Automatic Control Laboratory

ETH Zurich, D-ITET

Project Title: Optimal Adaptive design of Non-Pharmaceutical Interventions for Network Epidemics
Supervisors: Dr.Carlo Cenedese, Dr. Andrea Iannelli
Email: ccenedese@ethz.ch, iannelli@control.ee.ethz.ch
Professor: Prof. Dr. John Lygeros
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1 Posting

Understanding how to effectively control an epidemic spreading on a network is a problem of paramount importance for the scientific community. The ongoing COVID-19 pandemic has highlighted the need for policies that mitigate the spread, without relying on pharmaceutical interventions, that is, without the medical assurance of the recovery process. These policies typically entail lockdowns and mobility restrictions, having thus non negligible socio-economic consequences for the population. In this work, we focus on the problem of finding the optimum policies that “flatten the epidemic curve” while limiting the negative consequences for the society. To do so, we want to implement an Adaptive Model Predictive Control (MPC) scheme where the parameters of the epidemics model are learned from experimental data.

1.1 Description

The ongoing COVID-19 pandemic has highlighted the key role played by public health authorities in enacting Non Pharmaceutical Interventions (NPI) to “flatten the epidemic curve" when no effective pharmaceutical treatments such as vaccines are available. However, NPIs typically entail the implementation of harsh measures, including lockdowns and restrictions of personal freedom of movement, which may yield severe socio-psychological and economic consequences [1]. Thus, they should be implemented keeping a reasonable balance between safety and normalcy. To this aim, the development of tools to predict the course of an epidemic and evaluate the impact of different NPIs has become a task of paramount importance for the scientific community, aiming at assisting public health authorities in their decisions.

The mathematical modeling of epidemics has emerged as a valuable framework to perform such a task [2]. Relevant examples can be found in the useful insights provided into the ongoing COVID-19 pandemic [3, 4] and more in general on the spread of epidemics in over a network of communities, viz. states or cities [5]. Motivated by the encouraging predictive abilities of these models and by the recent developments in control schemes for optimal NPIs design [6, 7], we focus in this work on the development of a design based on Adaptive MPC. The strength of this approach is the capability of learning online the model coefficients making it robust to changes in the virus or in the environment, and consequently reliable for the policy-maker that has to finally select the NPIs.

1.2 Goals

The goals of the project are as follows:

1. Learn about (network) epidemic models for COVID-19;
2. Formalize the problem of optimal design of NPIs for the selected epidemic model;
3. Develop an Adaptive MPC scheme for the problem;
4. Validate your algorithm via numerical simulations based on real-data obtained from the current COVID-19 pandemic.

Publications: If the final results are promising they can potentially be turned into a publication.

1.3 Qualification & Preparatory courses

We are looking for a talented, outstanding, highly motivated student with theoretical background and/or interest in Control Theory, Model Predictive Control, Convex Optimization, Applied Mathematics, or related field(s), and with good command of the English language.
The following courses are relevant to the project:

- Model Predictive Control (essential);
- Advanced MPC (desirable, but not essential);
- Large-Scale Convex Optimization (desirable, but not essential);
- Advanced Topics in Control: Distributed Systems and Control (desirable, but not essential);
- System Identification (desirable, but not essential).

1.4 How to Apply

Please send your resume/CV (including lists of relevant publications/projects) and transcript of records in PDF format via email to `ccenedese@ethz.ch` and `iannelli@control.ee.ethz.ch`.

Start Date: Expected starting date is between January and March 2022.

1.5 Tasks list

1. Conduct a literature review on (network) epidemics models focusing on both classical models and those developed in particular for COVID-19. Start a write up in LaTeX;
2. Select or develop an appropriate epidemic model form task 1. Define and mathematically formalize the problem of optimal NPIs for the chosen model;
3. Develop the complete control scheme based on Adaptive MPC to compute the optimal NPIs;
4. Use real data obtained from the current pandemic to validate the control scheme designed in tasks 3 on the problem formalized in tasks 2. Create extensive numerical simulations and interpret the results with respect to practical implementations of NPIs.

1.6 Timeline

Month 1. Task 1;

Month 2. Tasks 1&2;

Month 3. Task 2&3;

Month 4. Task 3&4;

Month 5. Task 4;

Month 6. Final report and presentation.

References

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[3] G. Giordano *et al.*, "Modelling the COVID-19 epidemic and implementation of population-wide interventions in Italy," *Nat. Med.*, vol. 26, no. 6, pp. 855–860, 2020.

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