User-based solutions for increasing level of service in bike-sharing transportation systems

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Outline

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1. Introduction
2. Model description
3. Implementation
4. Results

Situation of sharing-bike systems

- Quick development across the world since 2000, starting from Europe ([DeMaio, 2009]).
- Around 200 systems in the world. Ecological and compatible ("sustainable") transport mode ([O'Brien et al., 2013]).
- Extensions to unexpected places ? USA ([Gifford and Campus, 2004]) where car is dominant, or China ([Liu et al., 2012]) where relation to bikes has strongly changed these last years.

But... intrinsic issues in the system

Figure: Full or empty docking stations in Paris: decrease in the level of service (source www.velib.paris.fr)

Solutions ?

- Better initial design of the system ? ([Lin et al., 2011, Lin and Yang, 2011]). But at least as complex as transportation predictive models.

- Optimal management by the operator ? Operational Research give answers for optimal redistribution ([Nair and Miller-Hooks, 2011, Nair et al., 2013]) but that usually does not solve totally the issues.

- Poor litterature on user-based models (e. g. [Barth et al., 2004], but for car-sharing system, for which problems are different). We want to explore through agent-based modeling impact of some user parameters on an overall system.

Outline

Settings and agents

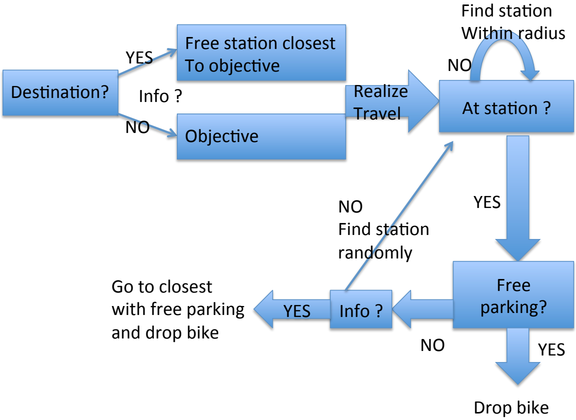
- Agents: bikers with information $i(b)$ (boolean), tolerated walking radius $r(b)$ and mean speed $\bar{v}(b)$; docking stations located in space with current standing bikes $p_b(s,t)$ and capacity $c(s)$
- Euclidian network $N = (V, E)$, representing the road network. Stations are nodes of the network and movement of bikers is embedded in the trace of N in $\mathbb{R}^2$
- Scale of the district; we suppose known temporal fields of origin $O(t)$ and destination $D(t)$ (probabilities of O/D given a trip), boundaries conditions $N(t)$ as flows (in- and outflows) at fixed boundaries points

Temporal Evolution

At each time step:

- Start new travels randomly using O, D, N
- Make bikers in travel advance of the corresponding distance
- Finish travels and redirect bikers when needed (see flowchart of bikers behavior)

Bikers behavior



Evaluation criteria of the level of service

Temporal indicators

- Mean load factor $\overline{l}(t) = \frac{1}{|S|}\sum_{s\in S}\frac{p_b(s)}{c(s)}$
- Heterogeneity of bike distribution (classical spatial heterogeneity index)

$$h(t) = \frac{2}{\sum_{s\neq s'\in S}\frac{1}{d(s,s')}} \cdot \sum_{\substack{s,s'\in S\\ s\neq s'}} \frac{\left|\frac{p_b(s,t)}{c(s)} - \frac{p_b(s',t)}{c(s')}\right|}{d(s,s')}$$

Evaluation criteria of the level of service

Aggregated indicators

With $\mathscr{T}$ set of travels for a realisation of the system on a day, $\mathscr{A}$ travels for which an adverse event (full or empty station) occured and $d_{th}(v)$ ($d_r(v)$) theoretical distance (resp. realised) for a travel v,

- Proportion of adverse events $A = \frac{|\mathscr{A}|}{|\mathscr{T}|}$
- Total quantity of detours

$$D_{tot} = \frac{1}{|\mathscr{T}|} \cdot \sum_{v \in \mathscr{T}} \frac{d_r(v)}{d_{th}(v)}$$

Outline

Parametrisation

- Statistical treatment of real data on 3 month for Paris (time-series clustering methods) to obtain a “standard day”; inference of O, D for the area using non-parametric multi-kernel Gaussian estimation.

