Decision Support during Biological Incident Management: the Employment of Multi-agent Simulations

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Abstract: - Decision making processes during biological incident management represent challenging and demanding as well as complex and important task. Various principles such as partial differential equations or Markov chains have been already utilized for the model development. Nevertheless, the multi-agent technologies can be also effectively employed. As an example, this paper presents model utilizable for the management of biological incidents created in the multi-agent NetLogo environment. The main contribution to the scientific field includes the characterization of specifics related to discussed type of decision-making process. Moreover, within the paper the description of the simulation model is provided, parameterization is explained, and areas for further research are outlined.

Key-Words: - Biological incident, Decision support, Epidemiology, Multi-agent technologies, NetLogo, Simulation

1 Introduction

Currently, biological incidents represent considerable threat for our society. These happen more often and have more serious consequences than ever before. This can be explained by more sophisticated biological agents, increasing insidiousness of the aggressors, increasing value of endangered assets and also by fast development of technologies within last few decades. The biological incidents can be categorized as follows. The first group comprises the biological incidents caused by the biological weapons and the second one includes the unintentional occurrence of such problems. The latter covers for example the leakage of a dangerous substance from a factory or laboratory, or natural incidence of a disease. In comparison with the second category, the intentional incidents are usually easier manageable, because their focal point can be typically identified quickly and localized more precisely. Therefore, the critical assets can be recognized faster and adequately protected. On the other hand, during these incidents it is hard to react quickly in the initial phase, because the first phase of the agent identification can last a significant time. Nevertheless, the biological incidents remain challenging as well as important task for both researchers and practitioners. If appropriately managed, their consequences can be minimized. Therefore, their simulation embodies considerable tool for decision support and for the improvement of the effectiveness of the course of action.

Obviously, the management of biological incidents represents the unstructured problem. For the purposes of its resolution, a vast amount of various real data must be considered. The determination of the appropriate combination of available reactions and suitable countermeasures should be supported by the data describing both the environment, where the incident proceeds, and the biological agent, which has spread within the environment. Therefore, it represents a noticeable potential for scientific research. This should provide for example with the answer to a question how to ensure the qualified decision support in certain situations which would enable relevant output acquisition applicable in practice.

Nevertheless, the problem complexity is not the only reason. Another motivation to examine this realm is the fact that such decisions are crucial, because they influence human lives. Moreover, these are performed by humans who are not absolutely reliable. The responsible people who make crucial decisions and give orders to coordinate the situation are not infallible. Additionally, they are usually not experts in biology and biomedicine. These are mostly “managers" whose decisions necessitate to be supported and improved to ensure higher reliability as well as appropriateness of the actual decision. Therefore, it is suitable to support the reliability by the employment of appropriate modern technologies. The ability to find the scenarios describing the incident development and their simulation represents a particular area which deserves attention. These can ensure better resource planning and their more effective utilization together with the minimization of losses and of inadequate actions. Likewise, they guarantee faster response to the certain incident and higher accuracy and adequacy of particular steps of countermeasures during the incident management process. At the general level, the decision making process during the biological incident management can be divided into the under-mentioned phases. After the identification of the incident and its description, it is necessary to create the scenarios of its further development. The set of countermeasures which will be realized in practice must be determined after the choice of the most pessimistic, most optimistic and most probable scenario. The entire system for the decision support based on the simulation of the biological incident should comprise the following parts:

1) module for the description of the emerging incident,
2) module for the creation of potential scenarios of further development,
3) module for the support of countermeasures selection.

Therefore, the paper aims to describe the second module, the subsystem supporting the scenario creation, and to propose the appropriate technology utilizable for these purposes.

2 Simulation as a Scientific Method

The simulation represents the examination of characteristics and behavior of a particular system on the basis of the experiments realized on the mathematical model of this system [13]. Similarly to other scientific methods, the simulation utilizes explicitly given presumptions. It does not aim to prove their validity, but it focuses on data generation on the basis of the accurate rules. Even from the essential presumptions, the unexpected results might arise. It is utilized within various realms of scientific research. Therefore, its employment in case of biological incidents which develop dynamically and quite often also unexpectedly over time seems to be relevant and particularly useful.

According to [2], there is a mutual relation among the simulation, induction and deduction. While the induction serves the general knowledge revelation from the specific particularities (for example the description of new relations discovered on the basis of the empirical data collected from the questionnaire survey), the deduction leads to the certain conclusion derivation on the basis of general knowledge (for example new statements about a particular case based on the given presumptions and valid axioms). Likewise the deduction, the simulation is based on the set of explicitly given presumptions which however do not lead to the verification of the certain conclusions. Within this context, the simulation results primarily in generation of data which are suitable for further analysis by the induction method. It is crucial that this process of such data generation follows accurate rules. Therefore, the data acquired by the simulation are absolutely different than the data collected and consecutively processed by the induction method.

