A research on coupling prediction model for multi-disaster

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Abstract

Through the introduction of the concept of disaster chain, this research set up the coupling prediction model for multi-disasters. In this model, the procedure of the prediction is divided into two levels: the first level focuses on single disaster forecasting, which is composed of one hazard and many hazard-affected bodies; the second is the disaster chain level, which consists of a series of interrelated and interacted single disaster prediction process. Multi-agent technology can be used in designing the elements and event handling mechanism can be used in realization of event trigger mechanism defined in this model. Compared with traditional methods of disaster analysis, the model analyses the genesis and influencing process of the primary and secondary disasters comprehensively. Thus MDCPS, a prototype system is developed to verify the feasibility and effectiveness of the model.

Keywords: natural disaster chain, event-chain, model, event-driven

1 Introduction

Natural disasters tend to arise more frequently and the losses caused by the disasters expanded more quickly, especially in recent ten years. Strengthening natural disaster prediction research is an important way to reduce disaster losses, and it is also a prerequisite for relief work. The research on disaster prediction and emergency system mainly concentrate on urban emergency management systems and single disaster prediction systems (Levya, 2007 Lu, 2002). But as an integrated system, the theoretical research on the disaster management system itself relatively lags behind and a unified senior management and operation platform need to be developed, on which every department can cooperate and coordinate effectively. Recent years, some research has focused on risk analysis for interdependent infrastructure systems (Guikema, 2009) and risks of multiple natural hazards on these systems (Gu, 2008). Based on the results of previous researches, this paper proposed a framework for multi-disaster coupling prediction model through the introduction of the disaster chain theory.

2 Natural disaster chains

The concept of disaster chain was introduced by Guo Zengjian (Guo, 1987) at first in 1987, which has developed into one of the most important disaster prediction theories. Disaster-chain refers to a compound system with an array of disaster elements, in which there are a series of consequent interactions among the elements and subsystems. Due to the intensity of the interactions, the system has the characteristic of entirety(Liu, 2006). The progression of many natural disasters will inevitably
lead to a series of secondary and derived disasters, which constitute a natural disaster chain. Earthquake disaster-chain, typhoon disaster-chain, cold wave disaster-chain, storm disaster-chain, drought disaster-chain etc. (Gao, 2007), are the most common ones. For example, Figure 1 illustrates the relationship between the causes of disaster chains.

![Earthquake disaster chain](image)

**3 Coupling prediction model based on disaster-chain**

Hazard and the loss of hazard-affected bodies constitute the two basic conditions for natural disasters. So hazard and hazard-affected body are essential elements of natural disaster prediction models. Hazard is the leading factor for a natural disaster. One hazard will lead to one or more hazard-affected bodies associated with the human society damage. The process is the formation of a natural disaster, and number of interrelated, interacting disasters make up a disaster chain. The relationship of hazard, hazard-affected body, and that of disaster and disaster-chain was shown in Figure 2.

![Composite aggregation of disaster chain](image)

**3.1 Single disaster prediction sub-model**

A single disaster is the basic aspect of a disaster-chain. There is only one hazard and one or more hazard-affected bodies in the process of a single natural disaster. Hazard refers to the motion, change or alienation of the matter, with the typical characteristic of timeliness and spatiality, which occurs naturally or artificially. The measurement criterion of hazard is the intensity of hazard. The hazard prediction is mainly embodied in that of the time, influence basin and intensity. Hazard-affected body refers to the affiliated bodies of natural disasters in social environment, which are the main force of human society and can be divided into three categories: life hazard-affected body, economy hazard-affected body and environment hazard-affected body. The fundamental purpose of natural disaster prediction is to master the loss of disaster damage, thus it is the main task of the disaster model to
forecast losses of the hazard-affected bodies in line with the hazard intensity. Hazard occurs—the hazard of time, space, strong features of forecasting—a corresponding loss of hazard-affected bodies constitute a single disaster prediction model (Figure 3).

