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Publisher: Rektor der Hochschule Zittau/Görlitz
Prof. Dr. phil. Friedrich Albrecht
Theodor-Körner-Allee 16
D - 02763 Zittau
Tel.: +49-(0)3583 61 14 00
Fax: +49-(0)3583 61 13 88

Finance and Economics

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System of Simulation of Epidemic Diseases Spreading

Yuri Chernyshev[1], Tetyana Chumachenko[2], Dmytro Chumachenko[1] and Andrey Tovstik[1]

[1]National Aerospace University "Kharkiv Aviation Institute", Informatics Department, Kharkiv, Ukraine
anny_cern@hotmail.com, dichum@mail.ru, thedarkest@i.ua
[2]Kharkiv National Medical University, Epidemiology Department, Kharkiv, Ukraine
tachum@mail.ru

Abstract. The possibility of the epidemic process of viral hepatitis B multi-agent simulation has been considered. Simulation model has been developed. Model allows predicting the dynamics of the viral hepatitis B epidemic process, identifying major factors that affect the intensity of the epidemic process and verifying the effectiveness of preventive measures. Using the developed model in the practice of public health suggests improving of the epidemiological diagnostics of hepatitis B and improvement of the quality of management decisions about epidemiological surveillance.

Keywords: simulation, epidemic disease, viral hepatitis B, prediction of the incidence.

1 Introduction

The maintaining and strengthening of public health is an important socio-economic problem, one aspect of which is the reduction of infectious diseases. Adequate prediction of its dynamics and identifying factors influencing the epidemic situation leads to the rational use of material and human resources and lets us develop and carry out cost-effective and adequate preventive control actions.

The epidemic process is a multifactor phenomenon with complex cause-effect relationships that are difficult to describe mathematically, because this phenomenon has a lot of uncertainties, which are random in nature. This problem can be solved by using a mathematical simulation, because it allows us to consider many factors influencing the epidemic process and makes it possible to conduct experiments with them [1].

The aim of the work is to construct an adequate information multi-agent interaction model and then using it to provide targeted interventions to reduce the incidence by an example of viral hepatitis B.

2 Problem of Distribution of Viral Hepatitis B

The high prevalence of viral hepatitis B in the world, severe clinical course, the high frequency of chronic infection, a significant proportion of liver cirrhosis due to hepatitis B cause the medical and social significance of infection [2 - 4].

The epidemic process of hepatitis B is characterized by the presence of natural and artificial modes of the virus transmission, whose structure can change and influence the manifestation of the epidemic process. In the last decade in Ukraine in order to reduce the incidence of hepatitis B vaccine is used for immunization of newborn and risk groups (health workers, etc.). Estimation of the leading drivers of the epidemic process and predicting of its dynamics makes it possible to rationally allocate resources to reduce the incidence of hepatitis B and improving the epidemiological situation.

In the work we used the official data about the incidence of hepatitis B and immune stratum of people in different age, social and professional groups of the population, own researches of the state of specific immunity against hepatitis B, the scientific data on the epidemic and infectious processes, hepatitis B, demographic data on the number of different age groups living in Kharkiv (Ukraine), data on the volume of medical care with parenteral interventions, etc.

3 Simulation model of epidemic process

In the last decade, several models of distribution of hepatitis B have been proposed [5-9]. Most of them are described using a set of differential equations with partial derivatives. The main limitation of these models is that they treat all people as a homogeneous, and do not consider the presence of vaccination, or believe that vaccination is carried out for the whole population. This approach entails the occurrence of errors and affects the quality of management decisions [10].

Intuitively, the epidemic process of hepatitis B is rather complex phenomenon, in varying degrees, depending on many parameters. In view of the disadvantages of the mathematical models given above the use of simulation is proposed to model the epidemic process. Considering also that the observation of the investigating epidemic process can not be done in real time, as well as for several other reasons, the use of a simulation model is preferred [11].

The model assumes joint behavior of large numbers of objects (about 100 thousand). In the way of using event-driven approach, the description of objects joint moving in space (the first type of event) taking into account the possibility of other types of events associated with the occurrence of changes in the internal state of objects have been reached.

4 The description of simulation system

The prototype of software system, which includes a subsystem of the multiagent simulation and specialized statistical and mathematical sub-system which can process the simulation results and perform a conditional optimization of the selected objective functions (incidence, the effectiveness of specific preventive and control activities and their price, levels of treatment centers ensure, etc.) have been developed. Screen forms are presented in Figures 1-3.

Four areas have been allocated for consideration:

1. home;
2. a place where you can become infected;
3. hospital;
4. the area for agents who are not participating in the simulation (another world).