During the biological incident management, the induction method is utilizable only to a limited extent. It can be employed in the phase focused on the prevention of potential problems. In case of existing problems it is necessary to utilize the simulation which eliminates the problem complexity due to the previously created model (for example by induction method). Moreover, also the demands on the decision maker decrease noticeably. Furthermore, the scenario development enables better preparation for the incident consequences thanks to the modeling of real situation development according to the given parameters. Evidently, it is thus easier to plan the utilization of the technical, human, time as well as financial resources more effectively. Biological incidents can be characterized as high open and at least high dynamic environments which include the uncertainty. Therefore, the application of multi-agent approach is worthy [13]. Generally, the multi-agent approach is currently successfully used within various fields because of its considerable advantages. Within practice the following examples are mentioned. The multi-agent technologies are employed in tourism [5], for the ontology derivation [7] or for improving health care services in terms of increase the quality and efficiency [20]. Moreover, these are successfully used within the business area as well - for example during the enterprise mobilization which covers the support of mobile workers [17], during distributed knowledge processing [16] or during market simulation providing the analysis and prediction of consumer groups' behavior and their interactions [6]. In all these cases, there is a given environment with a lot of actors (agents) who bear specific characteristics and who behave in a certain way. Furthermore, all the aforementioned processes are typically very complicated and during their development a lot of miscellaneous influential elements play important role. This proves the appropriateness of the multi-agent approach.

Such attitude ensures:

- the reduction in time necessary for the solution (thanks to the possibility of parallel and asynchronous procedures),
- the elimination of demands on the communication (specialized agents solve their assignments and deliver the results of their actions among themselves),
- the higher flexibility (the possibility to maintain the count of team agents),
- the higher reliability (everyone is replaceable, the loss of one member does not threaten the operation of the whole system),
- lower costs regarding the fact that each component (agent) is simpler and therefore cheaper than the whole system [18].

Among the advantages of the model utilization the following can be mentioned [13]:

- emergency capture - behavior which are not revealed by the local examination because these are not intuitive and predictable
- common tool for the investigation of the systems of a certain type - for example the modeling of emergency exits location in a building
- flexibility - the possibility to model the moving entities, define their relations and networks, etc.

The model utilization is naturally linked with particular disadvantages which follow:

- the model is created for a special purpose and with a specific level of detail - therefore, both these facts must be correctly interpreted
- modeling of irrational behavior, subjective viewpoints and complex systems is always difficult
- some variables are not quantifiable
- the created models cannot be verified, etc.

The disadvantages should be obviously taken into account to eliminate potential consequences of their omission. Nevertheless, the advantages of the utilization for biological incident management purposes prevail.

3 Simulation Prototype of Biological Incident Development

The simulation prototype of biological incident development can be perceived as an important part of the entire system for scenario creation. On the basis of created model, it is possible to simulate the agent spread within the environment. The aim of the simulation is the evaluation of the incident impact on the population and the appropriate focus and suitable coordination of preventive countermeasures and eventually rescue works. It is important to notify that the prototype described within this paper serves the purposes of technology verification and demonstration of its functionality. The input to the simulation is the subset of parameters defined in the table of information availability created by research team. Generally, these embrace domain knowledge about the certain agent and the up-to-date data about the environment. The domain knowledge is derived from the elaborated ontology which was created on the basis of semi-structured interviews with domain experts from fields of biology, medicine and epidemiology. The outputs of simulation are values of particular parameters in a certain time.

3.1 NetLogo Model

The model utilized for the biological incident simulation is based on the multi-agent technology [8]. This technology was chosen regarding the aforementioned advantages of such approach and especially due to the character of the biochemical incident where a lot of various factors with defined attributes and specific intended behavior emerge. Thus, the interaction of autonomous agents occurs within the defined environment. Therefore, such modeling enables to deal with the complexity of the progress of the particular incident management.

For the purposes of the described model and regarding its realization, the NetLogo environment which can be downloaded for free is used [11]. Moreover, the system requirements are not demanding. The NetLogo environment allows the observation of natural and social phenomena as well as the modeling of complex systems which develop over time. Additionally, the NetLogo environment provides with the library of pre-defined models which enable the simulation of pre-set situations from various areas (for example biology, mathematics, chemistry, system dynamics or computer science). Therefore, the environment offers the introduction of its options and functions to the users. Another advantage is the environment interactivity and flexibility which allows the input parameters setting as well as their adjustment. During the model creation, three basic types of elements are available - these are buttons, switchers and sliders. The user interface offers also the utilization of extensive dictionary of built-in constructs and mathematical operations [13]. Furthermore, various output formats can be selected. A range of quite a few extensions is also available. These include for example the addition of sound, the access to MySQL databases or the connection to Geographic Information System.

