Reactive dynamic traffic assignment in discrete-continuous large networks

Multiscale traffic flow simulation in very large networks

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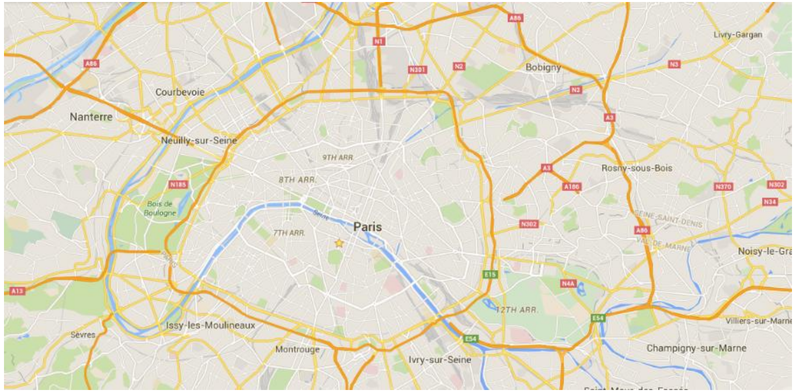
Outline

1. Introduction
2. Motivation & AIMS
3. The bi-dimensional traffic theory
4. Reactive dynamic assignment
5. Multiscale traffic flow modeling
6. Numerical Simulation
7. Conclusion and Perspectives

The scales with principal simulators

- **Several traffic/transport simulators which represent networks traffic in different scales. Scales are:**
  - Microscopic
  - Macroscopic: LWR, GSOM (Payne-Whitham, ARZ, Zhang, Colombo 2 phases) family models
  - **Two-dimensional → BTF** (Bi-dimensional Traffic Flow) **model**
- **Traffic simulators:**
  - SUMO
  - MATSim with VIA/OTFVIS, Dynameq 4, etc.
  - **BidiTSim:** the Bi-dimensional transport simulator

Ile de France road's network map

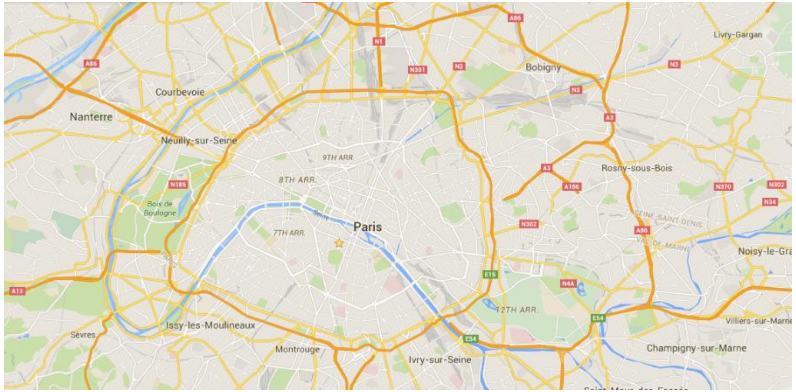


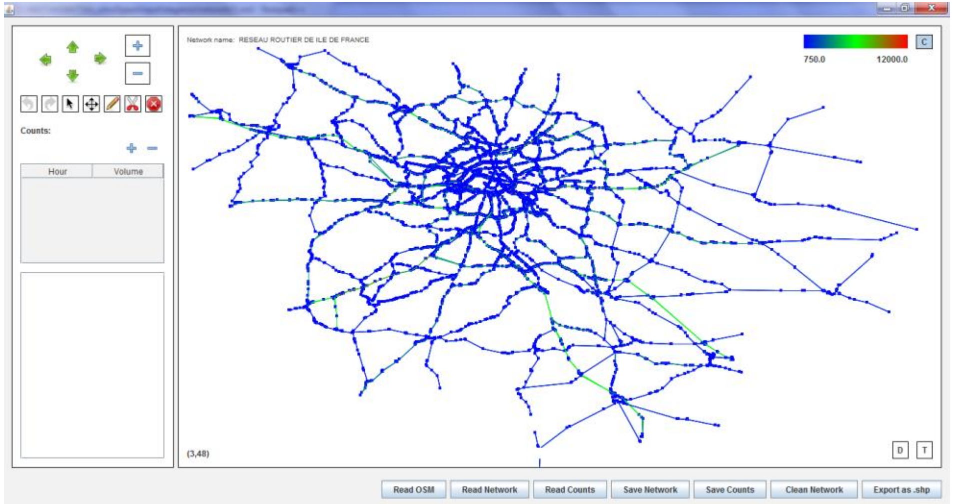
Ours AIMS:

- Traffic prediction/estimation
- Traffic regulation

of large networks comprising highways (the main roads) and urban area (the secondary roads).

