MIZAR Automazione S.p.A.

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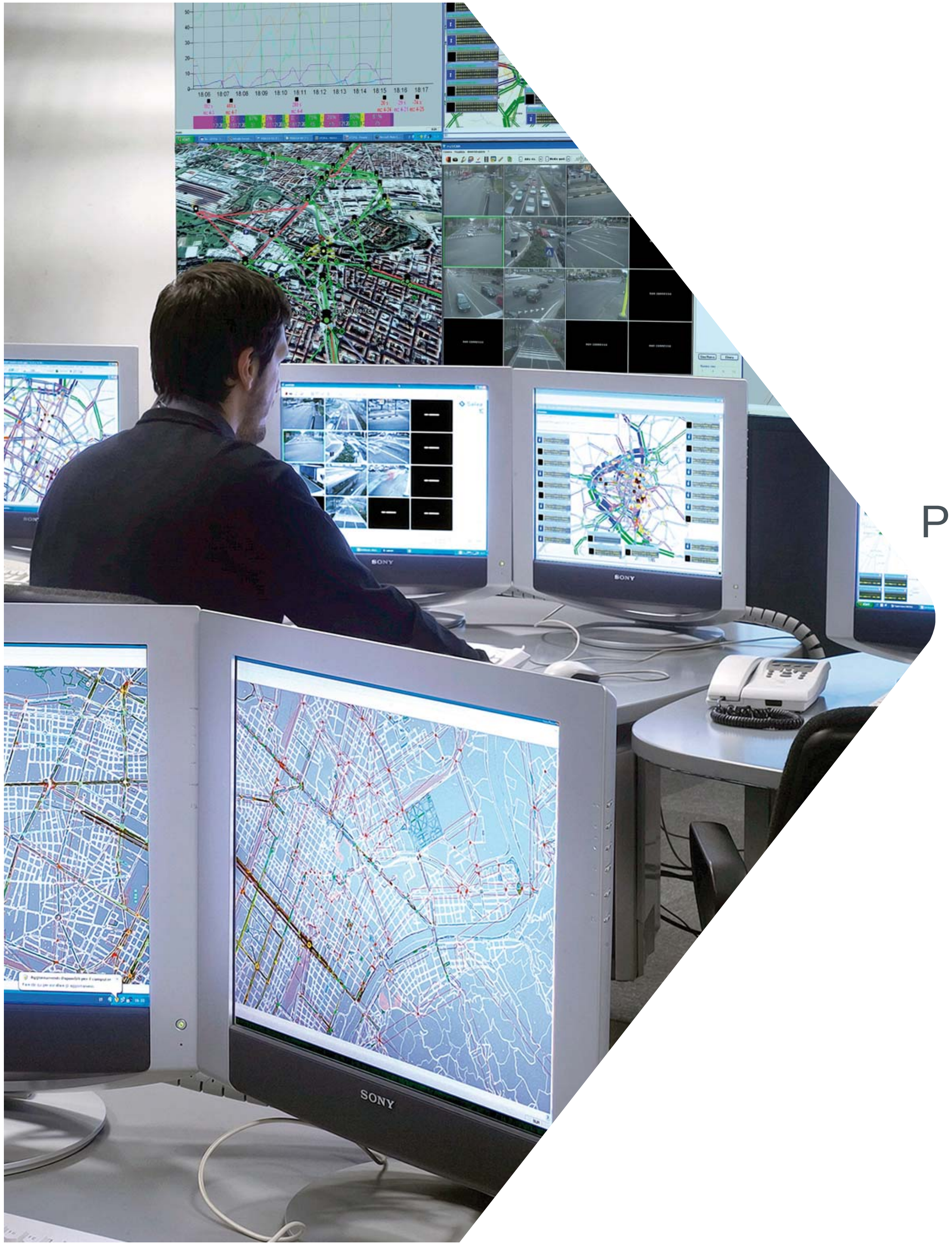
REGIONAL SCALE REAL-TIME O-D MATRIX ESTIMATION

TECHNIQUE AND DEPLOYMENT RESULTS

A Company of the SWARCO Group



Presentation Index

Introduction and Objectives

Traffic Management Systems (TMS), such as MISTIC, are becoming important tools for demand management.

Origin–Destination estimation makes it possible to know the traffic demand on a network, based on traffic measurement and is a key component of TMS.