Considering the purpose of the simulation, which is to verify the technology and demonstrate the required functionality, the selected environment is adequate and sufficient. Nevertheless, for more complex and complicated simulations it would be more suitable to utilize an advanced environment. Java Agent DEvelopment Framework is mentioned as an example [9].

3.2 Model Description

The prototype is primarily focused on the simulation of the spread of the agent transmissible through the air and its impact on the population. The basic agent classification corresponds to this fact. The agents are divided to these representing the population and the second group describes the contaminated cloud. The described model is the analogy of NetLogo model called Virus which is available in the Biology section of the Models Library of the NetLogo environment [11]. Nevertheless, the discussed model is amended according to research aims and purposes. The presence of a cloud of the infectious substance is added and the incident development is based on the different principles (see code of the Virus model in the NetLogo library and examples of code below). The detailed significant differences are observable while comparing the Figure 1 and Figure 2. The Figure 1 shows the NetLogo model Virus which illustrates only the number of health, sick and immune people. There is no influence of a cloud which supports the agent spread among people. The climate conditions and other factors as well as options to amend the model are apparently omitted or not available. On the contrary, Figure 2 demonstrates discussed model based on author's research and includes more factors mentioned below.

The entire model uses with a few layers. The first layer represents the environment within which the simulation proceeds. The second layer embodies the people considered for the model purposes. In addition to the initialization of people's characteristics (see code below), the rules determining their random movement within the environment are set. Sick-count is at the beginning of the simulation set to 0, because in case of biological incident, no sick people are considered to be present in the initial phase.

```
to setup-people
  set-default-shape people "person"
  create-people people-count
    [
      setxy random-xcor random-ycor
      set color blue
      set sick-count 0
      set immune? false
      set sick? false
      set will-survive true
      set size 10
      ]
  end
```

The people are divided into two groups. In the situation of the model initialization, only healthy persons are present as mentioned above. During the simulation progress, some healthy people become infected. In case of death, the particular person disappears from the simulation. This model of behavior described in discussed model is adapted according to the model called 'Virus' [11]. The people impacted by the contaminated cloud are infected regarding to the level of infectability. The infectability is highest at incident location and decreases gradually with the distance. The level of the infectability is determined by the distance from the incident location and the spread intensity.

As mentioned above, within the simulation there are also agents representing the particles of the contaminated cloud. The spread of a certain agent is characterized by particular parameters which comprise two interlinked phases. The initial phase represents the cloud expansion when its size grows according to the spread intensity (see code below). For the description of the cloud spread, the color differentiation is utilized. It demonstrates the infectability intensity expressed by the various color tones of grey where darker tone represents higher intensity and lighter lower intensity.

The cloud is divided into two parts, the inside and the edge, where only the edge spreads. Progressively, the cloud moves according to the wind direction and its consecutive dispersion. Simultaneously, the number of infected and dead people increases according to the fatality of given agent or eventually according to the probability of the transmission from one person to another.