- Parameters such as travel distance distribution, mean speed where taken from the litterature ([O'Brien et al., 2013] ,[Nair et al., 2013])

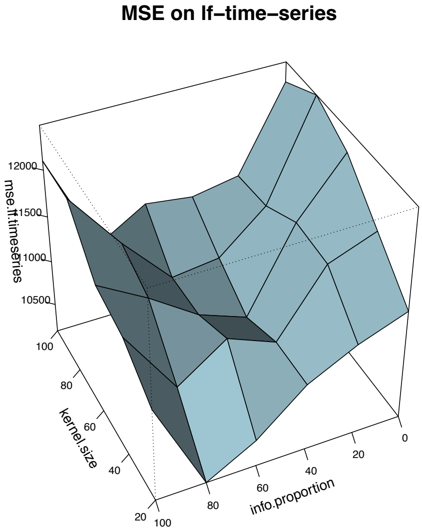
Calibration

- Three remaining parameters: quantity of information, walking tolerance radius and Gaussian kernel size

- Simplified calibration procedure (rough reasonable minimum of the objective) on the mean-square error on load-factors time-series:

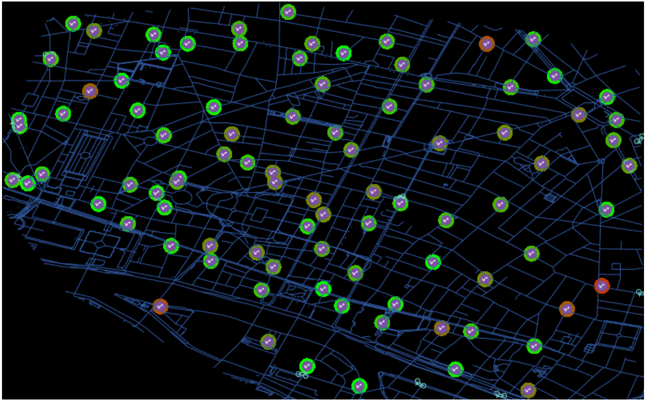
$$MSE = \frac{1}{|S||T|}\sum_{t\in T}\sum_{s\in S}(\frac{p_b(s,t)}{c(s)} - lf(s,t))^2$$

Calibration



Outline

Demonstration



Demonstration of the implementation of the model of simulation in NetLogo

Results: internal robustness

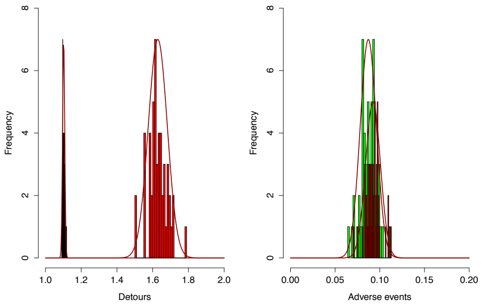
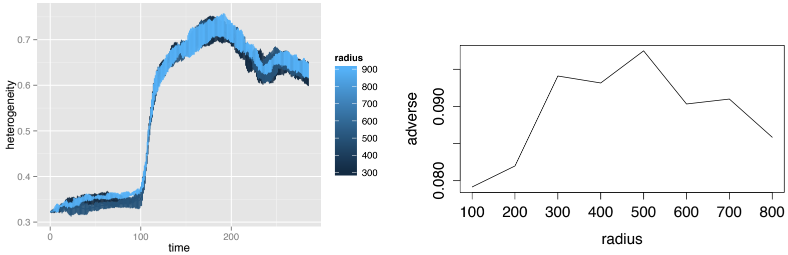


Figure: Statistical analysis of some outputs

Results: ambiguous influence of walking radius

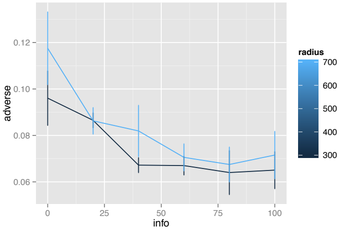


(a) Influence on heterogeneity time-series

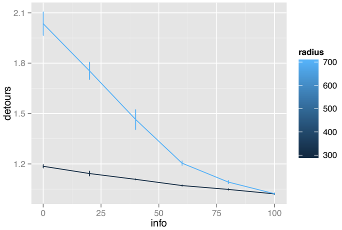
(b) Influence on quantity of adverse events

Figure: Exploration of the role of walking radius

Results: significant influence of information



(a) Influence on quantity of adverse events



(b) Influence on quantity of detours

Figure: Exploration of the role of quantity of information

Conclusion

- First step towards a comprehensive bottom-up of that hybrid transportation system. Parametrisation, calibration and exploration of a simple behavioral agent-based model
- Significant qualitative and quantitative results concerning information, less significant regarding walking radius (suggest deeper exploration of the relation between topology and users through spatial feedbacks).
- Ideas on an online adaptative algorithm for a bottom-up pilotage of the system, using stations as intelligent agents ? Link between adaptative intelligent traffic lights and ant algorithms ([Monmarché, 2004]) ?

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Questions

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