Epidemiological trends: models and software

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***Abstract*—Software and models for identifying epidemiological trends are considered from the standpoint of functionality, informativeness and ease of use.**

Keywords—software, models, COVID-19, usefulness, convenience, functionality.

I. Introduction

Outbreaks of infectious diseases and the COVID-19 pandemic in particular are an extremely serious public health challenge [1-3]. As of August 18, 2020, according to statistics from Johns Hopkins University, more than 22 million people were infected with coronavirus disease in the world, and more than 770 thousand deaths were recorded [4]. According to the National Health Service in Ukraine, more than 93 thousand people have been infected, more than 2 thousand deaths have been recorded [5].

To predict the consequences of the coronavirus pandemic and take timely measures, the working group on mathematical modeling of the problems associated with the SARS-CoV-2 epidemic in Ukraine was created by order of the Presidium of the NAS of Ukraine dated April 3, 2020 No. 198. The group included leading specialists from the institutions of the National Academy of Sciences of Ukraine, the National Academy of Medical Sciences of Ukraine and the Taras Shevchenko National University of Kyiv. Analysis of the forecasting results based on the developed models in the Ukrainian realities demonstrated a complex, very volatile and hardly predictable pattern of COVID-19 dynamics, the need to take into account the greatest number of factors, in particular, changes in the environmental conditions in which the agent (individual) is located during the adaptive regime of quarantine measures [6].

The reverse side of the challenges is always opportunities, and today such opportunities are information technology, decision-making systems, best practices of proactive management and control based on modern methods of data driven decision making and modeling [7-10].

Even more, a truly systematic approach should also incorporate the interaction of decisions taken in the field of health care and decisions on strategic economic development of the country, because, for example, overcoming the current consequences of COVID-19 through significant easing of monetary policy may result in an increase in the debt burden on future generations [11].

Though, for now, it is worth mentioning that for the initial analysis of the epidemiological situation, it is possible to use publicly available software, which, however, has quite powerful functionality [12].

II. Software and models overview

Mathematical modeling and scenario approach with an overview of hypothetically possible situations is the most appropriate and cost-effective tool for assessing the system's ability to resist an epidemiological threat.

Mathematical methods have been intensively used before, but now, thanks to the rapid development of computing power, reducing their cost, increasing availability, scaling technologies (grid computing [7], cloud services [8]), researchers can go beyond traditional deterministic models or even more progressive stochastic modeling and also try a modern agent-base modeling approach. The availability of appropriate programming languages and development environments (frameworks) makes possible to synthetically reproduce the epidemic model with the integration of more interrelated and complex dynamics (from the behavior of an individual to generalizing consequences to entire country population [13]).

Most managers and officials of various levels are forced to make their decisions without having the appropriate deep experience in modeling and constructing scenario calculations. However, it is during epidemiological outbreaks in their administrative territories that they require an accurate assessment of the consequences of choosing specific antiepidemiological measures. Moreover, it is necessary to constantly monitor the changing situation, for which real time modeling can be especially useful.

Analytical dashboards of the Cabinet of Ministers of Ukraine for providing medical institutions with resources against COVID-19 can serve as a certain monitoring tool. [14]. The information on the dashboards is presented in the context of territories. The main indicators of the availability of equipment, medical staff, means of protection are displayed. Deficit positions are indicated, it is possible to calculate the availability of resources for the period of 30 and 90 days. The functionality of the information platform has significant potential for further development.

There is a relatively wide range of publicly available software, which was originally developed by antiepidemiological institutions for internal usage and was subsequently open to the public [12]. Typically, these software were adapted for practical use, focused on potential problems. The possibility of adaptive use was provided. However, in order to use the intellectual component for informed management decisions, managers should focus on acquiring initial experience in mastering the skills of working with software products for monitoring and predicting the dynamics of epidemiological outbreaks, assessing possible countermeasures and the corresponding level of their intensity. By the type of methodology, the mentioned software can be conditionally divided into groups of deterministic, stochastic and agent-oriented models.

Deterministic models generate their result on the basis of calculations of partial differential equations. The mathematical relationships underlying these models suggest a number of assumptions. For example, the homogeneity of certain groups, instant contact between individuals and other behavioral simplifications. It is important to note that the danger of using any modeling methods, and, in particular, seemingly relatively simple and easy to use for beginners deterministic models, may lie in the user's choice of the wrong context, potentially resulting in misdirected misjudgment / prediction and consequently erroneous management decision or failure to make the necessary decisions due to rather reassuring forecasts [15].

