Application of Multi-agent Simulation in Animal Epidemic Emergency Management: Take an Example of AFS (Africa Fever Swine) Policy

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Abstract. This paper introduces the research status in the field of infectious disease prevention and control policy, focuses on the emergency management of animal epidemic events, and proposes to imitate multiple subjects. The real technology is applied to the policy analysis and emergency management of infectious disease prevention and control the application of multi-agent simulation method in the system is discussed. The research advantages of multi-agent simulation, construction process, functional structure and system in policy evaluation and Application in emergency management of animal epidemic events.

Introduction
Along with China urbanization level enhances unceasingly, rising population density, people and food industry suffering from all kinds of unexpected public events endanger the possibility of increasing, especially the severe acute respiratory syndrome (SARS) in the spring of 2003, one after another outbreak of highly pathogenic avian influenza, as well as the spring of 2018 A-type H1N1 flu, make whole world come to realize that sudden animal or avian epidemic events of great impact to society. How to strengthen the prevention and control of animal epidemic emergencies is an important issue we have to face and solve.

Sudden animal epidemic events refer to the outbreak of major infectious diseases, mass diseases of unknown causes, major food and occupational poisoning and other events that seriously affect animal epidemic. At present, infectious diseases are still one of the most serious disasters that cause the most sudden animal epidemic events. Therefore, it is very important to study the occurrence mechanism, transmission rules and prevention and control strategies of infectious diseases to deal with sudden animal epidemic events as early as possible. There are many contents of emergency management, including organization and policy, basic theory and method, technology and tools, and integrated emergency platform. This paper focuses on the research of integrated emergency platform based on computer technology, big data and AI.

As the objects affected by emergencies are often in various social networks, the impact of emergencies will also be along complex social networks spread. Infectious disease transmission is a typical phenomenon of transmission and diffusion. Researchers must fully consider the influence of complex network structure on transmission ring. In this regard, multi-agent modeling and simulation technology can naturally integrate network factors into a unified communication model framework. In the context of emergency management, we summarize the research on infectious disease prevention and control strategies at home and abroad, and propose a multi-agent simulation technical framework of infectious disease prevention and control policy simulation system. This policy simulation system can simulate the dynamic process of infectious disease transmission in the population, simulate the implementation process of prevention and control policy and emergency response and disposal plan, and provide strong support for the emergency decision-making of relevant departments by evaluating and verifying medical prevention and control measures and emergency plan of events.

Infectious Disease Prevention and Control Policy and Policy Simulation System
The control and prevention of infectious diseases has always been an important work of
governments and health departments of various countries, and the academic community has also carried out rich and in-depth and extensive research in this field. It mainly includes medical policy issues, resource allocation issues and other policy issues. Health policy issues refer to the issues that health policy makers deal with and solve that are directly related to infectious diseases themselves. These problems include the efficacy of new drugs, the efficacy of new therapies, the implementation effect of prevention plans and the comparison of immune strategies. Resource allocation refers to the allocation of medical resources during the implementation of the prevention and control plan, including the estimation of the quantity of medical resources, the cross-departmental allocation of medical resources, resource distribution, personnel allocation, traffic management schemes, etc. Decision makers must allocate resources not only between multiple competing alternatives but also, in some cases, between different animal epidemic sectors. Other decision-making issues refer to other issues in addition to the above two aspects, including the comparison of patient behaviors, the collection and collation of medical data, the establishment and implementation of medical information system and early warning system, the formulation and implementation of laws and regulations, and the cost-effectiveness analysis of the process. With the development of policy research on infectious diseases, decision support system for policy simulation evaluation has emerged. These decision support systems are involved

And covers the three aspects discussed above. Such systems provide scientific and effective decision-making support for the early warning and monitoring before the occurrence of infectious diseases, the prevention and control of infectious diseases and the disposal of infectious diseases after the occurrence. The policy simulation system proposed in this paper also belongs to this kind of decision support system. It can help research by simulating the dynamic process of infectious disease transmission, they can understand the occurrence mechanism and evolution process of communication, simulate the implementation process of prevention and control policies and emergency plans, and help researchers understand, compare and analyze the advantages and disadvantages of each strategy plan through simulation data.

Technology and Theory of Simulation System

The occurrence and development of animal epidemic events are irreversible and non-experimental. Therefore, simulation method is an important experimental means to study the occurrence mechanism and emergency management of public emergencies. In order to build this policy simulation system, it is necessary to select the appropriate research method according to the research object. For the spread of infectious diseases, the research object is a large number of swine, and the individual is heterogeneous, so the multi-agent modeling and simulation method is a smart choice.