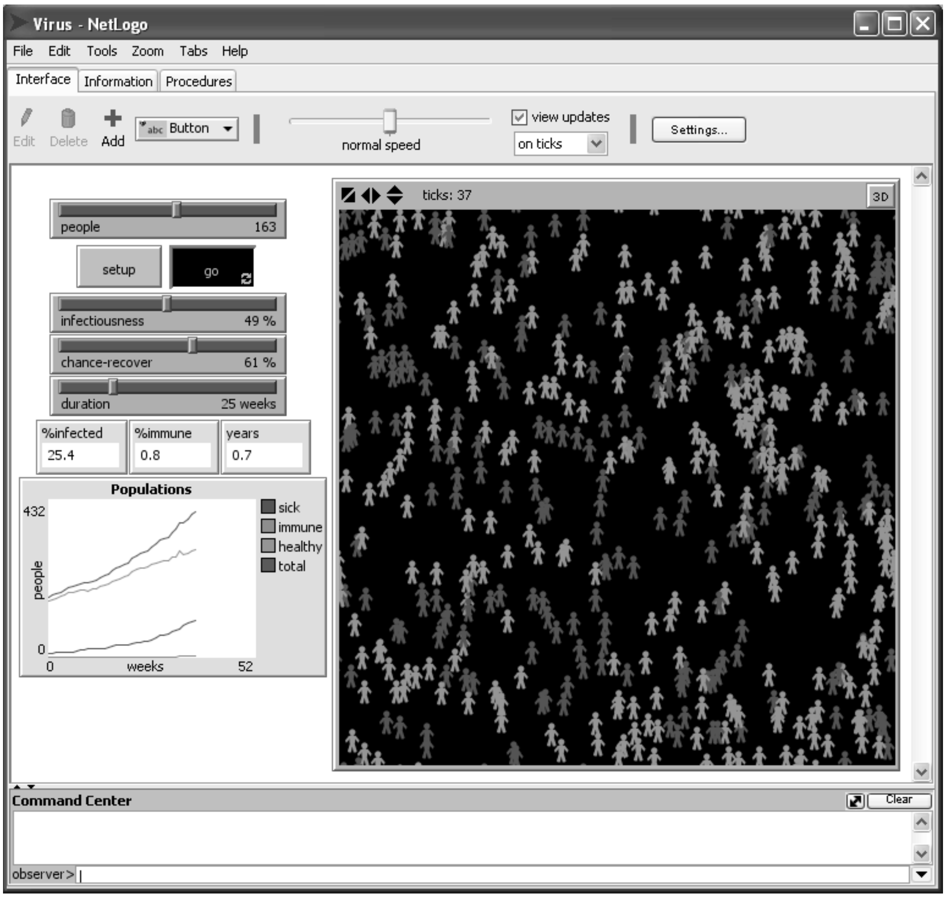


Fig.1: The NetLogo Model Virus [13]

The coloring of the cells (Environment Agents) proceeds in the wind direction. Nevertheless, this process runs only in case of cells in the neighborhood of already colored ones. Each time unit during the spread period, a cell in angle from -45 to +45 degrees is randomly chosen and colored.

```
to spread-cloud
   ifelse ( current-spread-period > 0)
  [
    ask cloud-line
    [
        if(random-float 100) < spread-
        intensity
        [ ;;ask neighbors with [(count
        turtles-here) = 0]
          ;; [ infect ]
          let angle 90
          repeat 3 [
              ask  patch-left-and-ahead
              angle 1 [
          if (count turtles-here) = 0
              [ spread ]]
             ask patch-right-and-ahead
             angle 1 [
          if (count turtles-here) = 0
              [ spread ]]
          set angle angle - 45
          ]
      ]
      set breed cloud-inner
    ]
  ]
  [ask cloud-line [die]]
end
```

Within the second phase, the diffusion process prevails. The progressive spread of the harmful agent is observable. This process is logically separated also in the code (see the description of this phase below). Nevertheless, during both phases the cloud moves according to the given wind speed and wind direction.

```
to diffuse
  ask cloud-inner
      [ if   (random-float   10000)   <
         age
         [ set pcolor green
           die ] ]
end
```

The exemplification of a prototype describing the agents' spread is illustrated in the Figure 2.

The modeling of cloud movement can be extended utilizing the NetLogo functions. The cloud movement is influenced not only by the climate, but in reality this phenomenon has partially a random character. Therefore, the inclusion of the possibility to set the share of actual climate conditions (wind speed and wind direction) and the share of random factors seems to be relevant. The actual setting of such slider would be then influenced by the trustworthiness of the climate conditions resource and the reliability of the forecast which is usually assessable. In practice the climate conditions would have ordinarily significantly higher impact (presumably more than 90 %).

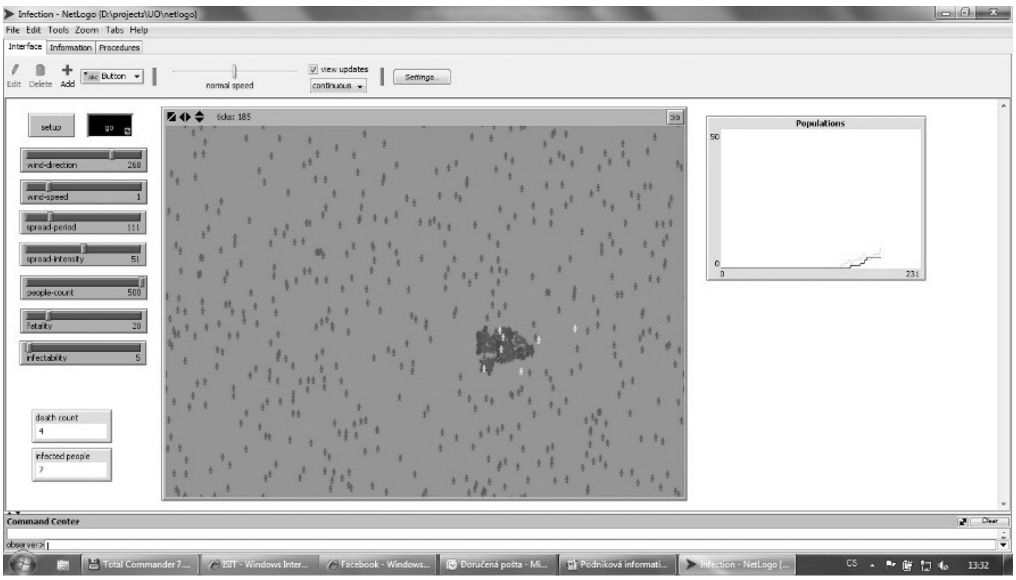
3.3 Parameterization

The parameters represent the input values of the simulation model. Therefore, especially because of the model accuracy and reliability, it is important to pay attention to these parameters and unambiguously determine them. NetLogo offers the input parameters' amendment according to the user's needs and thereby provides with the option to observe the agent behavior as well as environment changes under various conditions. The number of both parameters and autonomous agents is not practically limited.

