Models of growth for system of cities : Back to the simple

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Modeling Urban Growth

Spatial Interaction and Urban Growth

Role of spatial interactions in Urban Growth ?

$\rightarrow$ gravity-based flows influence population growth in a synergetic formulation [Sanders, 1992]

$\rightarrow$ Simpop models (from Simpop1 to SimpopLocal) [Pumain, 2012] : agent-based approaches ; more recently Marius [Cottineau et al., 2015] closer to system dynamics

$\rightarrow$ Simple random growth (Gibrat model) becomes quickly complex by adding spatial interaction [Bretagnolle et al., 2000] ; refined extension with waves of innovation in [Favaro and Pumain, 2011]

Research Objective

Model Rationale

→ Rationale : extend an interaction model for system of cities by including physical network, to investigate its influence on system dynamics

→ Work under Gibrat independence assumptions, i.e. $\mathrm{Cov}[P_i(t), P_j(t)] = 0$. If $\vec{P}(t+1) = \mathbf{R} \cdot \vec{P}(t)$ where $\mathbf{R}$ is also independent, then $\mathbb{E}\left[\vec{P}(t+1)\right] = \mathbf{R} \cdot \mathbb{E}\left[\vec{P}\right](t)$. Expectancies only for now (higher moments computable similarly)

→ With $\vec{\mu}(t) = \mathbb{E}\left[\vec{P}(t)\right]$, we generalize this approach by taking $\vec{\mu}(t+1) = f(\vec{\mu}(t))$

Model Formulation

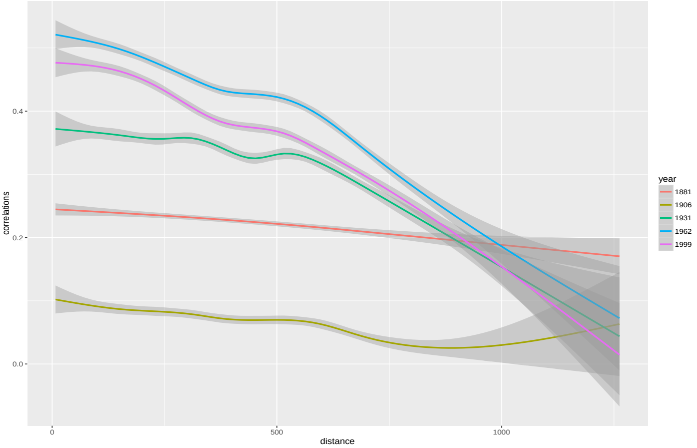
$\rightarrow$ In our case, $f(\vec{\mu}) = r_0 \cdot \mathbf{Id} \cdot \vec{\mu} + \mathbf{G} \cdot \mathbf{1} + \mathbf{N} \cdot$ with

- $G_{ij} = w_G \cdot \frac{V_{ij}}{<V_{ij}>}$ and $V_{ij} = \left(\frac{\mu_i \mu_j}{\sum \mu_k{}^2}\right)^{\gamma_G} \exp\left(-d_{ij}/d_G\right)$
- $N_i = w_N \cdot \sum_{kl} \left(\frac{\mu_k \mu_l}{\sum \mu}\right)^{\gamma_N} \exp\left(-d_{kl,i}\right)/d_N$ where $d_{kl,i}$ is distance to shortest path between k, l computed with slope impedance $(Z = (1 + \alpha/\alpha_0)^{n_0}$ with $\alpha_0 \simeq 3)$

Data : stylized facts

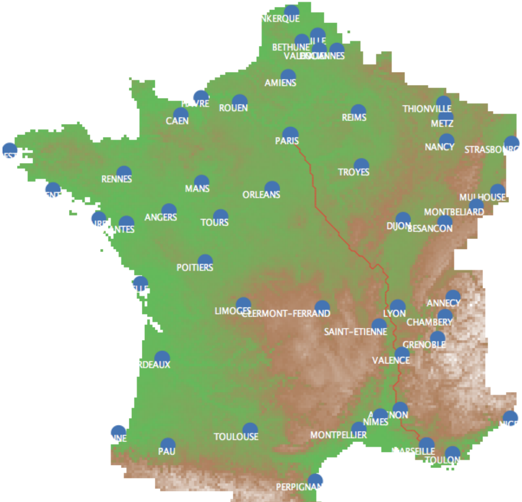
Population data for French-cities (Pumain-INED database : 1831-1999)