Multi-agent Modeling and Simulation and Heterogeneity

At present, the research methods of infectious disease transmission are mainly mathematical methods and simulation methods. The mathematical method USES the differential equation to describe the individual state change relations, analyzes the equilibrium solution characteristic and the parameter relations, obtains the infectious disease transmission rule in the population. However, the mathematical method has its limitations. First, mathematical methods are insufficient to study the dynamic evolution of infectious disease transmission process. Secondly, the spreading behavior is closely related to the individual behavior of the crowd. The mathematical model generally assumes that individual behavior attributes are the same, so it is difficult to reflect the influence of individual heterogeneity on the communication process. Thirdly, with the increase of free variables and constraints, the model complexity increases and the solution form is complex, which cannot be analyzed analytically. Due to the limitations of mathematical methods, many scholars apply simulation technology to the study of infectious disease transmission.

With the rise of complex science, multi-agent based simulation technology has been paid more and more attention and applied in various fields. From the perspective of complex systems, this simulation modeling technology simulates individual behaviors at the micro level, and then deduces
the macroscopic results of the system. It interprets the complex dynamics of the system at the macro level from the perspective of individual behaviors at the micro level/from the bottom up. In order to better describe the transmission process of infectious diseases, especially considering the influence of individual heterogeneity, we adopted multi-agent simulation modeling technology to treat each person in the crowd as an individual and assign some attributes to individuals to specify their behavioral characteristics. Through the interaction between individuals, infected individuals spread the virus to healthy individuals according to certain rules, and then infectious diseases spread among the population. Multi-agent simulation method emphasizes the heterogeneity of individual behaviors and attributes, which is suitable for detailed description of individual behaviors. For example, it can divide swine into different groups according to age, gender, occupation, region, etc. Depending on the individual's susceptibility, the population is divided into low-risk and high-risk groups; You can even assume the same person different behaviors at different times and so on. Multi-agent simulation is adopted the infectious disease transmission model constructed by the method can better describe individual behaviors. The influence of transmission process truly reflects the transmission and diffusion process of infectious diseases.

**Complex Network Theory and Population Contact Network**

Not only individual heterogeneity has a huge impact on the spread of infectious diseases, but also the mutual contact between individuals is an important factor affecting the spread behavior. Therefore, the model of infectious disease transmission must also consider the contact pattern between individuals to truly reflect the complex social network structure existing in the population. If individuals are regarded as nodes and certain relationships among individuals as edges, then the whole group will form a network. Empirical research shows that most real life networks have small world and Scale free characteristics. In infectious disease research, the network formed by individual contact is called contact network. The empirical study shows that contact network also shows complex network characteristics. However, most of infectious disease models are difficult to describe this complex network structure. These models oversimplify the contact relationship between individuals, that is, they assume that individuals have the same neighborhood. The new model must take into account the complex network characteristics of contact networks.

On the other hand, although many scholars have begun to study the spread of infectious diseases under the conditions of complex networks, most of these researches adopt statistical physics methods, and most of the results obtained are of statistical significance, and the types of networks involved are relatively single. For more complex network structures, these methods are far from enough. The micro perspective of multi-agent simulation method makes the contact relationship of a large number of individuals easier to express. Taking individuals as the unit, and record every pair of individuals with contact relationship, so as to retain the network structure information of the population lossless. The model construction part of this paper will give the concrete construction process of contact network.

**Infectious Disease Policy Simulation**

**Construction, Implementation and Use of the Simulation**

The infectious disease policy simulation system is implemented in three steps. The first step is to construct a complex infectious disease network based on multi-agent simulation method context propagation model. The multi-agent modeling approach treats everyone in the population as a micro-subject in the multi-agent system, and the infection spreads from the infected individual to the healthy individual through the interaction between individuals. First, to facilitate the description of this process, we designed some properties for individuals. These attributes include age, sex, status, infectivity, susceptibility, population grouping, latency, survival, etc. Among them, the state refers to the pathological stage of the individual, and the value is determined according to the characteristics of the disease. Infectivity measures the ability of infected individuals to transmit the virus to healthy individuals. Susceptibility measures an individual's ability to resist transmission of
disease by others and reflects how easily an individual is infected. Group lists refer to the type of group to which an individual belongs. These attributes were designed to study the effect of individual behavior on the spread of infectious diseases. Individuals can set different values for these attributes, which is the heterogeneity of individuals.

