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Optimal control and parameter estimation in some epidemiological models

Aziz Belmiloudi, Mathematics research institute of Rennes-UEB, Rennes, France

Fabrice Mahé, Mathematics research institute of Rennes-UR1, Rennes, France

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Introduction

In real word, experimental data in epidemiology are incomplete, uncertain, or even impossible to product. Therefore, the estimation of parameters and optimal adaptation of model in real process will become difficult tasks. In order to alleviate these difficulties, optimal control strategies (consistent with data measurements) coupled with mathematical modeling and numerical simulation tools, allow to build, to test and to compare theories and hypotheses on the spread/eliminate of infectious diseases.

In order to estimate the effectiveness of vaccination, isolation and treatment, and then to devising optimal intervention strategies, we are led to study different models corresponding to different situations. Often, a numerical code, adapted to each situation, is developed. We propose a general formalism allowing to describe many models and thus to simulate, with the same tool, different situations as well as to compare performances and reliability of these models.

Methods

We consider a generalized ordinary differential system for disease transmission and propagation which give a unifying framework for many epidemiological models including classical compartmental models, as well as more complex models with numerous classes. Moreover, this model allows to take into account heterogeneities and is characterized by some of data that can and some cannot be measured. Based on optimal control approach, we propose parameter estimation problems to determine unknown quantities or control certain inputs, in order to calibrate models, to develop optimal strategies to limit/eradicate of disease during an outbreak, etc. The formulated method includes sensitivity and adjoint problems (used to derive optimality conditions) and numerical gradient-based optimization algorithms.

Results

We present numerical experiments validating the efficiency and reliability of our approach.

Conclusion

To make them accessible, these tools will be included in a new free numerical software allowing the simulation and parameter estimation for many epidemiological models : differential equations, network models and individual-centered models.

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