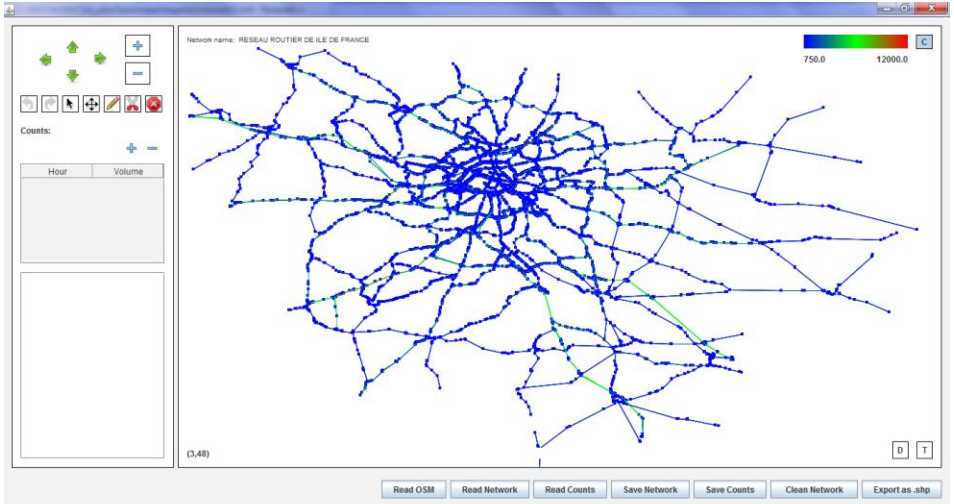
Ile de France road's network map





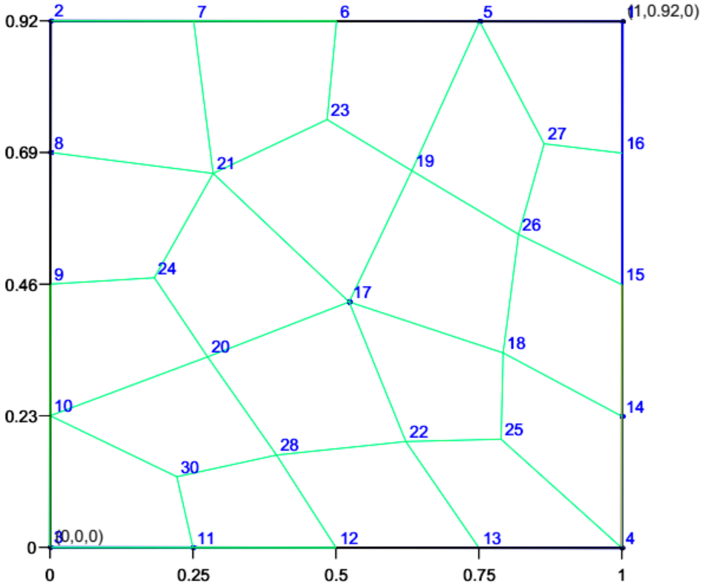
The network viewed in networkEditor of MATSim

- **Main issues:**
  - A huge number of arcs & nodes
  - Cumbersome calculations
  - Long time to get traffic outputs
- **Challenges:**
  - Find a good scale for traffic modeling -> Refine the traffic flow theory to achieve our goals
  - Get proper representation of traffic conditions on large network based on **the bi-dimensional traffic theory**

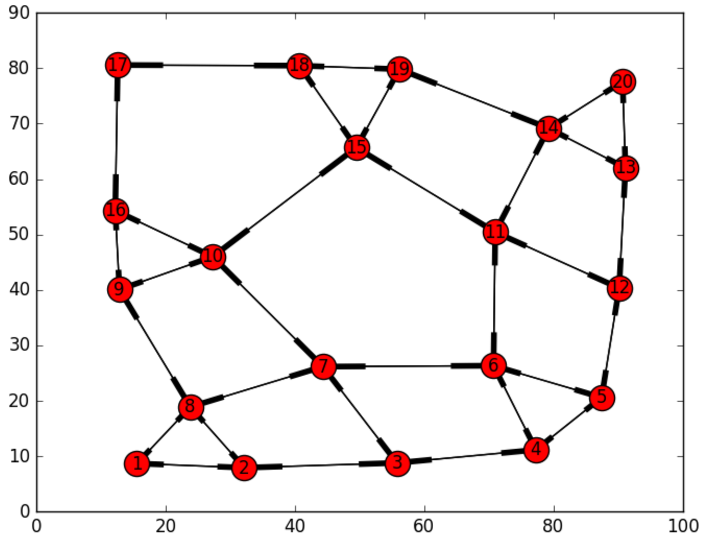


The network viewed in networkEditor of MATSim

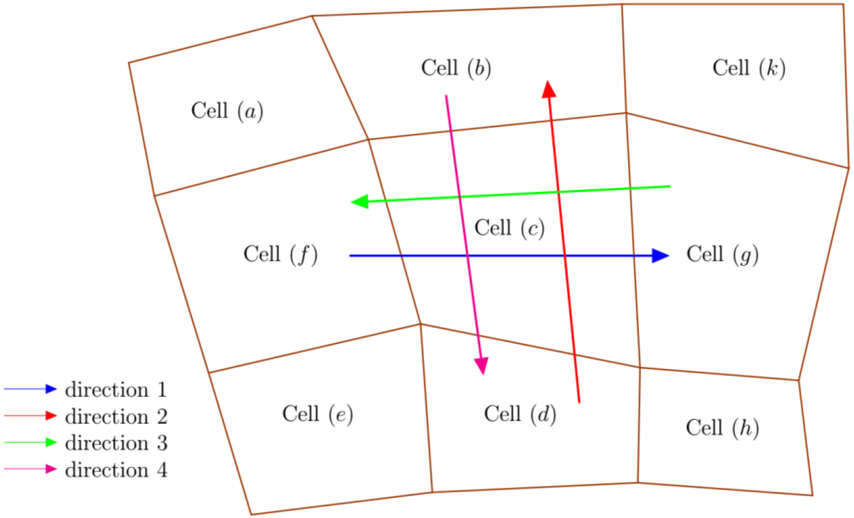
Simplification of the urban network: Network-domain



Zone-based representation of the Network-domain



Considered dominant directions within 2d cells/ traffic zones

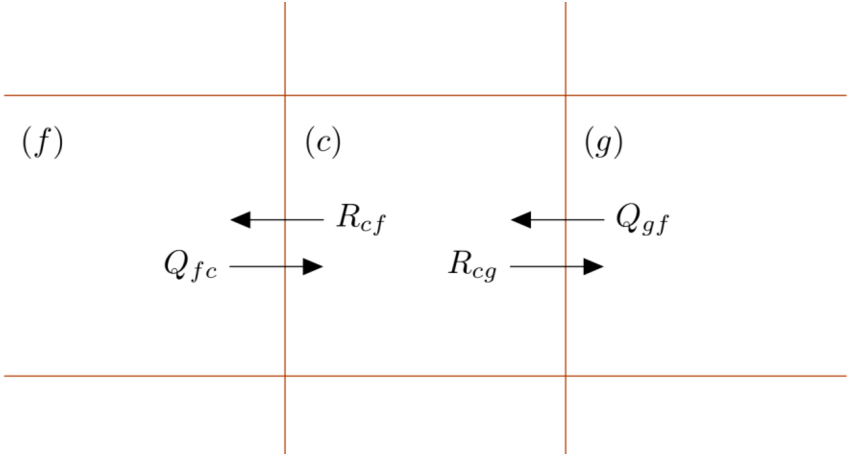


Flow optimization at internal intersections of 2d cells

$$\max_{(q,r)} \left(\sum_{i=1}^{4} \Phi_i(q_i) + \sum_{j=1}^{4} \Psi_j(r_j) \right)$$

