PhD thesis ASTRAGALE [1]

Title : Simulation, estimation and control of structured and spatialized epidemiological models

PhD **founded** by **CNRS** (via the MODCOV19 platform), starting on October, the 1st, 2021

The PhD student will be registered in the MSTII doctoral school and she/he will be attached to AIRSEA project/team at Jean Kuntzmann Lab(UMR 5224) in Grenoble (France).

PhD supervision :
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Key words : complex dynamical systems, compartmental models in epidemiology, model reduction, uncertainty quantification, dynamic resolution of inverse problems, constrained optimal control.

Skills required : Master level or equivalent in applied mathematics, skills in numerical solving for PDEs, in optimization and analysis of dynamical systems, skills and taste for programming (e.g. in Python, R, Matlab, Julia or C/C++...).

Summary of the thesis project : The ASTRAGALE project aims to understand the dynamics and the most determining parameters in the propagation of Covid-19, to propose epidemic control strategies in terms of containment policies, testing campaigns or vaccination, with the Auvergne-Rhône-Alpes territory as a study framework. For this purpose, we propose an original approach to the modeling of epidemic dynamics based on the development of a 3D advection-diffusion-reaction distributed parameter model (2 spatial dimensions and one age-related dimension) and the use of model reduction techniques, potentially avoiding the pitfall of over-parameterization of traditional SIR models. It is important to emphasize that the scientific approach we propose is generic and could be transposed to the study of pandemics on different geographical entities or to other epidemic transmission dynamics, or even to other application domains involving complex and potentially non-linear dynamics on a heterogeneous environment. The scientific challenges of this project are multiple : modeling of non-linear distributed phenomena on a complex 3D heterogeneous medium, assimilation of uncertain and heterogeneous data leading to ill-posed inverse problems, high dimensional optimal control problems. The PhD student will be supervised by Clémentine Prieur (LJK, UMR 5224) and Didier Georges (GIPSA-lab, UMR 5216) and attached to the LJK. The modeling stage will involve informed exchanges with E. Vergu (INRAE), expert in epidemiology and modeling, and R. Sameni (Univ. Emory, Atlanta), expert in modeling and compartmental systems analysis. A provisional schedule for the thesis is :

- Year 1 : bibliographical study on modeling in epidemiology, sensitivity analysis, model reduction and numerical solution of non-linear systems governed by partial differential equations, inverse problems and optimal control ; modeling and simulation of the epidemiological model ; construction and analysis of a reduced model ; first valorization of the results ;
- Year 2 : sensitivity analysis, formulation and resolution of the inverse problem using a moving horizon approach ; evaluation of the results ;
- Year 3 : formulation and resolution of an epidemic control problem based on the developed model ; finalization of publications, writing and defense of the thesis.

The project will benefit from the technical support of P. Bellemain (IE CNRS) for data collection and processing, as well as for the development of a simulator and the implementation of the algorithms developed in the framework of the project. We already have privileged access to the data of the COVID-19 platform of the French Ministry of Health. We will also have access to high performance computing and data processing infrastructures via GRICAD (UAR 3758).

1. Astragalus, more specifically the variety Astragalus membranaceus, is a very appreciated and frequently prescribed plant in traditional Chinese medicine. Among its species are Astragalus alpinus (Astragale des Alpes).