TMS provide a Traffic Operator and Road Users with:

- A single access point to the traffic state (traffic state, routing service)
- An single interaction point (traffic events, congestion detection)

Cooperative Systems give the chance for a Traffic Operator to “steer” the traffic based on a high level strategy and for the driver to be an “active” part of the system (data source).

The evolution of TMS has to meet following requirements:

- Larger data set (data coming from vehicles)
- Larger networks (from City to Regional Networks)
- Interaction with navigation systems

Problem Statement

Traffic on the Network is represented by Flow between Zones

d_{ij}: traffic demand between *i*–th zone and *j*–th zone (*n* pairs)

f_k: traffic flow on *k*–th network arc (*m* measured arcs)

relationship between demand and arc flow , in Matrix form:

$$\mathbf{f} = \mathbf{Md}$$

where ***M*** is the traffic assignment Matrix.
O-D Estimation can be formulated as:

$$\min \left\| \mathbf{Md} - \mathbf{f} \right\|_2^2 + \left(\mathbf{d} - \mathbf{d}_0 \right)^T \mathbf{\Lambda}^2 \left(\mathbf{d} - \mathbf{d}_0 \right)$$

$$s.t. \mathbf{d} \geq \mathbf{0}$$

$\mathbf{d}_0$ is previous demand, $\mathbf{L}^2$ weighting factor

Proposed Solution

Possible Approach

- Relax problem and iterate on parameter ***L*** if $d_i<0$
- Non Negative Least Square
- Quadratic Programming with inequality constraints
- Convex Programming
- Direct Method
- Iterative Method
- Gradient Based Method

To resolve an unconstrained Problem:

- Gram-Schmidt
- Direct Method
- Kalman Filter
- Taylor Expansion

Gram - Schmidt

Minimum Norm Problem

$$\min \|\mathbf{z}\|^2$$

$$s.t. \begin{cases} \mathbf{Az} = \mathbf{b} \\ \mathbf{z}_1 \geq -\mathbf{d}_0 \end{cases}$$

$$\mathbf{A} = \begin{vmatrix} \mathbf{M\Lambda}^{-1} & \mathbf{I} \end{vmatrix},$$

$$\mathbf{b} = \begin{vmatrix} \Delta\mathbf{f} \\ \mathbf{0} \end{vmatrix},$$

$$\mathbf{z}_1 = \Delta\mathbf{d}$$

$$\Delta\mathbf{d} = \mathbf{d} - \mathbf{d}_0,$$

$$\Delta\mathbf{f} = \mathbf{f} - \mathbf{Md}_0$$

Direct Method

Direct Solution, when *m<<n*

$$\Delta \mathbf{d} = \mathbf{\Lambda}^{-2}\mathbf{M}^{T}\left(\mathbf{I} + \mathbf{M}\mathbf{\Lambda}^{-2}\mathbf{M}^{T}\right)^{-1}\Delta \mathbf{f}$$

$$\Delta \mathbf{d} = \mathbf{d} - \mathbf{d}_0,$$

$$\Delta \mathbf{f} = \mathbf{f} - \mathbf{M}\mathbf{d}_0$$

Kalman filter

Kalman Filter can be applied, where an iteration step can also be used to reduce the number of measures (e.g. one measure update)

$$\begin{cases} \mathbf{d}_{k+1} = \mathbf{d}_k + \mathbf{v}_k \\ \mathbf{f}_k = \mathbf{M}_k \mathbf{d}_k + \mathbf{w}_k \end{cases}$$

$$s.t.\mathbf{d}_{k+1} \geq 0$$

Taylor Expansion

The Taylor Expansion is used to resolve the Direct Method Problem. The Sub-problem:

$$\mathbf{z} = \left(\mathbf{I} + \mathbf{M}\boldsymbol{\Lambda}^{-2}\mathbf{M}^T\right)^{-1}\mathbf{f}$$

