for minimal exposure path.
  - centralized knowledge
  - localized knowledge

My opinion

- Interesting theme.

BUT

- Very mathematical.
- Not as creative as I hoped.
- Algorithms much more interesting!

Sources

- **Exposure In Wireless Ad-Hoc Sensor Networks**
  Seapahn Meguerdichian
- **Coverage Problems in Wireless Ad-hoc Sensor Networks**
  Seapahn Meguerdichian
- **Localized Algorithms In Wireless Ad-Hoc Networks: Location Discovery And Sensor Exposure**
  Seapahn Meguerdichian
- **Minimal and Maximal Exposure Path Algorithms for Wireless Embedded Sensor Networks**
  Giacomino Veltri
- **Sensor Deployment Strategy for Detection of Targets: Traversing a Region**
  Thomas Clouqueur
- **Internet:** Wikipedia, Google, ...