$$\text{s.t.} \quad \left| \begin{array}{ll} 0 \leq q_i \leq \Delta_{ci}^{t+1/2}, & \forall i \in \{1,2,3,4\}, \\ 0 \leq r_j \leq \Sigma_{cj}^{t+1/2}, & \forall j \in \{1,2,3,4\}, \\ -r_j + \sum_{i=1}^{4} q_i \Gamma_{c,ij}^{t} = 0, & \forall j \in \{1,2,3,4\}. \end{array} \right.$$

Traffic changes between 2d cells/ zones



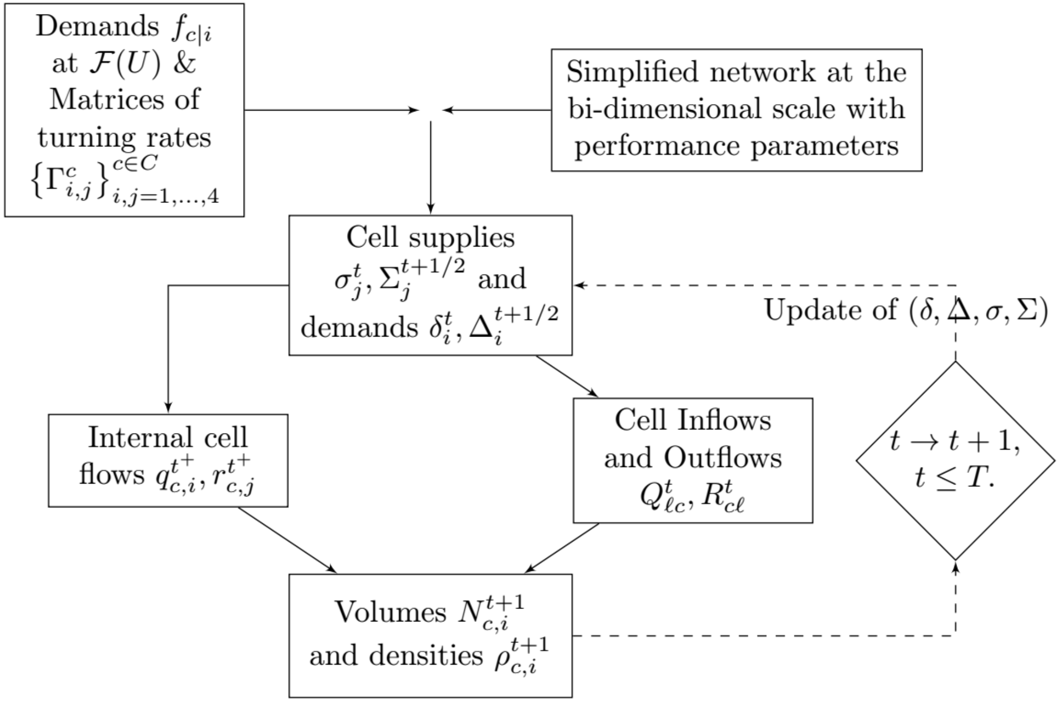
From the Law of the minimum

(Ref. LEBACQUE and al.)

$$\left[\begin{array}{l} Q_{\ell c}(t) = \min\left(\delta_{\ell,\ell->c}(t), \sigma_{c,\ell->c}(t)\right) \\ R_{c\ell}(t) = \min\left(\delta_{c,c->\ell}(t), \sigma_{\ell,c->\ell}(t)\right) \end{array}\right.$$

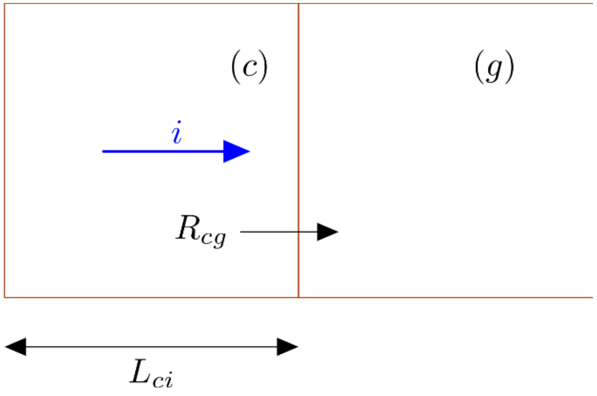
$$N_{c,i}(t+\delta t) = N_{c,i}(t) + \left(Q_{fc}(t) - R_{cg}(t) + r_{c,i}(t^+) - q_{c,i}(t^+)\right)\delta t$$