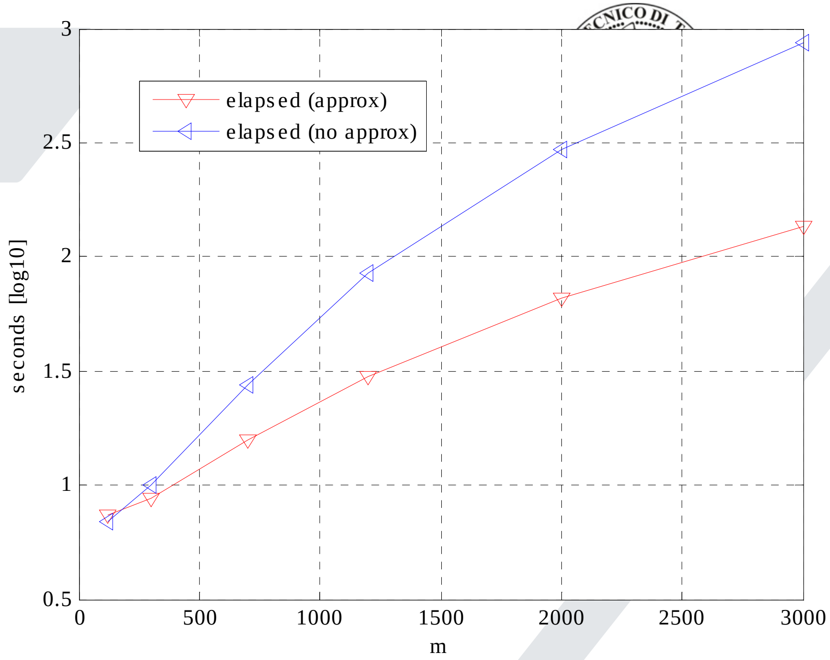
Is approximated with the Taylor series

$$\mathbf{z} = \sum_{i=0}^{K} a_i \left(\mathbf{M}\boldsymbol{\Lambda}^{-2}\mathbf{M}^T\right)^i \mathbf{f}$$

Where a_i are computed to minimize

$$\min_{a_i} \left\| \mathbf{f} - \left(\mathbf{M}\boldsymbol{\Lambda}^{-2}\mathbf{M}^T\right)\mathbf{z} \right\|$$