3.2 **Hazard chain process model**

The character of chain-reaction of the disaster determines that the consideration of a mere natural disaster process cannot fully reflect the damage conditions. The main line of the disaster chain is a consecutive reaction process in which a hazard sets in motion another. The inter-connection of the disaster chain exhibits in the chain transmission process, which is in essence the transmission of energy. This, in turn, is inseparable from the physical medium. When the existential state of the physical medium has changed to a certain threshold value, a new hazard will be created. If that change is not big enough to create a new hazard, then the hazard chain will end. Hazard—the change of existential state (hazard-affected body damage) the cycle of hazard constitutes a hazard chain process model (Figure 3).

3.3 **Coupling prediction model**

The hazard chain controls the sequence of the disaster chain in the coupling prediction model(Figure 3). So the sequential simulation of disaster chain can be realized by constructing precise hazard chain process model. The intermediate objects in the energy transmitting process may or may not belong to the hazard-affected bodies, because in catastrophology, the latter refers to the receptor associated with human society. In order to simplify the model, the concept of hazard-affected body was extended to such an extent that all the energy transmission media in the process of hazard chain could be defined as this, and dummy hazard-affected body as a new type was added to it. The media which were not well-defined currently were classified as dummy hazard-affected bodies in this model. In this way, the change of intermediate state in the chain can be reflected by the damage of hazard-affected bodies. Hazard-affected body in the model plays multiple roles, both as a receptor for hazard, but also the main target of disaster assessment, while its own change of state may lead to a new hazard occurrence. It is a predisposing factor in the hazard. The coupling prediction process based on disaster chain can be decomposed into multiple single disaster prediction sub-models. The hazard-affected body platform will record the change of the hazard-affected bodies’ properties subject to a specific hazard, and the properties will be used in the next single disaster prediction. Finally, the loss of the disasters will be evaluated through the hazard-affected body management platform with the user’s assessment model.

![Figure 3. Coupling prediction model based on disaster chain.](image-url)
3.4 Driving mechanism of the coupling prediction model using event chain

The main obstacle for constructing the disaster prediction model lies in the complexity of the chain effect of natural disaster. By the construction of the event chain based on the event trigger mechanism, the self-organization of sub-models has been realized. In the event chain, the object causing the event is called the event-sender, and the object of the acquisition and response side is called event-receiver. There are three elements in the event chain: firstly, the initiation of the event. This is a passive course which includes the original event and events triggered by this; secondly, the occurrence of the event. This will produce a series of destructions; thirdly, the follow-up events. It’s an initiative course, which refers to a series of consequences that will happen after the events. The event-trigger mechanism means that all the hazards, damage of hazard-affected bodies can be boiled down to incidents, which can be triggered interactively or by corresponding conditions. We derive independent sub-models from prediction of hazards and hazard-affected bodies involved in the coupling model, and every single sub-model encapsulates corresponding trigger interface. When the first-degree hazard/primary event happens, it is the hazard-formative factor (trigger condition). If there are hazard-affected body sub-model responding to the factor, the damage of hazard-affected body will become new hazard-formative factor (trigger condition). All levels of secondary events can make automated judgments with the existing hazard-formative factors (trigger condition), and if there are not enough factors to initiate a new event, then the event chain will come to an end (Figure 4).

![Figure 4. Workflow of the event chain.](image)

4 Realization of the model

4.1 Design of the elements in the model using multi-Agent technology

Agent is a physical or abstract object, which exist dependently in a certain environment and form a part of it (Liu, 2001). It can perceive the environment and affect it. In turn, by making active response to the environmental change according to its own belief, desire, intention, etc (Rao, 1975). In the multi-agent systems the agents are heterogeneous, and it has the characteristic of autonomy, interactivity, responsibility and functionality, therefore the multi-agent technique has an incomparable ability to represent complex systems.