For the purposes of the discussed simulation, the parameters fatality, infectability and the way of transmission from one person to another are considered. Particular values of these parameters depend on the chosen agent. These are acquired from the modeled domain knowledge in subsystem modeling the incident. This knowledge is adopted from the Biological and Chemical Agent Characteristics [3] compiled on the basis of data from the Committee on Toxicology [4] and U.S. Department of the Army [22]. Moreover, the population size can be chosen. Within the described model, the population size can be selected from 0 to 500. Such extent is sufficient for the illustrative purposes of the simulation. Higher population size unnecessarily increases the demands on the computational complexity and proportionally decreases the simulation speed. This problem might be eliminated by the employment of various methods (for example Parallel Computing [15]). Furthermore, the characteristics of the environment can be adjusted. These noticeably influence the agents' spread. Especially, the influence of weather and climate conditions in the impacted area is considered. Within the depicted model, the parameters relating to wind are reflected because of the fact that the mentioned agent is transmissible through the air.

For this particular simulation the following parameters are used. These can have under-mentioned values. Obviously, these parameters together with their values are easily amendable for specific purposes of each incident.

- Wind Direction: 0-360 degrees
- Wind Speed: 0-10 points per time unit
- Spread Period: 0-500 time units of the simulation; time period of the cloud spread during the simulation
- Spread Intensity: probability of the infection spread within the cloud further into the environment (the edge of the cloud)
- People Count: 0-500
- Fatality: probability of death of an infected person (taken from appropriate resources - e.g. [21]); such person disappears from the screen after death
- Infectability: probability that the cloud infect a person.