Complexity and Performance Analysis

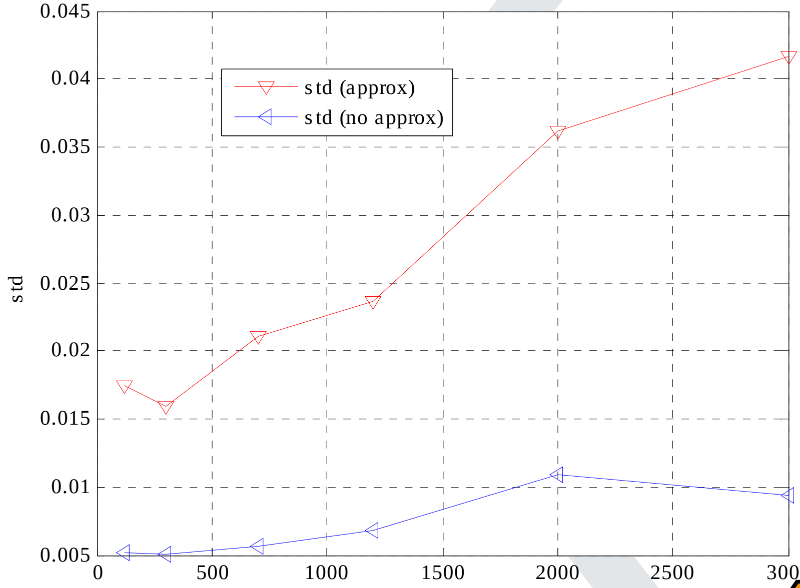


Original Direct formulation

- $O(m^3 + nm^2)$

Taylor Expansion, requires

- $O(K^3 + Kmn)$
- Where K is the degree of expansion of the Taylor series



Performance loss is low with compare to speed advantage

- 2% sparcity factor,
- n=100'000,
- m between 120 and 3'000

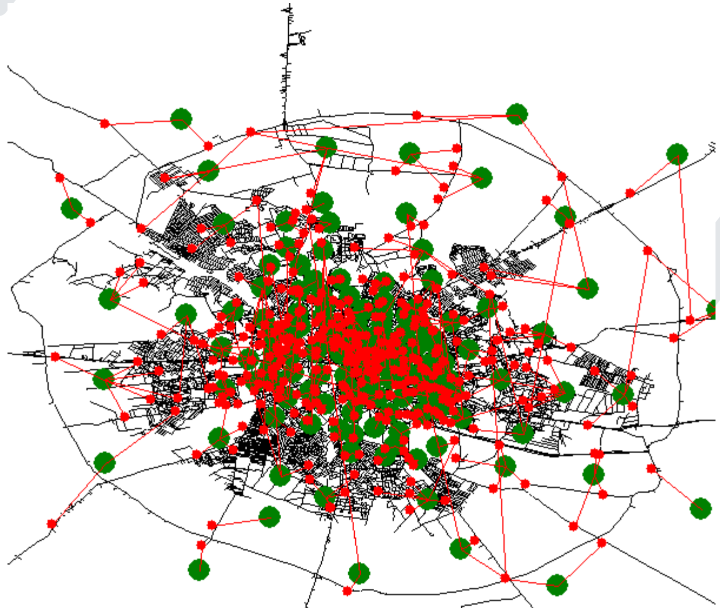
m=3000, error of 4% vs 1% and speed 10x

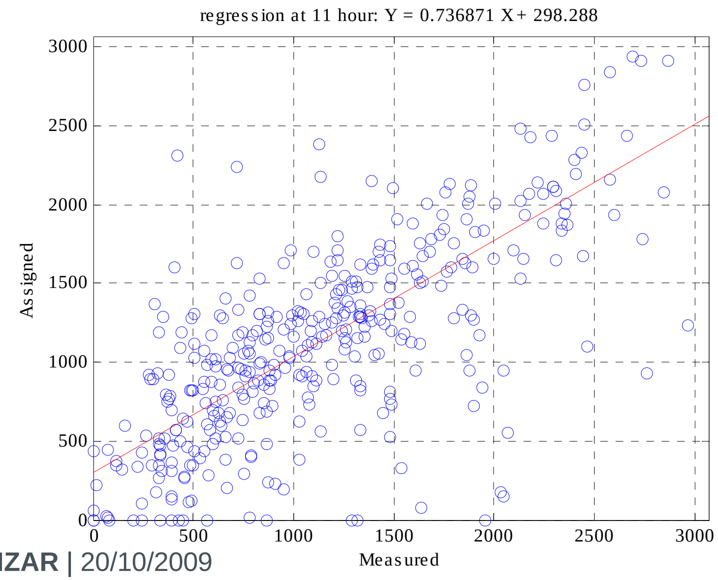
BUCAREST

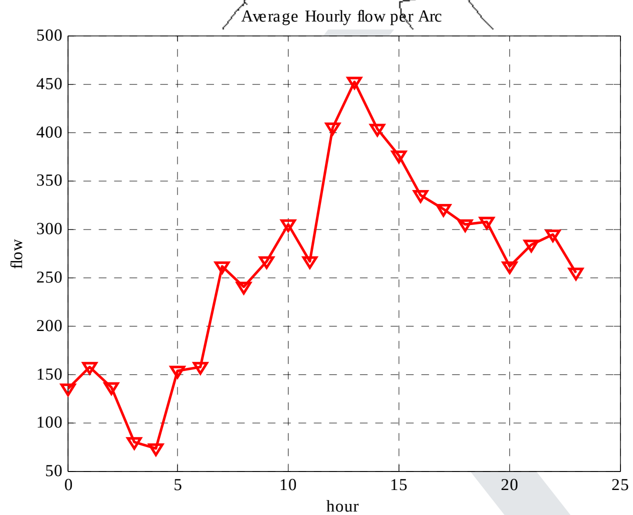
A high level network made up of about 12,000 arcs and 140 zones

O-D Estimation problem of 400x19,600

Performance reduced from 30 minutes to 2 minutes on typical server.