At the beginning of the simulation, all individuals were in a susceptible state except for a number of randomly assigned individuals. When a healthy individual comes into contact with an infected individual, the healthy individual is infected with a certain probability. At this time, the state of the individual changes from a susceptible state to an infected state. After the sera have passed the positive, the infected individual enters a contagious state and has the ability to infect others. During the incubation period, the carrier shows symptoms of AFS and the state becomes morbid state. After the survival period, the individual state changes to death and is subsequently removed from the model.

Once an individual attribute has been specified, a contact network must also be built between individuals. There are two ways to build a network. On the one hand, build a real network structure. The method is to conduct a questionnaire survey on the population of a certain area, determine the contact relationship between the individual and the individual, and reconstruct the contact network when the simulation system is running according to the obtained information, and the system uses the network to simulate the propagation process on the real contact network. This kind of network structure obtained from the actual investigation can be a good representation of the contact relationship of swine in a certain area and is representative. The contact network characteristics of the crowd are very complex, and there is not yet a best complex network model that can describe the complete and true expression of all the complex features of the contact network. This makes the simulation model more inconsistent with real-life/real prototypes. However, for the propagation problem, the small world characteristics and the scale-free characteristics are the two most significant factors affecting the propagation behavior. It is enough for the simulation model to grasp these two characteristics. After constructing a suitable contact network, the simulation system can dynamically simulate the propagation of infectious diseases in the population.

After implementing the infectious disease simulation model, you need to determine the input parameters of the model. These parameters are summarized through other infectious disease research literature, census data, announcements by relevant state departments, and after careful screening and analysis, and are required to meet objective and actual conditions. For example, the birth rate, mortality rate, sex ratio, etc. of the population can be used to determine the population size change rate within the model; the prevalence of an infectious disease in a certain area can be obtained from the medical department, and the initial infection at the beginning of the simulation can be determined. The number of swine; the incubation period and the onset period of an infectious disease can be obtained from the relevant medical research report and used as the attribute value of the individual's incubation period and the onset period; the probability of propagation of the individual in one contact can be obtained through medical clinical laboratory reports as the individual infection degree and The value of susceptibility, and so on. In addition, the network structure required for model simulation can reconstruct the contact network of a local population in a certain region by using the actual survey data results, or refer to the empirical literature of the complex network, select appropriate network parameters, and generate a certain algorithm. Of course, the data obtained by the above method cannot be directly used, and must be converted into a parameter value that is meaningful to the model after being summarized and analyzed. After the parameter values are determined, the individual attributes and behaviors of the model are determined, so that the model can be used for simulation experiments. Of course, these parameters are not selected once and must be adjusted through the simulation results. The principle of adjustment is to make the simulation results have reasonable practical significance.

After implementing the policy simulation system of each functional module of the system function on the computer, the system can be applied to complete the decision support of the policy solution evaluation. The process of policy program evaluation is shown in Figure 7. As can be seen from the figure, the early stage of the policy plan evaluation is to continuously correct the model...
through data. This process obtains relevant data from the real world and estimates the initial parameter values of the model by analyzing the data. Input the parameter values into the system, and output the results after the simulation system runs. After analyzing the results, the model is further revised, the data is supplemented, and the simulation model is refined. When the model is calibrated, the model can better represent the real system corresponding to the characterization. At this time, according to the research question, a corresponding set of parameter combinations is specified for each policy plan to be evaluated, and each parameter combination is simulated several times to obtain different simulation running results. By summarizing these simulation results, we can evaluate the performance of a policy program and give policy recommendations. This process is called policy analysis based on simulation methods.

The policy simulation system of this paper starts from a simple simulation model of infectious disease transmission, and gradually expands various types of subjects such as medical department, logistics department and government management department, and adds various functional models to form a preventive control policy. And decision support systems for emergency response assessment of public emergencies.

Several problems in Modeling and Implementation

(1) Establish the simulation model correctly. Decision makers need to make reliable, scientific and timely forecasts of the development of infectious diseases, which require a deeper understanding of the development of infectious diseases. We need to rationalize the behavior of the individual in response to the characteristics of the spread of infectious diseases, and give appropriate descriptions from different sides. These efforts largely determine the credibility of the research results. First of all, it is necessary to abstract the necessary micro-individuals from the real life as the main body in the model according to the needs of the research questions. Secondly, it is necessary to determine the attributes of each type of subject, accurately describe the behavior of the subject, and design the interaction between the subjects. Finally, determine the size of the system, that is, the number of each type of subject. The above process needs to refer to existing mathematical models of infectious diseases and resource allocation algorithms and schemes.