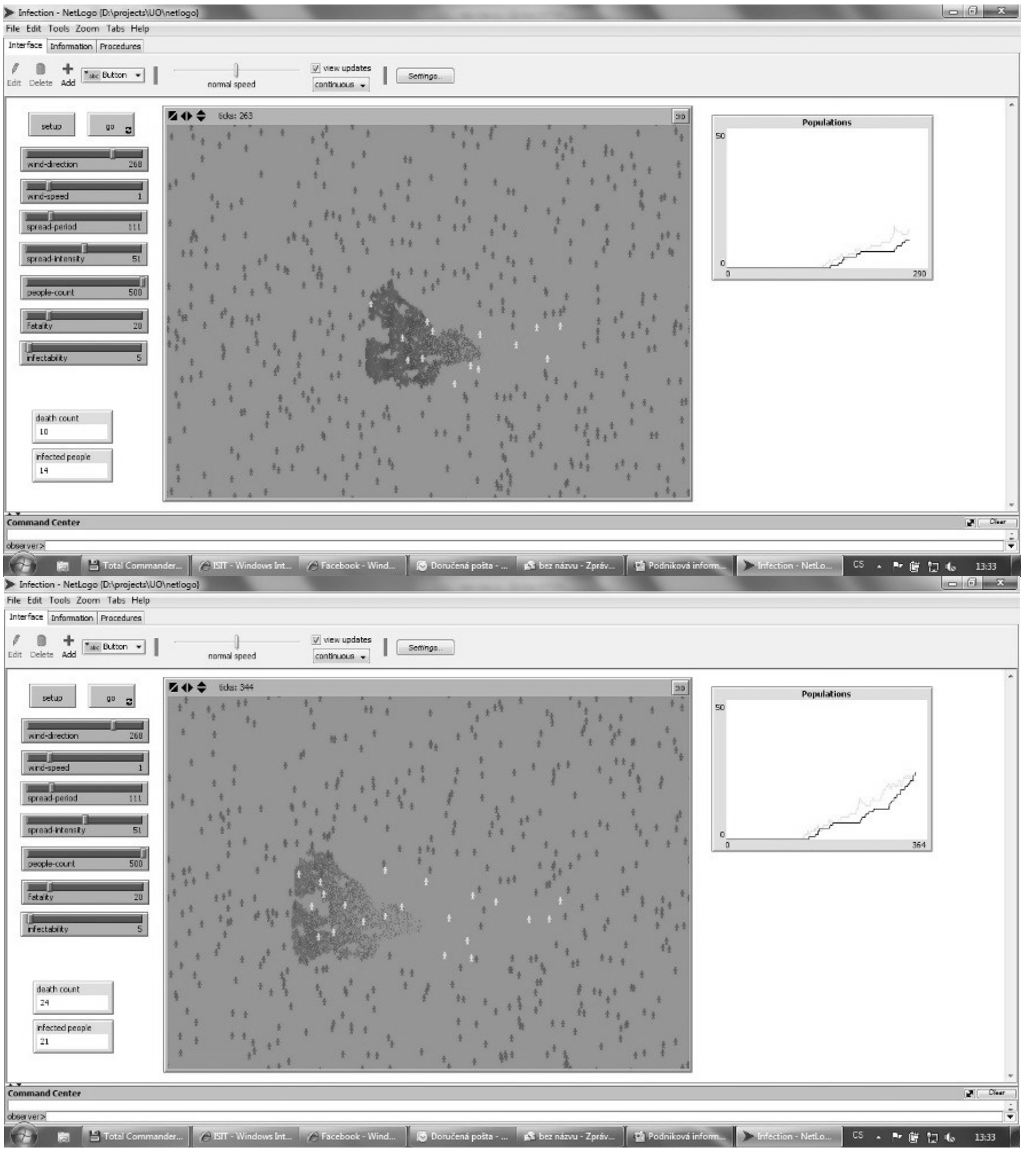


Fig.2: Agent-based Scenario Development (authors' research)

4 Further Research

The further research covers a lot of various areas. First of all, the discussed model itself can be developed. Further precision and specification of the simulation can be reached through the employment of the suitable epidemiological models of agent spread - for example see [1], [14], [19]. As already stated, the real data can be added, eventually utilized for more accurate illustration of the actual situation. Such data and information can be acquired from relevant sources. Among others, demographic data, strategic documents or medical and epidemiological systems are mentioned. Likewise, the inclusion of more parameters describing the environment especially in terms of weather conditions should be considered due to the importance of their influence on the agent spread, potentially on the incident development.

These data and information are available in various hydro-meteorological institutes. Such institutions provide the real time data mostly online and free of charge. Therefore, their inclusion as well as utilization is both relevant and realizable without any demanding procedures necessary through their implementation. The crucial characteristic of such data is their up-to-datedness which secures the appropriateness of course of action and prevents the wastage of resources. Generally, it is possible to extend the amount and the details of the input parameters. However, this possibility is connected with higher demands on both the user who input the data and their availability as well as format. The entire model can be consequently more accurate, but also less clear and comprehensible. Therefore, this fact should be taken into account since the begging of the model creation. Moreover, the parameters should be optimized according to the purpose of the model and the needs of its users. Prospectively, the prioritization of the selected input parameters can be considered because of the fact that each parameter in the model bears different level of reliability during the incident modeling and each parameter is diversely important for the incident development.

Moreover, the connection of the model to other applications is possible. The general context of the simulation is illustrated in Figure 3 which depicts the framework for the biological incident management with all its potential components. Not only are the external resources represented by the input data into the model shown. Such data necessitate to be transformed into relevant and comprehensible information for the end users who decide on this basis. Therefore, the utilizable tools and methods for the data transformation and analysis mostly based on the principles of business intelligence [12] are demonstrated. The Figure 3 also describes the significant importance of the simulation especially for the end users who are represented by the decision-makers. All the mentioned end users need to possess as precise information about the incident development as possible. The simulation obviously influence and specify both the course of action and the particular countermeasures they decide to take. As an example, the data and information about the wind direction, density of defined population, or maps from Geographic Information Systems (GIS), which can be improve the visualization [10], can be connected to the current model – the related trajectory of data and information flow is depicted in the Figure 3. Apparently, the data from resources databases are gathered with help of ETL tools (Extract, Transformation, Load) to the Data Warehouse, from which they can be used for either periodical reporting, or ad hoc inquiring. Regular reports can provide the simulation model with initial setting of parameters, while ad hoc inquiries can be used for what-if analysis. Hence, the improvement based on the utilization of online analytical processing (OLAP) which provides fast data analysis and fast response to given questions can be included. This would enable even quicker and more precise decisions leading to better assets protection and losses minimization.

In this concept simulation can be also connected with other systems with various functionalities. However, their further interrelation is more the engineering problem than the research one. For instance, the employment of web services is a useful option for future improvement. This should be considered because of particular advantages which are discussed below. Web-based applications would operate continually and thus would be available constantly to all potential users. The proposed arrangement of the web applications can be based on the client-server architecture, where the database and application logic are available on a server, while the presentation layer is available for all users online. This is one of the main advantages of a web application in comparison with the desktop one. As mentioned above, such structure enables the access of more users. Moreover, the utilized data are gathered from resources covering usually not only particular regions, but mostly the whole state. Nevertheless, the web application used for these purposes should be tailored according to the needs of various end users and according to their abilities and skills. Therefore, its development would require appropriate time, financial and human resources.

