Decision Support System for Sanitary Teams Activities

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ABSTRACT

This paper describes the information system that has been built for the support of sanitary teams. The system is aimed at supporting analytical work which must be carried out when there is a risk of an epidemic outbreak. It is meant to provide tools for predicting the size of an epidemic on the basis of the actual data collected during its course. Since sanitary teams try to control the size of the epidemics, such a tool must model also sanitary teams activities. As a result a model for the prediction can be quite complicated in terms of the number of equations it contains. Furthermore, since a model is based on several parameters there must be a tool for finding these parameters on the basis on the actual data corresponding to the epidemic evolution. The paper describes the proposition of such a system. It presents, in some details, the main components of the system. In particular, the environment for building complex models (containing not only the epidemic model but also activities of sanitary teams trying to inhibit the epidemic) is discussed. Then, the module for a model calibration is presented. The module is a part of server for solving optimal control problems and can be accessed via Internet. Finally, this paper shows how optimal control problems can be constructed with the aim of the efficient epidemic management. Some optimal control problems related to that issue are discussed and corresponding numerical results are presented.

Keywords: Decision Support Systems, Epidemic Models, Forrester’s Models of Sanitary Teams Activities, Optimal Management of Sanitary Teams Activities

1. INTRODUCTION

The paper presents a novel approach to decision support systems supporting activities of sanitary inspections teams. Unique features of the proposed approach are:

- Models describing the spread of epidemics are obtained with the help of Systems Dynamics methodology (Sterman, 2000)
- Models can be calibrated by using dynamic optimization techniques available at the IDOS server (Pytlak et al., 2013) which can be accessed by Internet

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• Models of epidemics can be linked with models of sanitary inspections teams activities – combined models can then be optimized by using the IDOS.

The built DSS is aimed at providing analytical tools which could help predicting the possible outcome of an epidemic in terms of the number infected people but also in terms of costs associated with efforts which try to minimize that number. However, in order to estimate the costs of fighting an epidemic we must go further than using standard models derived from the SIR model which can only show trajectories susceptible, infected, recovered (or trajectories of some other variables which appear in derived models) populations for the assumed values of epidemic parameters. In the case of estimating the costs associated with an epidemic we must also model activities of sanitary inspections teams which can influence the epidemic spread. Eventually, we obtain two models which must be interlinked since inspections teams activities influence trajectories of SIR-like model populations.

The combined model of an epidemic evolution is useful provided that its parameters reflect the considered epidemic. Estimating epidemic model parameters rarely can be achieved by applying analytical formulae (Murray, 1993; Murray, 2001), in general one has to use numerical methods. Therefore, our DSS has the functionality of calibrating combined epidemic models with the help of numerical methods for dynamic optimization (Pytlak et al., 2014).

Realistic models of sanitary inspection teams activities must include decision rules followed by inspection teams. These rules refer to some parameters which should be continuously adjusted in order to maximize the effectiveness of the activities with respect to some chosen criteria and by taking into account current states of the epidemic. These adjustment can be made by performing model simulations with different parameters of decision rules. However, much more efficient way of finding these parameters would be accomplished by solving the associated dynamic optimization problem in which these parameters are decision variables. Furthermore, one step further in this avenue would be accomplished by replacing decision rules with controls (functions of time) which are found by solving dynamic optimization problem which is not parametric in this case. When developing our DSS we equipped it with this functionality.

Optimizing sanitary inspections teams by using the combined models places our work in the subject of mathematical theory of diseases control. In that subject several models of disease control are considered. We can group these models into two categories. In the first category we have models used for the qualitative analysis. In the second category epidemiological models are treated by optimal control theory with the aim of finding optimal strategies.

Papers describing models from the first category concentrate on qualitative analysis of epidemiological models containing controls variables such as vaccination and treatment (Anderson & May, 1991; Brauer & Driessche, 2008; Capasso, 1993; Eckalbar & Eckalbar, 2011; Hu et al., 2011; Wang et al., 2012; Wang, 2006; Wang & Ruan, 2004; Zhang &d Liu, 2008), In these papers one wants to find conditions (system parameters) which guarantee a required long term system behavior such as a long term stability of the SEIR (Susceptible Exposed Infected Removed) or other models of SIR class. These models are sometimes described as the SVI (Susceptibles–Vaccinated–Infectious) epidemic models (Gumel & Moghadas, 2003). The general SVI model presented in (Gumel & Moghadas, 2003) describes an infectious disease spread as a function of three parameters: a non-linear force of infection and two controls: a vaccine volume given to susceptible population and therapeutic treatment given to infectious population.

Models from the second category are in fact the optimal control models. These models are used to find control trajectories that provide the best possible outcome – usually the optimization should guarantee the minimum number of infected people. Typically these optimal control models have at most two controls: preventive vaccination given to susceptible part of popula-
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