Bi-dimensional network flow computing engine



Travel cost

$$\varpi_{cg}(t) \approx N_{c,i}(t)/R_{cg}(t)$$

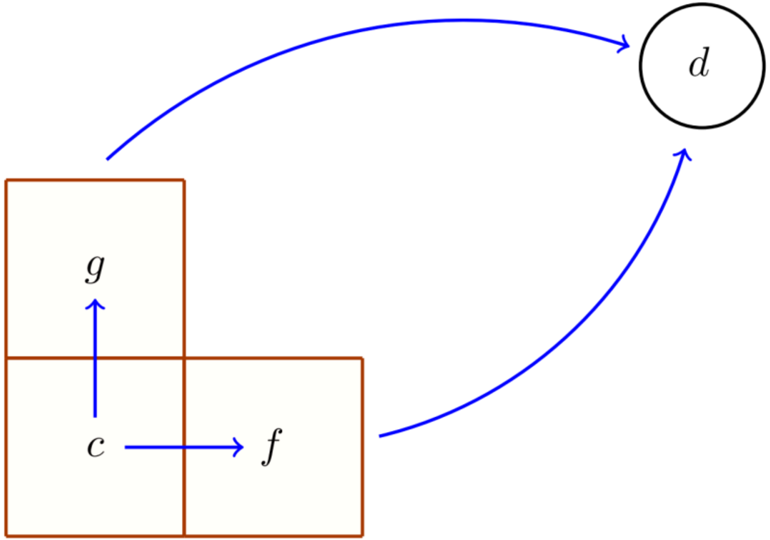


Instantaneous travel time

$$ITT(\text{path};t) = \int_{\text{path}} d\chi/V(\chi,t)$$

Logit formulation (1)

$$\pi_c^d(t) \quad \rightarrow \quad \begin{cases} \varpi_{cf}^t + \pi_f^d\left(t + \varpi_{cf}^t\right) = C_f^d(t) \\ \varpi_{cg}^t + \pi_g^d\left(t + \varpi_{cg}^t\right) = C_g^d(t)\,. \end{cases}$$

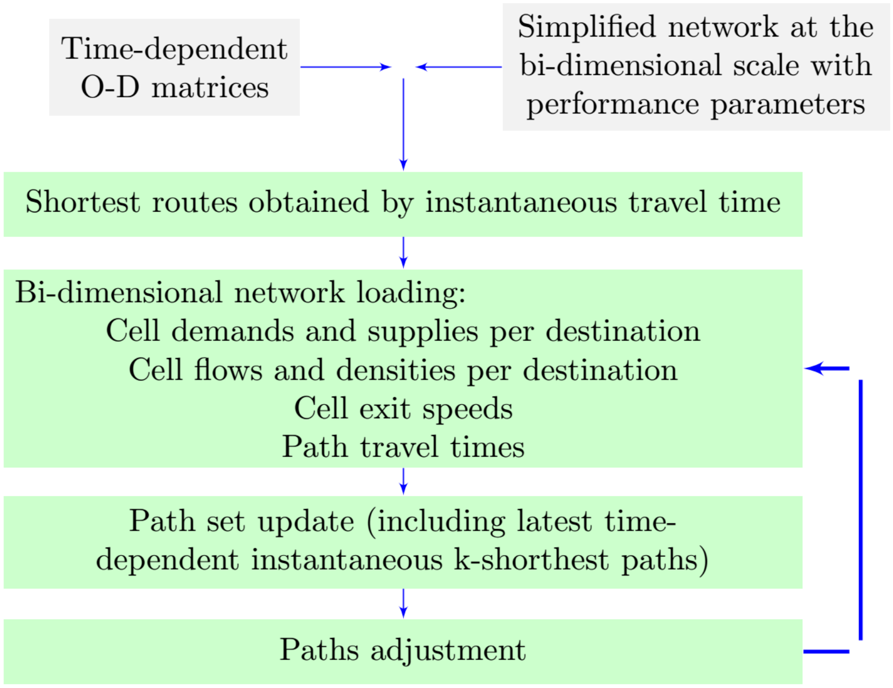


Logit formulation

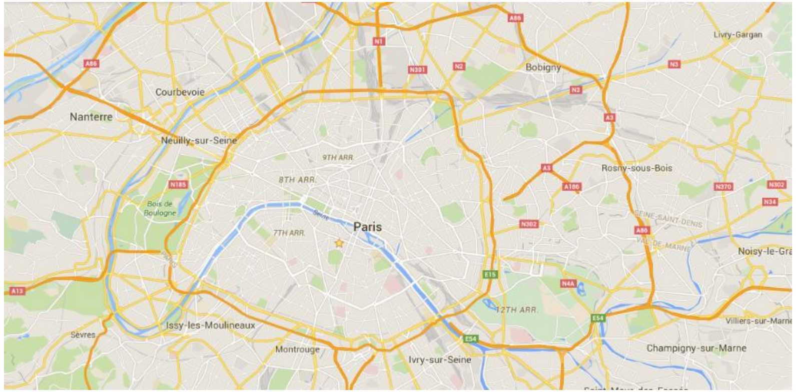
The Probability of route's choice by users is formulated as follows:

$$\begin{cases} \mathrm{P}((\text{choice} = (f)/\text{Dest.} = d)(t) = \dfrac{\exp\left(-\theta C_f^d(t)\right)}{\exp\left(-\theta C_f^d(t)\right) + \exp\left(-\theta C_g^d(t)\right)} = \mathscr{F}_{cf}^d(t) \\ \\ \mathrm{P}(\text{choice} = (g)/\text{Dest.} = d)(t) = \dfrac{\exp\left(-\theta C_g^d(t)\right)}{\exp\left(-\theta C_f^d(t)\right) + \exp\left(-\theta C_g^d(t)\right)} = \mathscr{F}_{cg}^d(t) \,. \end{cases}$$

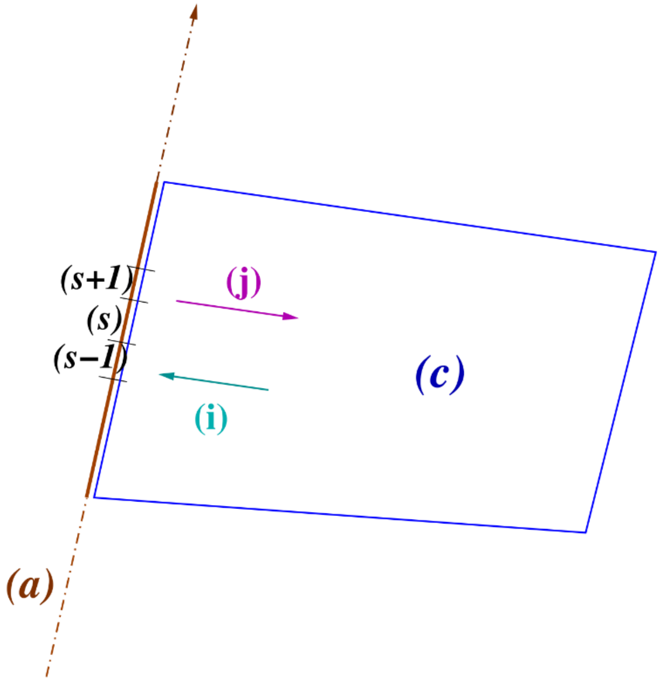
Reactive Dynamic Traffic Assignment Scheme