Furthermore, subsequent improvement lies in mobile services instead of using web services. The mobile services provide potential access to predefined analyses and other valuable outputs for mobile clients and facilitate the utilization of these processes out of office.

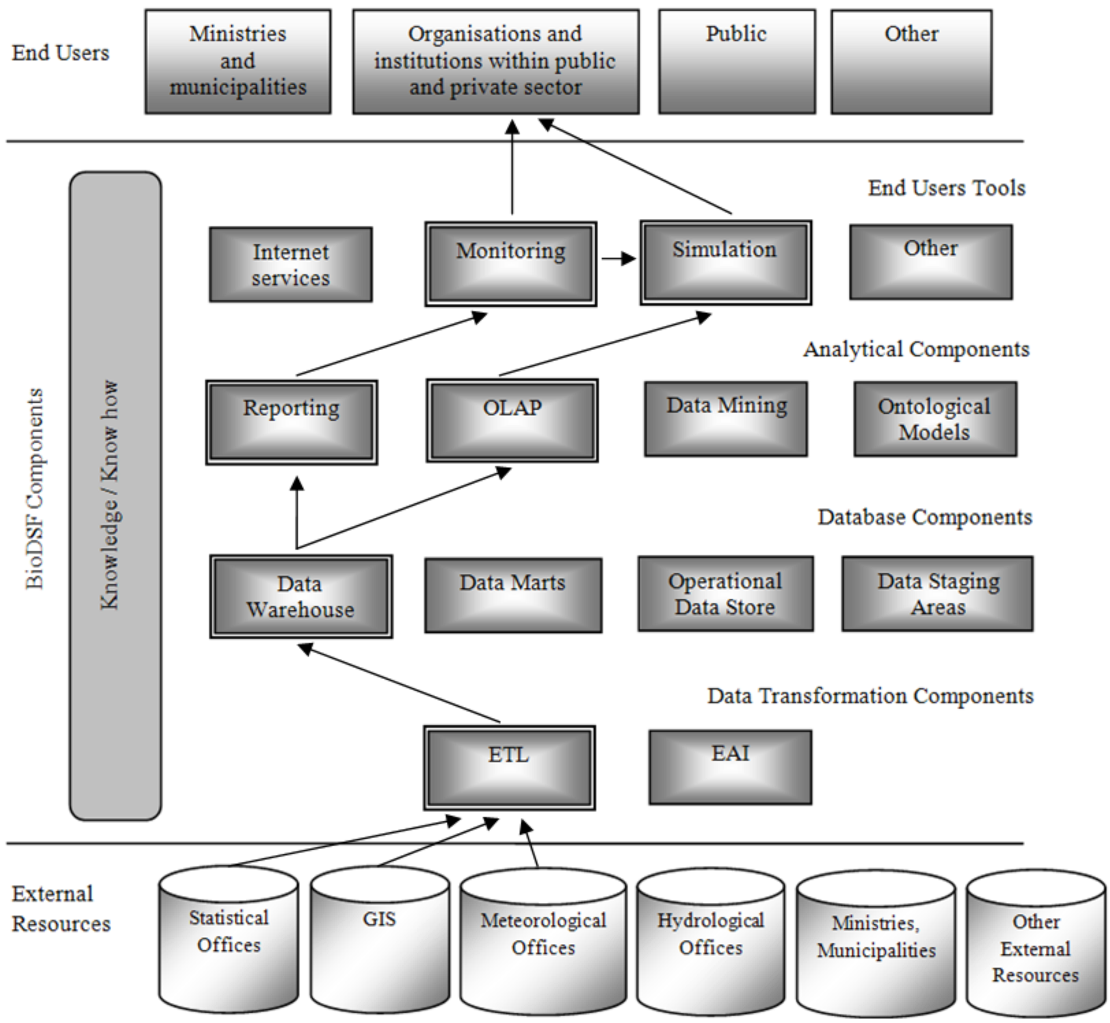


Fig.3: The Context of the Simulation within the Biological Incident Management (author's research adapted from [12])

5 Conclusion

Biological incidents remain an unstructured and very complex issue. Considering the sophistication of potential aggressors, the increasing value of impacted assets and growing demands on humans who make decision under pressure with limited resources and cognitive skills, the readiness for the biological incident management needs to be supported. This paper confirms that the computer-based scenario simulations, if correctly managed and interpreted, represent a useful tool for decision support during such situations. Therefore, the discussed multi-agent based technology can be recommended and employed to improve the impact elimination, resource planning or future preparedness for similar incidents.