According to the different roles they play in this model, the main intelligent agents in the model can be divided into five types: interface agent, hazard agent, hazard-affected bodies agent, decision support agent and warning assessment agent. Interface agent is human-computer interaction of the system where the interaction between users and system is presented; hazard-affected bodies agent, combined with the disaster-pregnant environments database, compose the environmental management platform of the model; the core business of the entire model is composed by the hazard agent, hazard-affected bodies agent and disaster-pregnant environments database. It can be realized by the interaction and triggering of the intelligent agents on the basis of the multi-disasters coupling prediction process of disaster chain; decision supporting layer, formed by the decision support agent, can provide decision support on two levels: first, decision support agent at the system level; second,
decision algorithms and tools according to the decision support request by other intelligent agents. The assessment agent in the model can be customized according to system requirements.

4.2 Realization of the event chain

Event trigger mechanism can be realized by the event handling mechanism in many Integrated Development Environments (IDE). We can easily add one or more response methods to the event of any IDE. One event may have several response methods, while one method may respond to several events. The access authority, return value type and parameters, even the method and name of an event response method are not fixed. When a certain hazard occurs, the system will start the corresponding processing module. When a hazard occurs, the system will start corresponding process module, and will publish the results in the way of event message. Through event subscription, secondary event will respond to its correspondent event message, thus the event chain procedure can be established automatically. In this way, the whole process of disaster chain prediction can be realized through event publication and subscription.

5 Case study

In order to study the feasibility and effectiveness of the multi-disasters coupling prediction model, this author develops a MDCPS, a prototype system on the basis of the multi-disasters coupling model with C# language in a Visual Studio. NET environment. In the experiment, some houses, roads, personnel in Shantou City, as well as tectonic stress (dummy hazard-affected bodies), are used as hazard-affected bodies; and earthquake is used as the primary hazard, while hazards include landslide, building collapse and road network destruction. The workflow of the disaster chain is as illustrated in Figure 5. It simulates a case in which a magnitude 7.5 tremor occurred in Shantou City. The epicenter location (E: 116.6, N: 23.4), the Richter scale (7.3) and the angle of the fault (10°) is entered through the interface agent in the case. Interface agents issue seismic input event to the earthquake agent, which then will start the agent process, thus the seismic intensity distribution will be obtained and seismic catastrophic event will be published. When the building agent, road agent and tectonic stress agent receive that event, they will start their respective process, and the predicting results will be obtained and corresponding hazard-affected bodies’ damage event will be published. Building collapse agent, landslide agent and road network damage agent receive those hazard-affected bodies damage event correspondingly, and each start their own process and publish corresponding hazard event; while road agent and personnel agent receive hazard event such as landslide and building collapse, and start their own forecasting process to give the prediction of the road damage and casualty situation. Assessment agent provides the prediction of intensity distribution scope, building destruction, casualty distribution situation, landslide risk level distribution and road damage. Figure 6 shows the predicting outcomes of the MD-PWDSS about the reliability of road network and homeless people’s distribution.

6 Conclusion

Compared with traditional methods of disaster analysis, the multi-disaster coupling prediction model based on natural disaster chain has four advantages: First, based on the disaster-chain theory, the model analyses the genesis and influencing process of the primary and secondary disasters comprehensively. It has changed the traditional disaster-analysis pattern and made it more comprehensive and accurate. Second, the model introduces the module design idea and event-chain method, and effectively solve the complexity of the theoretical analysis of the disaster chain through the single disaster model as the encapsulation and adapter design of the event, making the integrating of every disaster system become possible. Third, the setting-up of the model has offered a unified top management & dispatching platform for natural disaster administration. The model is an extensible
open system with the encapsulation mechanism and trigger mechanism. It can be extended and adjusted continuously with the deepening of people’s grasp of the natural disaster pattern to improve the comprehensive treatment of disasters. Fourth, the introduction of the event trigger mechanism makes it possible for the coupling among every single disaster in the disaster chain. It simulates the environment and the genesis process of the disaster chain, which provides a self-adaptive system for the comprehensive prediction of natural disaster. The application of this model will avoid the systematic and artificial inadequacy during the prediction.

Figure 5. Workflow of the disaster chain. Figure 6. Result of the Prediction.

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