Ile de France road's network map



Traffic change between links and 2d Cell



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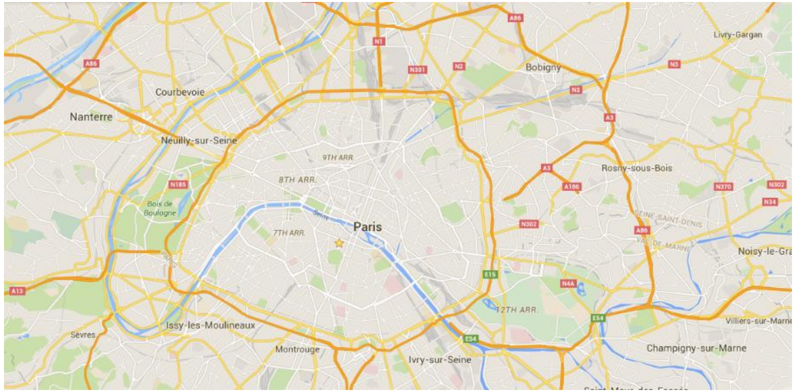

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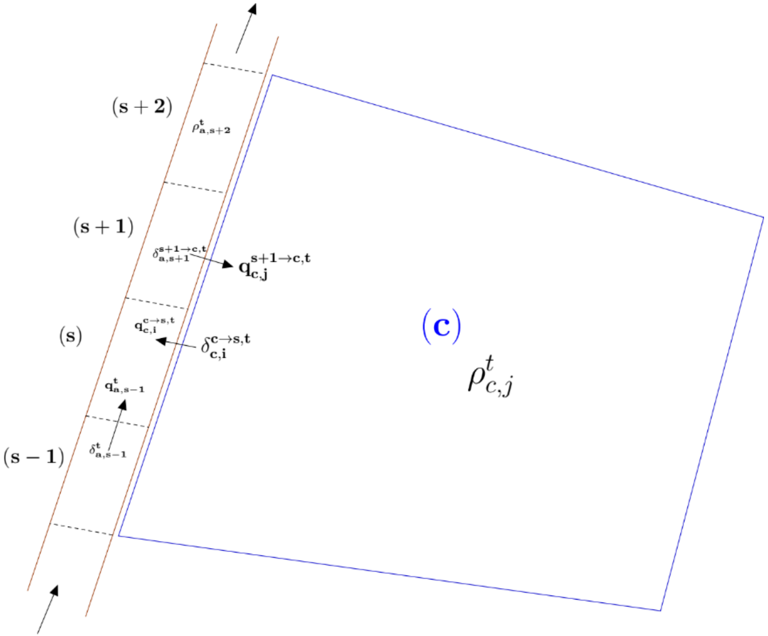
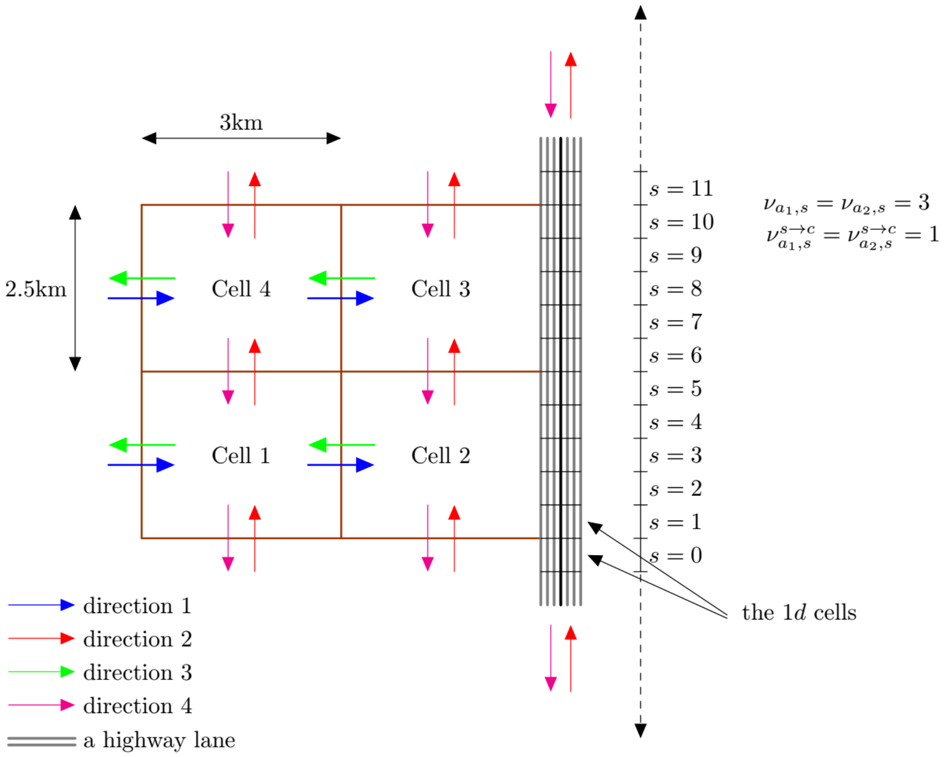