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References:

[1] Ajelli M., Goncalves B., Balcan D., et al., Comparing large-scale computational approaches to epidemic modeling: Agent-based versus structured metapopulation models, *BMC Infectious Diseases*, Vol. 10, No. 1:190, 2010.

[2] Axelrod R. Advancing the Art of Simulation in the Social Sciences, in *Handbook of Research on Nature Inspired Computing for Economy and Management*, Idea Group, 2005, pp. 90-100.

[3] Biological and Chemical Agent Characteristics, *NBC Product and Service Handbook.* Online, available on http://www.approvedgasmasks.com/BioChemAgentCharacteristics.pdf, accessed 22/01/2011.

[4] Committee on Toxicology, National Research Council, *Review of Acute Human-Toxicity Estimates for Selected Chemical Warfare Agents.* Washington, D.C., National Academic Press, 1997.

[5] Čech P., Bureš V., Advanced Technologies in e-Tourism, *The 9th WSEAS International Conference on Applied Computer Science*, Genova, WSEAS Press. 2009, pp.85-92.

[6] Geng Z., Key Consumer Group for Late Comers in Network Effect Product Markets: A Multi-agent Modeling Approach, *WSEAS Transactions on Computers*, Vol. 7, Iss. 10, 2008.

[7] Iordan V., Naaji A., Cicortas A., Deriving Ontology Using Multi-agent Systems, *WSEAS Transactions on Computers*, Vol. 7, Iss. 6, 2008.

[8] Ishida T., Multiagent Simulation Meets the Real World, *AAMAS '06 Proceedings of the fifth International Joint Conference on Autonomous Agents and Multiagent Systems*. New York, NY, 2006.

[9] JADE, *Java Agent Development Framework*. Online, available on http://jade.tilab.com/, accessed 22/01/2011.

[10] Ježek B., Vaněk J., Information Visualization Methods, *6th Conference of the Society of Military Doctors, Pharmacists and Veterinarians.* Hradec Králové, Czech Republic. 2006.

[11] NetLogo, c1999-2010, *NetLogo*. Online, available on http://ccl.northwestern.edu/netlogo/, accessed 22/01/2011.

[12] Novotný O., Pour J., Slánský D., *Business Intelligence*. Prague, Czech Republic, Grada Publishing, 2005.

[13] Olševičová K., *Problémy s omezujícími podmínkami řešené agentovými systémy* (translated as Problems with the Restrictive Conditions Solved by Agent Systems). Habilitation thesis, in Czech, University of Hradec Králové, Hradec Králové, Czech Republic, 2009.

[14] O'Neil C.A., Sattenspiel L., Agent-Based Modeling of the Spread of the 1918-1919 Flu in Three Canadian Fur Trading Communities, *American Journal of Human Biology*, Vol. 22, No. 6, 2010, pp. 757-767.

[15] Panuš J., Parallel Computing for Modified Local Search, in Fujita H. and Sasaki J. (eds.) ACS'10 Proceedings of the 10th WSEAS International Conference on Applied Computer Science. Iwate, Japan. 2010, pp. 508-513.

[16] Popirlan C.I., Knowledge Processing in Contact Centers using a Multi-Agent Architecture, *WSEAS Transactions on Computers*, Vol. 9, Iss. 11, 2010.

[17] Shepehrdson J., Lee H., Mihailescu P., Evaluation of Multi-agent Platforms as an Enabler of Enterprise Mobilisation, *WSEAS Transaction Journal on Systems*, Vol. 4, Iss. 11, 2005.

[18] Štěpanková O., Mařik V., Lhotská L., Distribuovana uměla intelligence (translated as Distributed Artificial Intelligence), in Uměla inteligence 2 (translated as Artificial Intelligence 2), in Czech, Academia, Prague, Czech Republic, 1997.

[19] Tsai M.T., Chern T.C., Chuang J.H., et al., Efficient Simulation of the Spatial Transmission Dynamics of Influenza, *PLoS ONE*, Vol. 5, No. 11, 2010.

[20] Turcu C., Cerlinca T., Turcu C., Cerlinca M., Prodan R., An RFID and Multi-agent Based System for Improving Efficiency in Patient Identification and Monitoring, *WSEAS Transactions on Information Science and Applications*, Vol. 6, Iss. 11, 2009.

[21] U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID), *USAMRIID's Medical Management of Biological Casualties Handbook,* 6th edition, Maryland, 2005. Online, available on http://www.usamriid.army.mil/education/bluebookpdf/USAMRIID%20BlueBook%206th%20Edition%20-%20Sep%202006.pdf, accessed 07/01/2011.

[22] U.S. Department of the Army, Potential Military Chemical/Biological Agnes and Compounds, U.*S. Army Field Manual 3-9, (NAVFAC P-467, AFR 355-'7), 12 December 1990*. Washington, D.C., Government Printing Office, 1990.