Also two types of agents have been defined:

1. responsible, who rarely leaves home;
2. irresponsible, the probability of transition into the area of infection of whom is high.

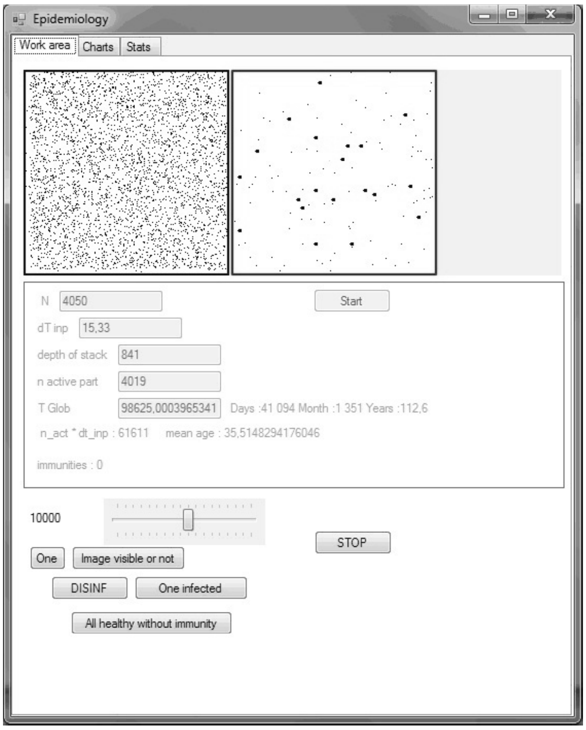

Fig. 1. The main panel of the simulation process management

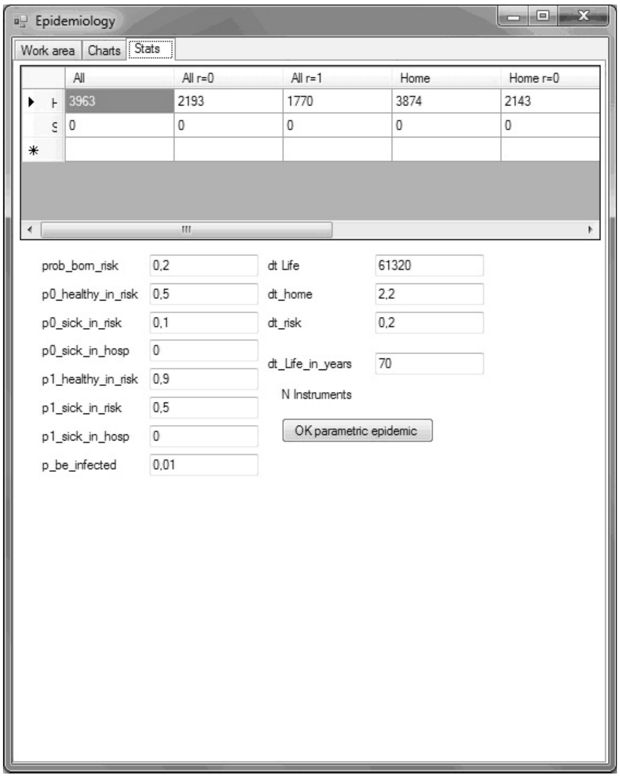

Fig. 2. The probability settings panel

Agents can be in one of the following states:

1. healthy;
2. infected;
3. acquired immunity;
4. dead.

Different probabilities of transition to the risk zone in a healthy state, the transition to the risk zone in an infected state and the transition to the area "Hospital" are characterized for each type of agents.

In total, length of stay in the area "Home" and at risk zone forms the model day. To simplify the model transition to the area "Hospital" is carried out only from the area "Home." The moment of transition in the area "Hospital" is equal to the moving into the zone of risk. The transition from the zone of risk and the area "Hospital" is carried out only to the area "Home".

At the end of stay at risk zone the agent has a chance to become infected. We assume that the agent can not recover on his own, so it remains in state "infected" as long as it does not visit a hospital, or until it dies.

After the transfer of the agent from the area "Hospital" to the area "Home", it is considered recovered and his state changes to "acquired immunity". Also, with the transition from hospital to home, the agent can change its type to "Responsible". Agents, who have acquired immunity, can still move in the risk zone, but they are not affected by the disease.

There is lifetimes in the model defined. If this time is exceed the state of the agent is changed to "dead" (agent dies because of old age). Death of the agent is implemented by transition to area "another world".

For a realistic model, it was determined that the agents not only die, but are born (otherwise the investigated population would quickly been exhausted due to illness and aging). "Birth" of a new agent is happening by moving it from the area "Other world" to the "Home" with the installation of all of its characteristics to the initial state (age, condition).

