

Project: GAME THEORY AND EPIDEMIOLOGY

FCT/Portugal Exploratory project: EXPL/MAT-CAL/0794/2013

SUMMARY

This project was the recognition of the effort we started, some years ago, to find a research topic that would bring together the expertise and interests of the elements of the group, in particular, game theory and epidemiology.

An increasing effort has been made to include human behaviour into epidemiological models. One way to model this behaviour is through game theory, which assumes that individuals make their decisions in order to maximize their gain or minimize a particular risk.

In our work we consider a SIRS model with time dependent transmission rate. We assume time dependent vaccination which confers the same immunity as natural infection. We study two types of vaccination strategies: (i) optimal vaccination, in the sense that it minimizes the effort of vaccination in the set of vaccination strategies for which, for any sufficiently small perturbation of the disease free state, the number of infectious individuals is monotonically decreasing; (ii) Nash-equilibria strategies where all individuals simultaneously minimize the joint risk of vaccination versus the risk of the disease. The former case corresponds to an optimal solution for mandatory vaccinations, while the second corresponds to the equilibrium to be expected if vaccination is fully voluntary.

We are able to show the existence of both optimal and Nash strategies in a general setting. In general, these strategies may not be functions but Radon measures. For specific forms of the transmission rate, we provide explicit formulas for the optimal and the Nash vaccination strategies. This work was published in 2016 in the journal J. Math. Biology.

From the project we highlight the research grant. Tiago Costa was supervised by Fabio Chalub and Paula Rodrigues. We studied vaccination models with spatial heterogeneity. This work is submitted for publication.

We also highlight the organization of the special session 'Mathematical Models in Epidemiology' in the context of the AMS-ESM-SPM meeting 2014 in Porto, with the participation of all team members and the project consultants.

Project ID

EPIGAMES - GAME THEORY AND EPIDEMIOLOGY

FCT/Portugal Exploratory project: EXPL/MAT-CAL/0794/2013

Funding: € 25,000.00

Duration: 01/03/2014 to 30/06/2015

Main Research Area: Mathematics - Calculus of Variations, Differential Equations and Dynamical Systems

Secondary Research Area: Biological Sciences - Evolution and Phylogenetics

Keywords: Mathematical biology; Game theory; Epidemiology; Dynamical systems

INSTITUTIONS

Main Contractor: NOVA.ID.FCT - Associação para a Inovação e Desenvolvimento da FCT (NOVA.ID.FCT)

Main Research Unit: Centro de Matemática e Aplicações (CMA/FCT/UNL)

TEAM

Principal Investigator: Paula Cristiana Costa Garcia da Silva Patrício Rodrigues

Researchers: Fabio Augusto da Costa Carvalho Chalub; Maria do Céu Cerqueira Soares; Paulo José Fernandes Louro Ribeiro Doutor

Research fellow: Tiago J. Costa

Consultants: Max Souza, Universidade Federal Fluminense, Brasil; Nicolas Bacaer, Univ Paris 06, France.

Project Results

PUBLICATIONS

Paulo Doutor, Paula Rodrigues, Maria do Céu Soares, and Fabio A. C. C. Chalub. Optimal vaccination strategies and rational behaviour in seasonal epidemics. *J. Math. Biol.*, pages 1–29, 2016.

Tiago J. Costa, Fabio ACC Chalub, and Rodrigues. Vaccination schemes in regions connecting sites with good and poor health systems. Submitted

WORKING VISITS

Visit of Max Souza (project consultant) to Universidade NOVA de Lisboa, Caparica, Portugal, from 5 to 17 of December 2014, to discuss the work on optimal and voluntary vaccination. The consultant also met with Tiago Costa to discuss his work on vaccination models with spatial heterogeneity. The visitor has also presented a talk, on December 10, entitled ‘Conservative Parabolic Problems’.

Joint meeting with all team members and the project consultants in Porto, Portugal on the occasion of the International Meeting of AMS-EMS-SPM, June 10-13, 2015.

OTHER ACHIEVEMENTS

Special session ‘Mathematical models in Epidemiology’ at AMS-ESM-SPM meeting 2014, Porto, 10-13 Junho 2014.

GROUP MEMBERS’ PUBLICATIONS (DURING THE PROJECT)

F. A. C. C. Chalub and M. O. Souza, Discrete and continuous SIS epidemic models: A unifying approach. *Ecological Complexity* 18, 83- 95 (2014).

F. A. C. C. Chalub and M. O. Souza, The frequency-dependent Wright- Fisher model: diffusive and non-diffusive approximations. *J. Math. Biol.* 68:1089–1133 (2014). D’Almeida, A. F., Teixeira, R. C. and Chalub, F. A.. Much or More? Experiments of Rationality and Spite with School Children. *North American Journal of Psychology*, Vol. 16(1), 163-178 (2014).

F. A. C. C. Chalub and M. O. Souza, Fixation in large populations: a continuous view of a discrete problem, *Journal of Mathematical Biology*, Vol. 72(1-2), 283-330 (2015).

Pinho STR, RODRIGUES P, Andrade RFS, Serra H, Lopes JS, Gomes MGM. Impact of tuberculosis treatment length and adherence under different transmission intensities, *Theor Popul. Biol.* Vol 104, 68-77 (2015).

Olga Danilkina, Max O. Souza, Fabio A. C. C. Chalub. Conservative parabolic problems: non-degenerated theory and degenerated examples from population dynamics. (submitted)

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