Case Study

Number of lanes in 2d cells

Nu_c1	26
Nu_c2	25
Nu_c3	23
Nu_c4	21



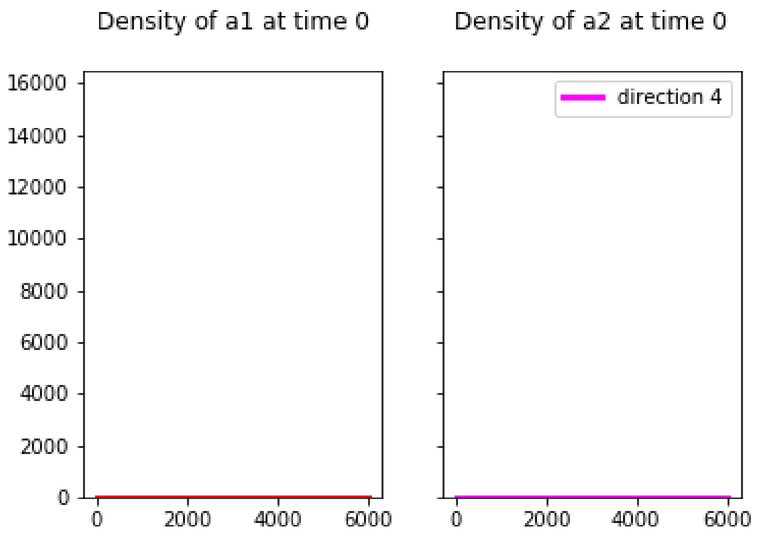
Characteristics of the surface network (network domain)

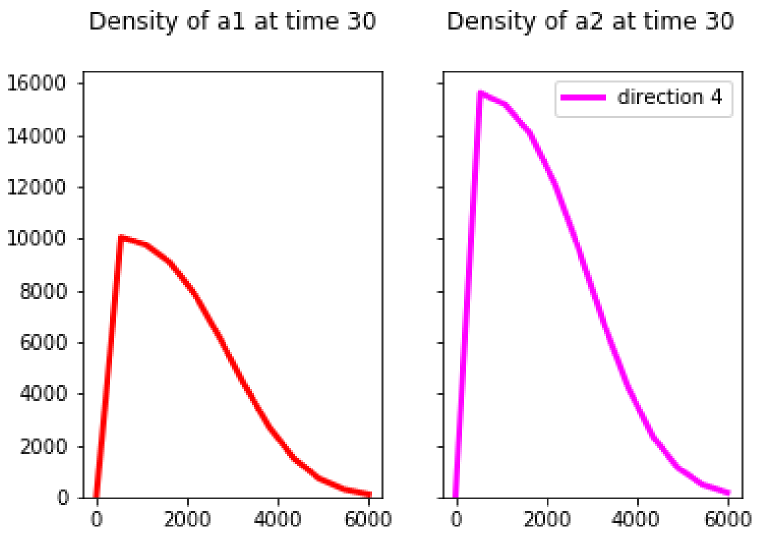
Maximal density	236.25 Veh/km/lane
Critical density	33.75 Veh/km/lane
Maximal velocity	80 km/h/lane
Maximal flow	2700 Veh/h/lane

Characteristics of the principal artery for GSOM flow computing

Maximal density	720 Veh/km/lane
Critical density	97.2 Veh/km/lane
Maximal velocity	50 km/h/lane
Maximal flow	1350 Veh/h/lane

Evolution of the Density on Arteries





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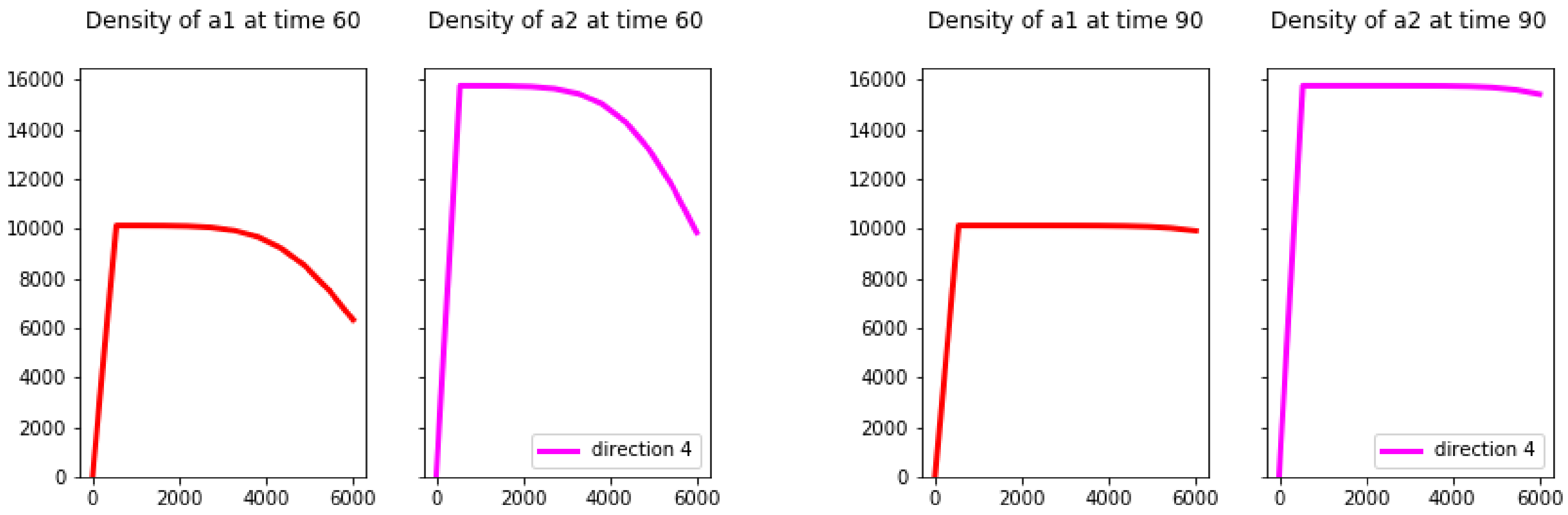

