Integrating Compartment and Point Process Models for Spatio-Temporal Modeling of Infectious Diseases

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Methodology

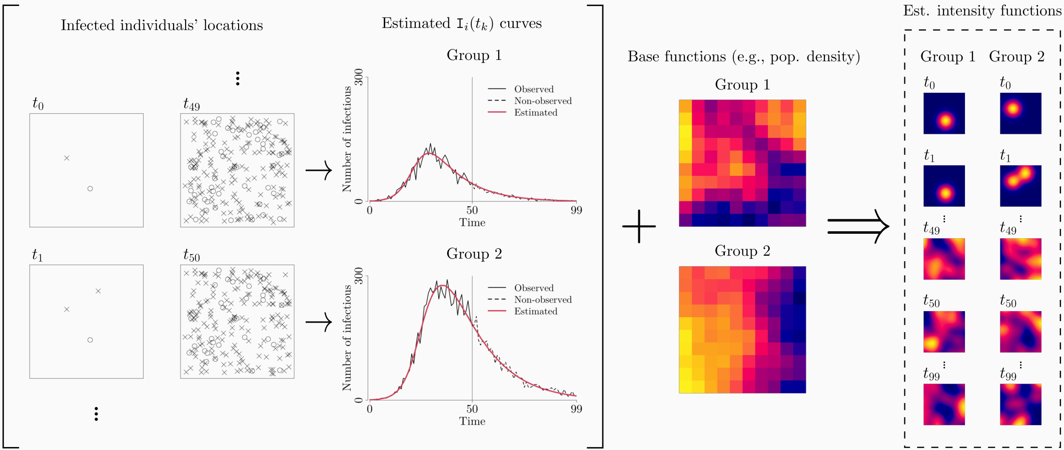

Figure 1: Two-step spatio-temporal modeling approach for infectious in all groups.

Temporal and Spatio-temporal modeling

SIR Model

Let $\mathtt{S}_i(t)$, $\mathtt{I}_i(t)$, and $\mathtt{R}_i(t)$ denote the counting curves for all compartments.

$$\frac{d\mathtt{S}_i(t)}{dt} = -\beta \mathtt{S}_i(t) \sum_{\text{all } j} C_{ij} \cdot \frac{\mathtt{I}_j(t)}{\mathtt{N}_j}$$

$$\frac{d\mathtt{I}_i(t)}{dt} = +\beta \mathtt{S}_i(t) \sum_{\text{all } j} C_{ij} \cdot \frac{\mathtt{I}_j(t)}{\mathtt{N}_j} - \gamma \mathtt{I}_i(t)$$

$$\frac{d\mathtt{R}_i(t)}{dt} = +\gamma \mathtt{I}_i(t),$$

such that C_{ij} is a contact matrix, $\mathtt{N}_i(t) = \mathtt{N}_i$, $\forall t$, and $\beta, \gamma > 0$.

LGCP Model

Assuming we already estimated $\mathtt{I}_i(t_k)$, $\forall i, k$, the main model can be specified as follows

$$\begin{aligned} \mathcal{N}_i(t_k) | \Lambda_i(\mathbf{u}; t_k) = \lambda_i(\mathbf{u}; t_k) &\sim \text{Po}\left(\int_{\mathcal{U}} \lambda_i(\mathbf{u}; t_k) d\mathbf{u} \right) \\ \Lambda_i(\mathbf{u}; t_k) &= \mu_i(\mathbf{u}; t_k) \cdot \exp\{\zeta_i(\mathbf{u}; t_k)\} \\ \mu_i(\mathbf{u}; t_k) &= \lambda_{0,i}(\mathbf{u}; t_k) \cdot \mathtt{I}_i(t_k) \\ \zeta_i(\mathbf{u}; t_k | \boldsymbol{\eta}_i) &\sim \text{GP}(\beta_{0,i}, \phi_i(h; t_k | \boldsymbol{\eta}_i)) \\ \boldsymbol{\eta}_i &\sim \text{priors}, \end{aligned}$$

such that $\phi_i(h; t_k | \boldsymbol{\eta}_i)$ is a covariance function, and $\boldsymbol{\eta}_i$ is a vector of parameters.

Data Simulation

We consider as a study region an area of approx. 3 km^2 in São Paulo, Brazil. For such a region, we divided people into three age groups: 0–19, 20–59, 60+.

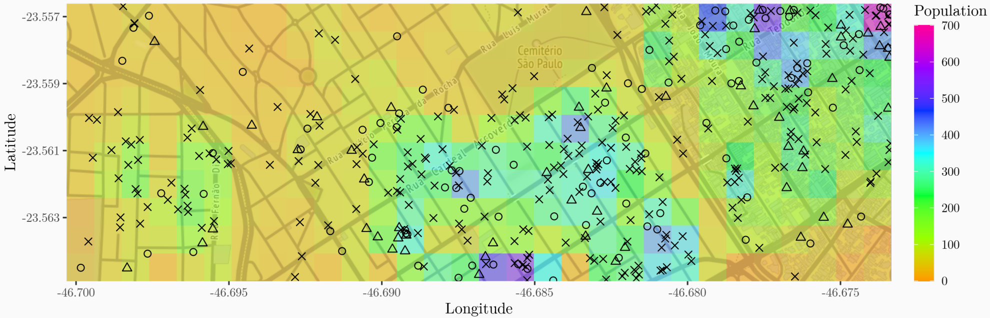

Figure 2: Studied region in São Paulo (Brazil) with the overlapped grid for the estimated population and infected individuals' locations.

Model Assessment

Obtained errors for the null and alternative models under two different settings.

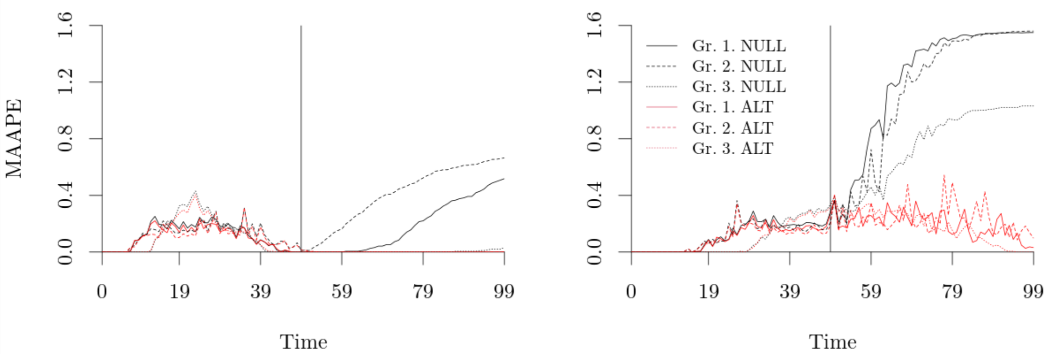

Figure 3: Computed Mean Arctangent Absolute Percentage Error (MAAPE) for groups 0–19, 20–59, 60+. Models were fitted with data up to t_{49} (vertical solid line).