Non-stationarity of log-returns correlations function of distance



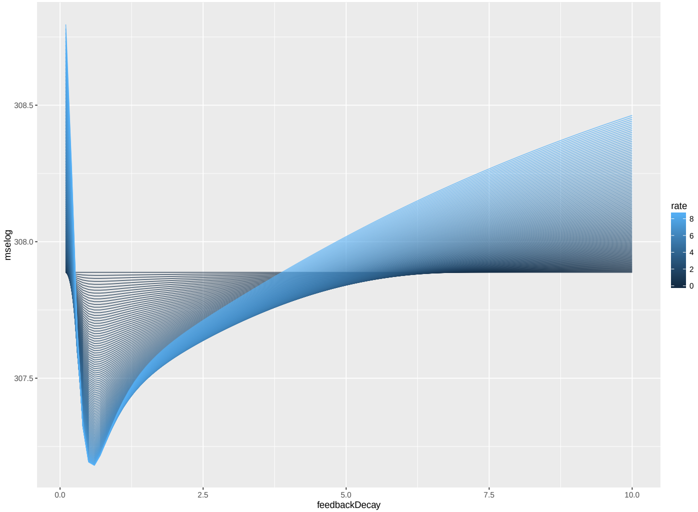
Data : geographic abstract network

Physical transportation network abstracted through a geographical shortest path network



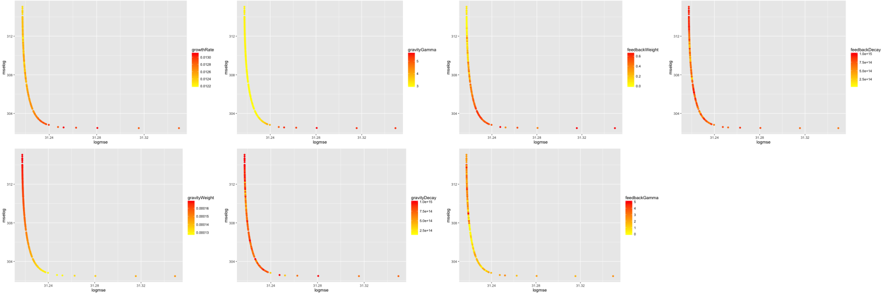
Results : model exploration

Evidence of physical network effects

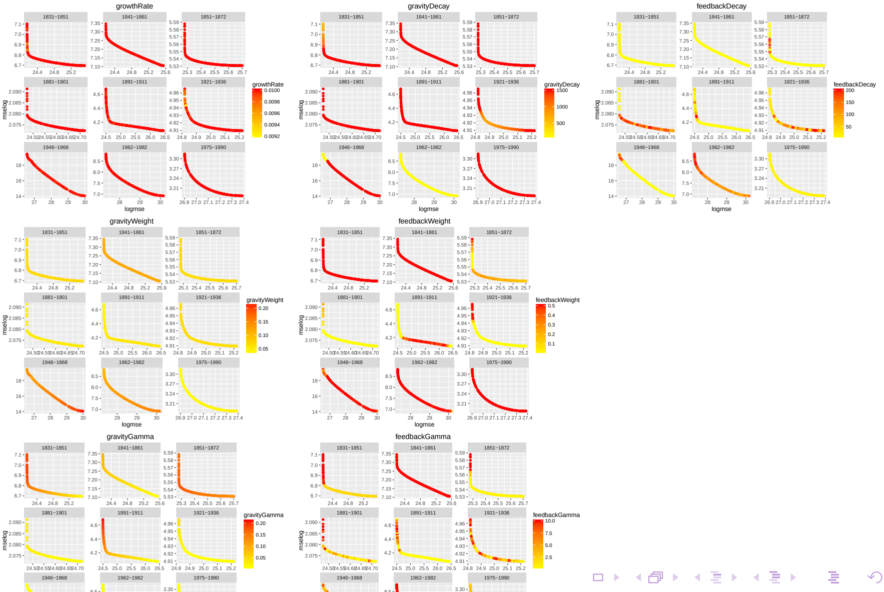


Results : model calibration

Model calibration using GA on computation grid, with software `OpenMole` [Reuillon et al., 2013]



Results : non-stationary model calibration



Quantifying overfitting

Not clear nor well theorized how to deal with overfitting in models of simulation

Intuitive idea : Approximate gain of information by approaching models of simulation by statistical models

Empirical AIC

Discussion

Conclusion

- All code available at
https://github.com/JusteRaimbault/CityNetwork/tree/master/Models/NetworkNe

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Calibration with fixed gravity effects (iterative calibration)