Optimal vaccination strategies and rational behavior in seasonal epidemics

Fabio A. C. C. Chalub, Paula Rodrigues, Paulo Doutor, Maria do Céu Soares
Centro de Matemática e Aplicações, Universidade Nova de Lisboa, Portugal.
{*chalub,pcpr,pjd,mcs*}*@fct.unl.pt*

Abstract

We consider a fixed size population divided in three different classes: **S**usceptible, **I**nfeccious and **R**ecovered. In particular, we consider a classical SIR dynamics: ($S + I \xrightarrow{\beta} 2I$, $I \xrightarrow{\gamma} R$, $R \xrightarrow{\alpha} S$) where the infecctious term $\beta(t)$ is a periodic function. We include in the model a periodic *vaccination function* $p(t)$, such that the trasition $S \xrightarrow{p} R$ is also allowed.

We show the existence of an optimal vaccination p_{opt}, in the sense that it can be approximated by vaccination functions able to prevent outbreaks and all these other functions will necessarily imply the existence of a vaccination effort at least equal to the vaccination effort of p_{opt}. For some examples, we are able to show explicitly p_{opt} as a function of β.

Finally, we introduce a population of rational individuals and we will show how the *voluntary vaccination* affects the dynamics. In particular, we consider that each individual is *rational*, i.e., each individual decides freely, according the the available information, if he or she is willing or not to be vaccinated. To this end, we will couple a system of differential equation with principles from game theory. We prove the existence of a Nash-equilibrium vaccination function p_{Nash} (i.e., when all individuals in the population are rational) and, for some simple examples, we show explicit formulas for p_{Nash}.

Keywords: SIR model, Vaccinations, Seasonal Epidemics, Rational Behaviour.

References

[1] Doutor, P., Rodrigues, P., Soares, M.d.C., Chalub, F.A.C.C.. J. Math. Biol. (2016) 73: 1437.