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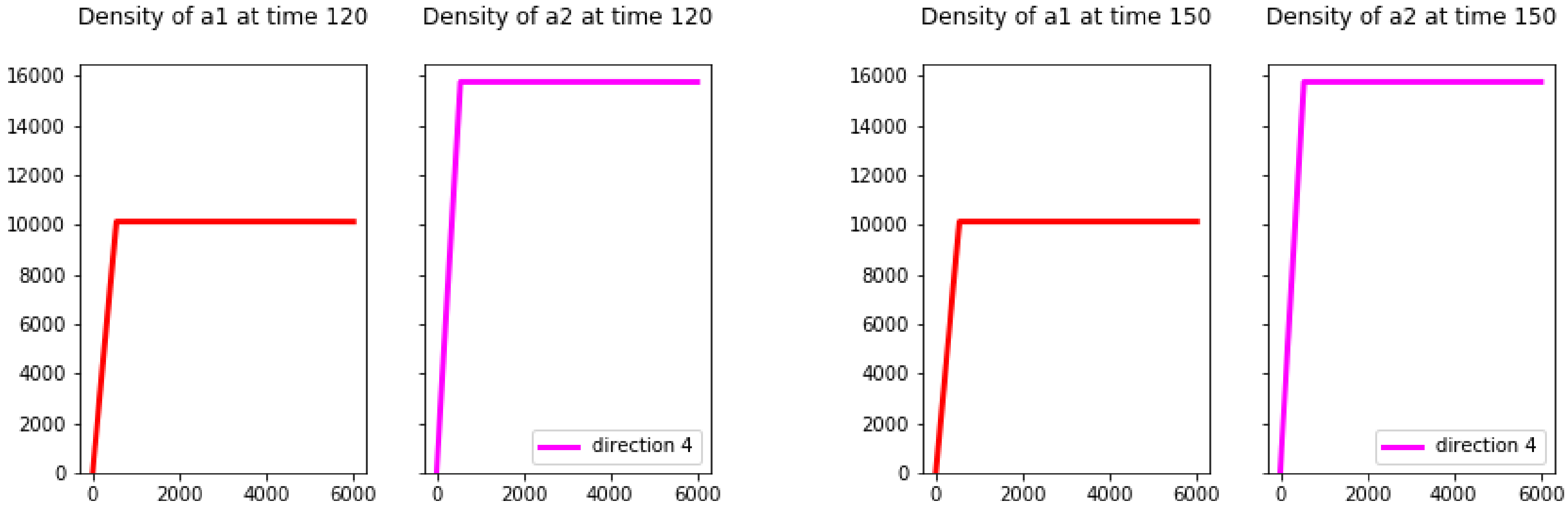
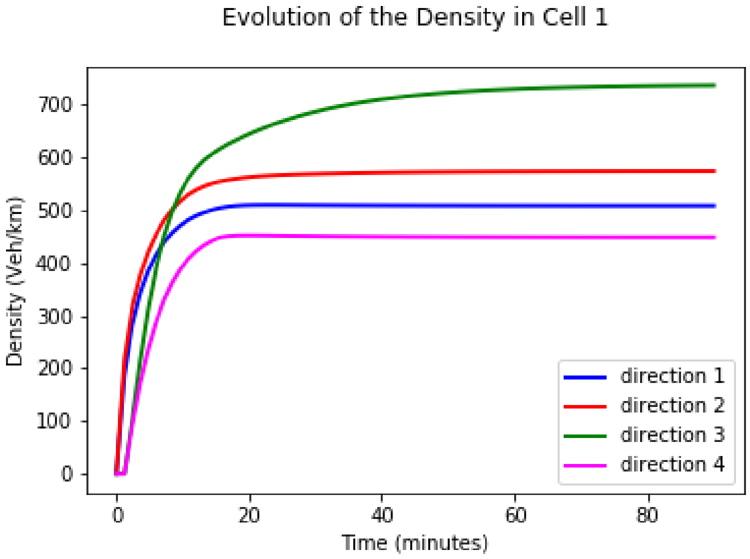
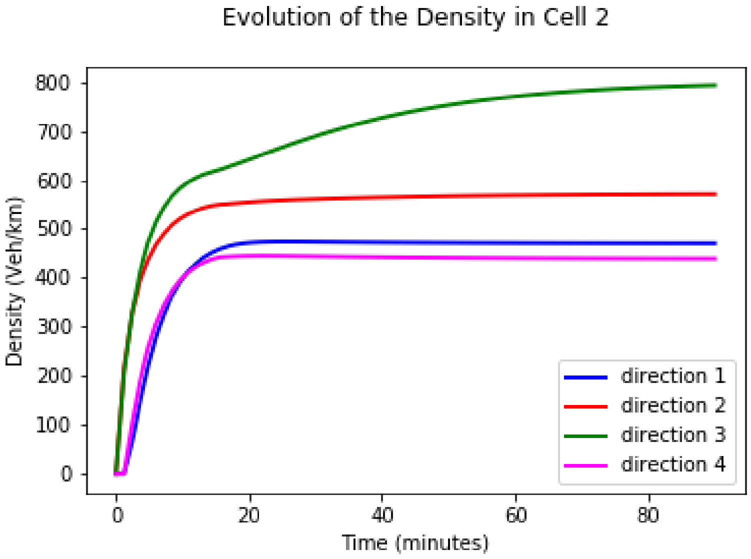
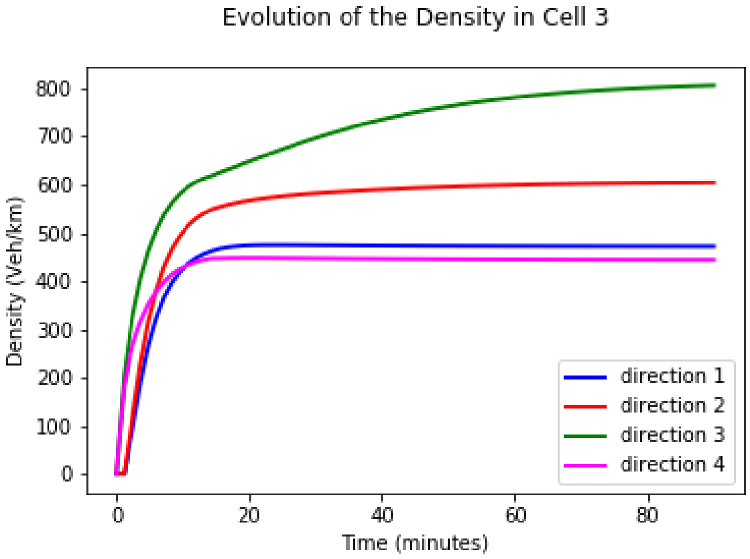