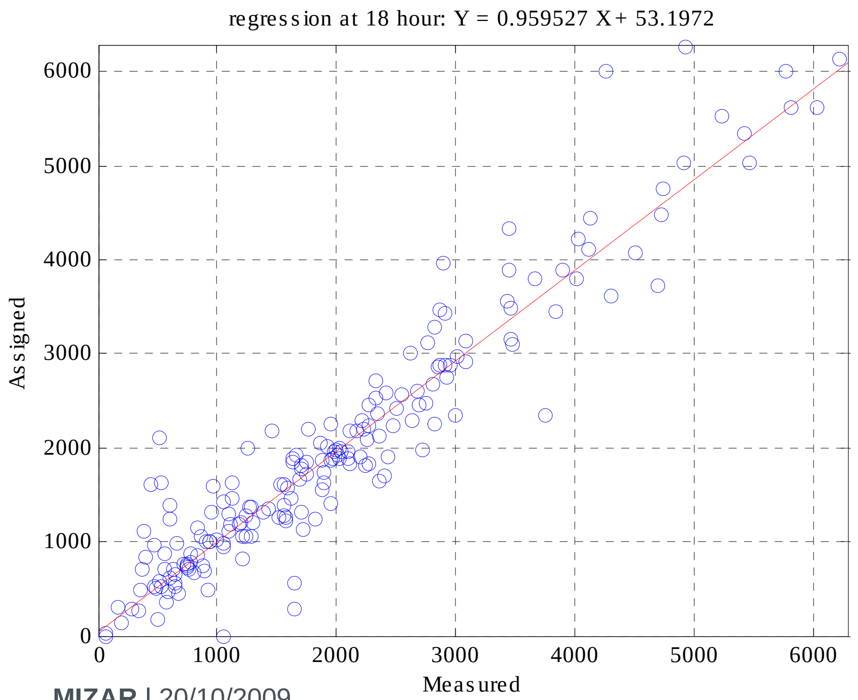


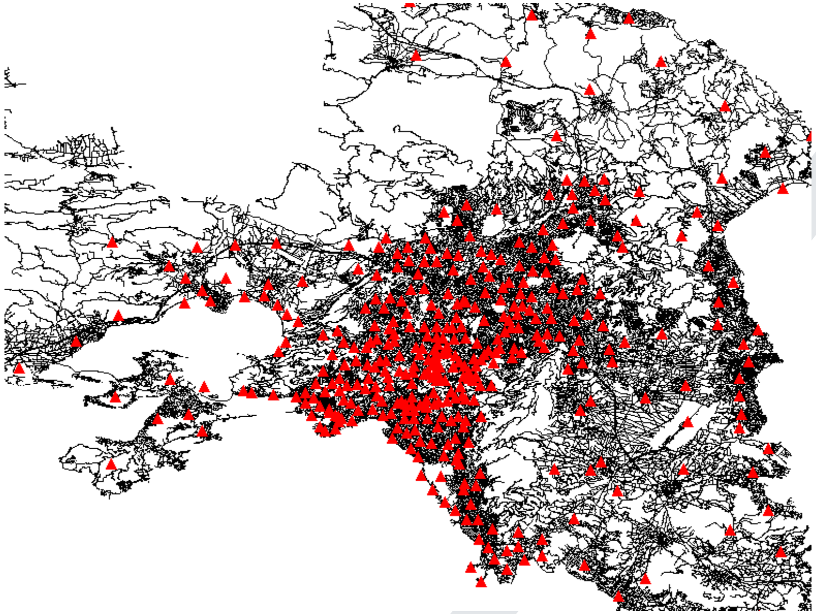


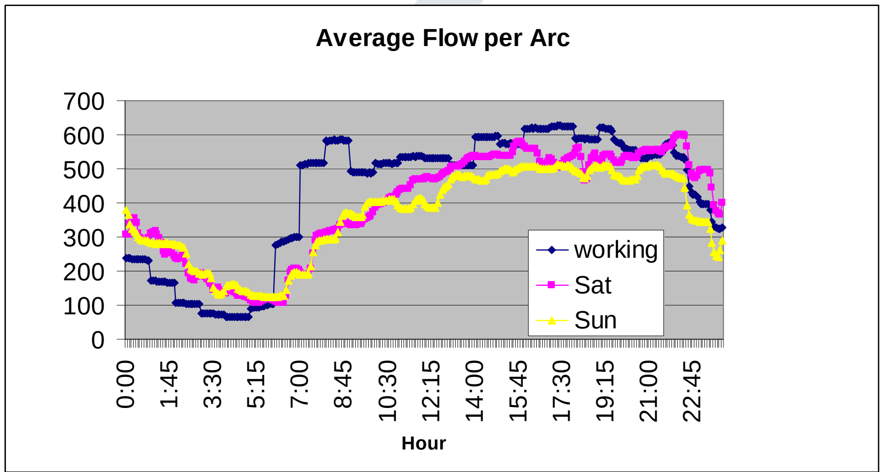
Attika Region

A high level network made up of 13,000 arcs, 5,000 nodes, 400 Zones

OD estimation with 160,000 OD-pairs







Conclusions and further work

TMS with approximate solution methods can estimate traffic demand on regional level using data from ground traffic collection systems and possibly with data from probe vehicles (FCD)

Speed computation improvement can be used to increase network size or increase time resolution.

A hierarchical TMS system can be designed to integrate information from regional systems to build a national TMS.

Thank you for your attention

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