Although deterministic models are ready for practical use without specific additional settings, they are still inferior in terms of their functionality to other groups. To obtain assessment results from stochastic and agent-oriented models, first, in fact, you need to set a model of the epidemic, which requires deeper knowledge in the field of epidemiology, a good understanding of the statistical basis and the main assumptions on which the model is built, a certain period for mastering the software tools. The software of the last two groups has good support and feedback forms.

Stochastic models could rely on a sufficiently powerful service architecture to support the interactive epidemiological simulation. Example of such architecture is Indemics (Interactive Epidemic Simulation), developed by K. Bisset et al. [16]. Indemics is based on high performance computing and designed to support decisions in real time, monitor the situation, analyze various countermeasures policies at both the individual and social levels. Also, the user can stop the simulation at a certain stage and initiate the simulation of a new counteraction policy or strengthen (weaken) the existing one - thus it is possible to assess the adaptation of citizens' behavior based on the complexity of the situation at the moment. A web interface is used that allows working with the system not only for data analysis (modeling) specialists, but also for the general public, medical personnel and government officials. The idea of dividing it into three key components turned out to be highly effective: the data-demanding component of the assessment of complex interventions and behavioral adaptation; data-demanding component of state assessment; a relatively general but computationally demanding component of disease propagation modeling. It should be noted that the tasks of the last component are better solved precisely on the high-performance computing cluster (HPC-cluster).

The formal mathematical model of Indemics consists of two parts: a graphical discrete dynamic system of coevolution (CGDDS), the task of which is to reproduce the dynamics of the spread of a disease in a social environment, taking into account the behavior of an individual; and from the partially observable Markov Decision Process (POMDP), which introduces an element of control and optimization. The Indemics authors extend the POMDP component and overlay it on top of the extended CGDDS component to create an interactive system [16].

Among the agent-oriented models, EMOD (Epidemiological Modeling software) from the Institute for Disease Modeling (http://idmod.org/), funded by the Bill and Melinda Gates Foundation, is the leader in functionality. Specifically, EMOD includes:

- tools for modeling the mobility of individuals;
- building estimates and forecasts by demographic groups;
- a comprehensive adaptive approach to modeling based on feedback, agent-environment interactions or recursion;
- support for high-performance computing (HPC - High Performance Computing), that is, the possibility of large-scale computing on supercomputers, or modeling tasks with high detail;
- real-time data processing;
- retrospective and prospective simulation mode;
- decision support system;
- methodology for supporting the risk assessment and risk management system.

EMOD is able to accurately model the most complex phenomena and uncertainty, support a wide range of potential management decisions. Getting the most out of this functionality requires a user experience in setting up the required configuration and building epidemiological models.

Figure 1 shows a comparison of the most well-known software that uses these models, in terms of informativeness, usability and functionality. Visually, we can note the sufficient software informativeness and usability in the group with deterministic methods. Also, such models have a fairly narrow functional focus. Stochastic models provide more functionality, but lose somehow in usability. The maximum functionality is typical for agent-oriented models, although their effective use requires appropriate coding skills.

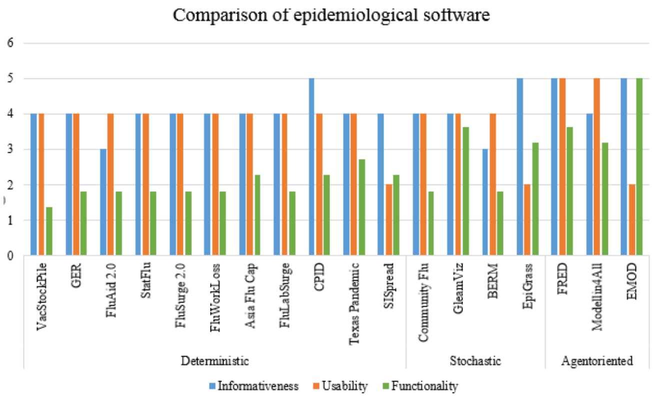

Figure 1. Comparison of epidemiological software

CONCLUSIONS

Outbreaks of infectious diseases and the COVID-19 pandemic in particular are an extremely serious public health challenge. We have free access to a relatively wide selection of software, which was originally developed by antiepidemiological institutions for internal usage in decision-making and was later opened to the general public. Later, these programs have been adapted to improve their practical application and have narrower focus on defined issues. The option of further adaptation and more sophisticated configuration is provided.

We can note the sufficient informativeness and convenience of using the software of the group of deterministic methods. Also, such models have a rather narrow functional focus. Stochastic models provide more functionality, but lose some of their ease of use. We have the maximum functionality from agent-oriented models, although for their most effective use it is necessary to have the appropriate skills of writing program code.

The service architecture is quite powerful to support interactive epidemiological modeling Indemics (Interactive Eidemic Simulation), based on high-performance computing.

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