A distinctive feature of multiagent approach in the preparation of the algorithm of the agent behavior in this case is the representation of automata. In the absence of pair interactions the entry of each of them is the time of the next event. If the current time exceeds the specified time of the next event, this event is processed. The result of processing is a number of new area, the number of the new agent status (healthy, infected, dead), the next event and its number. It is also possible to find a new type (was irresponsible, became responsible).

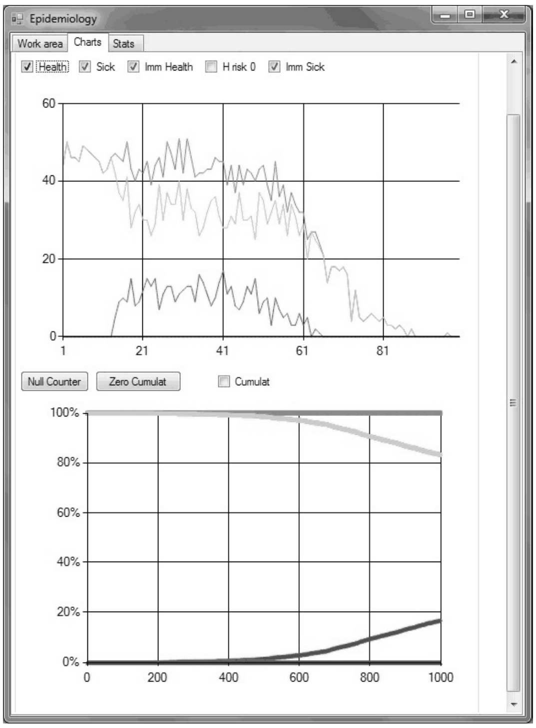

Fig. 3. Graphical visualization of simulation process

The agent states are designated by three indexes:

0. Its type. Varies from 0 to 1.
1. The area. Varies from 0 to 3.
2. A state of health. Varies from 0 to 1.

The event approach is applied to the team of agents (model particles) moving in the area represented by a set of rectangular cells. In the list of events there are cells border crossing, these events form the flow of events of the first type. Events of this type are represented by an increasing sequence of time moments, each of which is treated as a transition from one cell to another. If we consider the modeling of contact-type diseases, the additional need to handle collisions. In this model of the spreading of non-contact diseases it is proposed to consider only the transitions from cell to cell.

The time moment when the event happens is calculated for each event of the first type. This is the basis of the model. The fact is that it allows recording the onset of the events of the second stream of events associated with the transition from one internal state to another.

In implementing of this approach it is reveals that the total amount of states is very large, but the huge number of cells is empty in the tables of the transitions of automata. In order to optimize it makes sense to build the processing as a set of possible production rules.

The next should be introduced:

the length of staying at home Δt_{home}; for example, 2;

the length of being in the risk zone Δt_{risk}; for example, 22;

the limiting duration of life Δt_{life}; for example, 4000 conventional units.

Δt_{input} is the time interval for the act of birth. Keeping the number of agents in an amount of 8000 (on average) for given values of these parameters and in case of the disease absence is provided at Δt_{input}=0.5.

P_0, P_1 are the probabilities of a normal agent and the agent which inclined to take risks.

5 The use of fuzzy logic in the model

The use of fuzzy knowledge bases is the most advanced technology in the agent-based modeling [12]. The most significant fuzzy relationships of the model are presented below:

The transition from the area "Home" to the zone of risk, being healthy.

The transition from the area "Home" to the zone of risk, being sick.

The transition from the area "Home" to the area "Hospital".

The transition from the risk zone to the area "Home" with the change of state from "healthy" to "infected".

In addition, each change of state can be defined differently for responsible and irresponsible agents.

For example:

IF *healthy* moves from *risk zone* to *home* with *responsibility* is *Low* THEN *healthy* became *sick*,

IF *healthy* moves from *risk zone* to *home* with *responsibility* is *High* THEN *healthy* became *sick*,

where *Low* and *High* are linguistic variables.

6 Conclusion

The simulation model of the epidemic process of viral hepatitis B, based on data obtained in Kharkiv (Ukraine) is developed.

The simulation results allow:

- predicting of the dynamics of the epidemic process in time in a particular area, taking into account the specific epidemiological situation;
- testing the effectiveness of various preventive measures (sterilization of instruments, vaccination of certain groups of people, etc.).

Using the developed model in the practice of public health suggests improving of the epidemiological diagnostics of hepatitis B and improvement of the quality of management decisions about epidemiological surveillance.

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