Probabilistic, mean-field and transport PDE models of Covid-19 epidemics, with variable contact rates and user mobility

Akian MARIANNE, Inria and CMAP, Ecole polytechnique, CNRS, IP Paris - Palaiseau

I will present works done during the Covid-19 epidemic crisis of March–May 2020.
In [2], we have studied the evolution of the epidemic in the Paris area, by analyzing the medical emergency calls received by the Emergency medical services (EMS) of the four central departments of this area (Centre 15 of SAMU 75, 92, 93 and 94). Given a transport PDE epidemiological model, we show that the logarithm of each epidemic observable can be approximated by a piecewise linear function of time. Such an approximation allows us to distinguish the different phases of the epidemic, and to identify the delay between sanitary measures and their influence on the load of EMS. This also leads to an algorithm, allowing one to detect epidemic resurgences, by identifying nondifferentiability points.
Piecewise linear approximability is established using methods from Perron–Frobenius theory. We then compute a piecewise linear approximation, by minimizing the ℓ^1 norm of the error.
In [1], we considered discrete time mean-field models, to which Perron–Frobenius techniques can be applied. We also considered probabilistic models, which are more relevant when we deal with not-so-large infected populations or in sub-critical cases. Estimation of the parameters done by minimizing the ℓ^1 norm of the error is illustrated on Paris hospitalization data. We also proposed more complex models including variable contact rates and routing mobility, and shown how to infer the corresponding parameters.
The first part of this work was done jointly with the following physicians of the SAMU of AP-HP and applied mathematicians from INRIA and École polytechnique : Stéphane Gaubert, Marianne Akian, Xavier Allamigeon, Marin Boyet, Baptiste Colin, Théotime Grohens, Laurent Massoulié, David P. Parsons, Frédéric Adnete, Érick Chanzy, Laurent Goix, Frédéric Lapostolle, Éric Lecarpentier, Christophe Leroy, Thomas Loeb, Jean-Sébastien Marx, Caroline Télion, Laurent Tréluyer, and Pierre Carli, see [2].
The second part was done jointly with Luca Ganassali, Stéphane Gaubert, and Laurent Massoulié, see [1].

[1] M. Akian, L. Ganassali, S. Gaubert, L. Massoulié. *Probabilistic and mean-field model of covid-19 epidemics with user mobility and contact tracing*, 2020.

[2] S. Gaubert, M. Akian, X. Allamigeon, et al. *Understanding and monitoring the evolution of the Covid-19 epidemic from medical emergency calls : the example of the Paris area.* C. R. Math. Acad. Sci. Paris, **358(7)**, 843–875, 2020.

Contact : `marianne.akian@inria.fr`