(2) Determine and adjust model parameters. Verify the rationality of the model parameters and the credibility of the results. This process requires the collection and collation of macroscopic data on the spread of infectious diseases in China and microscopic data on individual behavior. Data sources can be officially published by the government, data provided by medical organizations, and field survey data from research institutions. It is a very important step to analyze the data after obtaining the data to determine the value of the simulation parameters. In addition, the simulation model needs to be further corrected and improved after comparing the results of the simulation run with the actual results.

(3) Choose the right software tools. Choose a programming language or an integrated development platform to implement the model. There are many simulation platforms based on multi-agents, such as Swarm, Netlogo and so on. These platforms already provide a framework for simulation models and a large number of class libraries, so researchers can focus on the design of the subject. In addition, most of these tools provide complex network simulation modules, and provide several complex network generation algorithms to facilitate the implementation of complex network models.

The Application of Policy Simulation System in Emergency Management

The infectious disease policy simulation system has broad application prospects in the emergency management of animal epidemic events. The simulation system can help decision makers prepare for the rain and be fully prepared beforehand. Animal epidemic incident monitoring and early warning work is an important part of emergency management of animal epidemic emergencies. Early monitoring and prior material reserves are important for the effective disposal of animal epidemic emergencies. The simulation system can help strengthen the monitoring and early warning of infectious diseases, determine the optimal number and optimal location of the early warning.
monitoring points, and help solve the problem of site selection planning for medical materials storage warehouses. Usually such problems are very complex, involving logistics, transportation, climate, terrain and many other aspects, the general method is difficult to give intuitive results. Through the simulation system, decision makers can have a general understanding of the emergency response and disposal process beforehand. The evolutionary development process of animal epidemic emergencies is also an important part of emergency management research. Understand the general rules of the process of animal epidemic events in the population, and master the evolution of various animal epidemic events under different conditions, which is essential for effective disposal of animal epidemic events. Use the policy simulation system to observe the propagation process of animal epidemic events under different conditions, predict the number of swine and suspects, estimate the number of swine infected, predict the development direction and scope of the event in time, and guide the prevention and control of the work. Studying emergency response strategies after animal epidemic emergencies is also an important part of emergency management. For example, study immunization strategies under specific population conditions, study mandatory segregation measures, study medical resource allocation strategies and transportation strategies, and study event detection and monitoring point establishment strategies. The policy simulation system can easily study various prevention and control strategies, simulate the impact of the implementation of different emergency measures on the animal epidemic event propagation process, and then evaluate different emergency policies, find the deficiencies of existing strategies, and identify key points and Bottlenecks, improvements and improvements to existing programs.

**Conclusion**

In terms of emergency management, the simulation method has obvious advantages in dealing with the uncertainty of event evolution, the dynamics of information and related factors, and the interactivity in complex social networks. It is more suitable for practical large-scale complex systems and gradually becomes a worthwhile Method. Obviously, the multi-agent simulation method provides a new tool for studying the mechanism of emergencies, the process of event occurrence and the determination of emergency plans. The emergency response simulation system requires the integration of the evolution of emergencies, multi-sector collaboration, resource scheduling configuration, and rescue strategy evaluation to perform real-time simulation to obtain the evolutionary consequences of different scenarios. The main difficulty lies in the need to fully consider the complexity, uncertainty and dynamics of the emergency response process. Therefore, in view of the current research status, this paper proposes to apply multi-agent simulation technology to the emergency management of animal epidemic events, and construct an infectious disease policy simulation system. The system can reproduce the dynamic process of transmission of sudden infectious diseases, simulate the implementation of prevention and prevention policies, and the whole process of emergency response and disposal, and evaluate prevention and control policies and emergency plans. The article demonstrates the advantages of multi-agent simulation technology in the study of the spread of infectious diseases, and describes the application prospects of multi-agent simulation technology in emergency management of sudden animal epidemic events. The simulation system of this paper combines multi-agent modeling and simulation technology with complex network theory to solve a practical problem, and provides a reference example for the study of complex systems composed of a large number of individuals in the future social and economic fields.


**References**