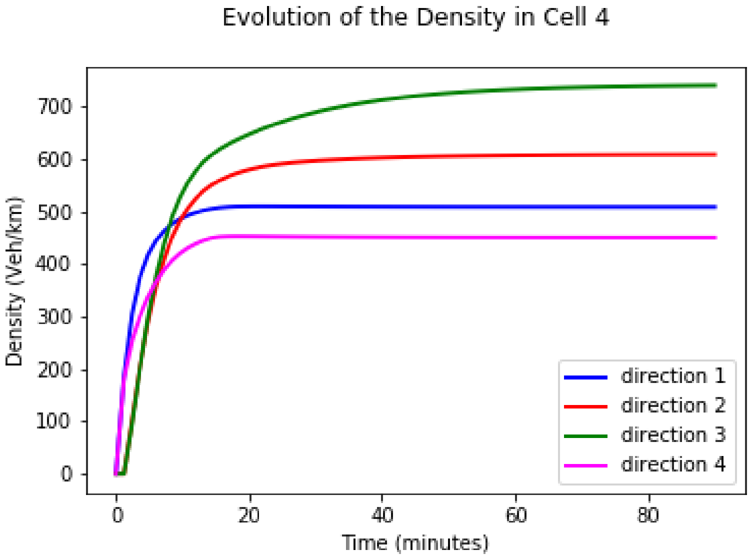
Evolution of the Density on 2d Cells



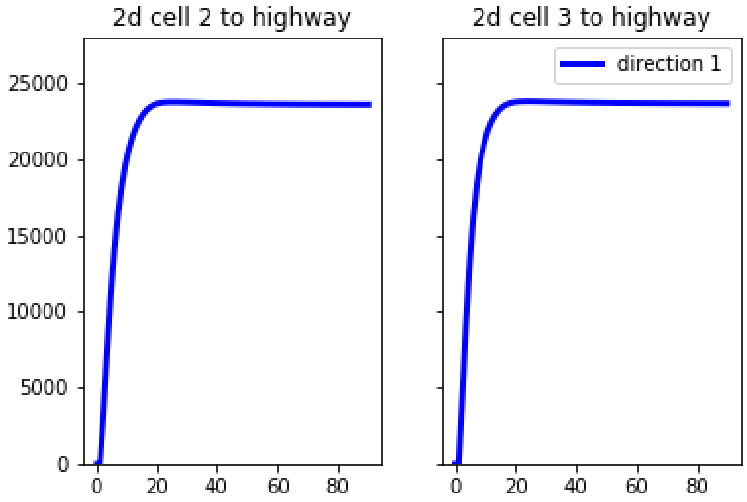


Evolution of the Density on 2d Cells

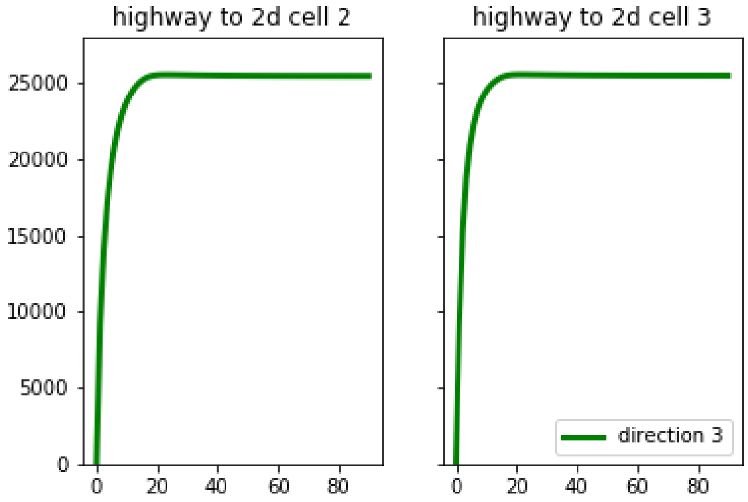




Flow from 2d Cells to Arteries



Flow from Arteries to 2d Cells



Conclusion

1. Reduction of cumbersome calculations when large networks is involved
2. Traffic flow estimation ← Traffic information and Instantaneous travel time

Perspectives

1. Automatic detection of dominant directions of propagation
2. Automatic detection of number of routes and lanes of bi-dimensional (2d) cells
3. Application of the **multiscale traffic flow model** to Real case scenarios
4. Take into account Traffic attributes:
    1. modes of transportation
    2. Class of vehicles

Some References

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2. SOSSOE, K., and LEBACQUE, J.-P. **Reactive Dynamic Assignment for a Bi-dimensional Traffic Flow Model.** AISC 539, ICSS 2016, 2017, ch. 17.
3. LEBACQUE, J., MAMMAR, S., and HAJ-SALEM, H. **Generic second-order traffic flow modeling.** In *Proceedings of the 17th International Symposium on Transportation and Traffic Theory* (London, 2007), B. H. E. R.E. Allsop, M.G.H. Bell, Ed., pp. 749–770.
4. KHOSHYARAN, M., and LEBACQUE, J. **A Reactive Dynamic Assignment Scheme.** Mathematics in Transport Planning and Control (Default Book Series, Volume), 1998, ch. 13, pp. 131–143.

THANKS FOR YOUR ATTENTION !

QUESTIONS, PLEASE !

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