地理学报(英文版) 2002年第12卷第3期

# A study on the early-warning technique concerning debris flow disasters

作者: ZHOU Jinxing WANG Lixian

According to the principle of the eruption of debris flows, the new torrent classification techniques are brought for ward. The torrent there can be divided into 4 types such as the debris flow torrent with high destructive strength, t he debris flow torrent, high sand-carrying capacity flush flood torrent and common flush flood by the techniques. In this paper, the classification indices system and the quantitative rating methods are presented. Based on torrent cla ssification, debris flow torrent hazard zone mapping techniques by which the debris flow disaster early-warning objec t can be ascertained accurately are identified. The key techniques of building the debris flow disaster neural networ k (NN) real time forecasting model are given detailed explanations in this paper, including the determination of neur al node at the input layer, the output layer and the implicit layer, the construction of knowledge source and the ini tial weight value and so on. With this technique, the debris flow disaster real-time forecasting neural network mode l is built according to the rainfall features of the historical debris flow disasters, which includes multiple rain f actors such as rainfall of the disaster day, the rainfall of 15 days before the disaster day, the maximal rate of rai nfall in one hour and ten minutes. It can forecast the probability, critical rainfall of eruption of the debris flow s, through the real-time rainfall monitoring or weather forecasting. Based on the torrent classification and hazard z one mapping, combined with rainfall monitoring in the rainy season and real-time forecasting models, the debris flow disaster early-warning system is built. In this system, the GIS technique, the advanced international software and ha rdware are applied, which makes the system´s performance steady with good expansibility. The system is a visual infor mation system that serves management and decision-making, which can facilitate timely inspect of the variation of th e torrent type and hazardous zone, the torrent management, the early-warning of disasters and the disaster reduction and prevention.

A study on the early-warning technique concerning debris flow disasters ZHOU Jinxing1, WANG Lixian2, XIE Baoyuan2, FE I Shimin1, WANG Xilin2 (1. Inst. of Forestry Research, Chinese Academy of Forestry Science, Beijing 100091, China; 2. College of Resource & Environment, Beijing Forestry University, Beijing 100083, China) Abstract: According to the principle of the eruption of debris flows, the new torrent classification techniques are brought forward. The torren t there can be divided into 4 types such as the debris flow torrent with high destructive strength, the debris flow t orrent, high sand-carrying capacity flush flood torrent and common flush flood by the techniques. In this paper, the classification indices system and the quantitative rating methods are presented. Based on torrent classification, deb ris flow torrent hazard zone mapping techniques by which the debris flow disaster early-warning object can be ascerta ined accurately are identified. The key techniques of building the debris flow disaster neural network (NN) real tim e forecasting model are given detailed explanations in this paper, including the determination of neural node at the input layer, the output layer and the implicit layer, the construction of knowledge source and the initial weight val ue and so on. With this technique, the debris flow disaster real-time forecasting neural network model is built accor ding to the rainfall features of the historical debris flow disasters, which includes multiple rain factors such as r ainfall of the disaster day, the rainfall of 15 days before the disaster day, the maximal rate of rainfall in one hou r and ten minutes. It can forecast the probability, critical rainfall of eruption of the debris flows, through the re al-time rainfall monitoring or weather forecasting. Based on the torrent classification and hazard zone mapping, comb ined with rainfall monitoring in the rainy season and real-time forecasting models, the debris flow disaster early-wa rning system is built. In this system, the GIS technique, the advanced international software and hardware are applied, which makes the system´s performance steady with good expansibility. The system is a visual information system that serves management and decision-making, which can facilitate timely inspect of the variation of the torrent type and hazardous zone, the torrent management, the early-warning of disasters and the disaster reduction and prevention. Key words: debris flows; disaster early-warning technique; torrent classification; mapping of the hazard zones; the neural networks technique CLC number: P642.23 1 Introduction China has become one of the countries most seriously affected by the debris flow disasters in the world(Shi, 2000). And the disasters often occur in the mountainous areas that cover 2/3 of the total area of China, which causes a loss of 36 billion yuan (RMB) every year (Zhou, 2001a). With economic development in the mountainous areas of China, the loss from the calamity tends to increase. Every time the debris flow happens, the loss can generally reach several billion yuan. Such has evoked the high attention from the people. To reduce the loss of the debris flow disaster is the prerequisite of the sustainable development of mountainous areas (Zhou et al., 2001). Beijing, the capital of China, has a mountainous area of 10,800 km2, accounting for 62% of the total. It often witnesses debris flows and flood, especially the surrounding area in north and northeast of Beijing is often implicit by extreme rainfalls causing debris flows. Many houses are destroyed thereby and people are killed (Xie et al., 1993). In recent 40 years, the debris flows occurred in 200 torrents. The disaster occurs once every 3 years in frequency. Up to now, 515 people have been killed by the disaster, along with a loss of several billion yuan, 7 thousand houses and 60 thousand ha of farmland and 160 thousand fruit trees were destroyed (Zhang, 1991). Therefore, the work of forecasting the debris flows should be carried out in order to reduce the loss of the disasters. Since 1992, the research on torrent classification and mapping of hazard zones has been conducted, which is the scientific cooperative object between China and Austria. Torrent classification is a method to help identifying easier factors causing these disasters and to evaluate preventive measures, while hazard zone mapping is an instrument to separate zones where damages are probable. Based on these techniques, the space of the disaster can be forecasted, but the time still cannot be done. Therefore, in order to take effective measures to prevent buildings from these disasters and lessen the damages to the minimum degree and raise the practical value and efficiency of these techniques, it is necessary to study the real-time forecasting technique. Through the current five years of research, the very important thing we found is to ascertain the debris flow disaster early-warning object and build the real-time forecasting model and the early-warning systems. 2 Research methods and materials 2.1 The research technique route At first, the conditions of Beijing mountain region should be given a detailed investigation to obtain the history of the debris flow disasters well and the natural conditions and characters, and label the units of torrents and prepare much data for torrent classification. The second step of the work is torrent classification, then mapping the hazard zone for each type of torrent. In the third step of work, the range of hazard zones is to be mapped on the topographic map at a scale of 1:2,500. This work also includes filing the information of protective objects, recording the name of head of household in the hazard zones and raising the suggestion for taking precaution against the disasters from torrent and debris flows. The fourth step is very important, which is to find out the key influencing factors leading to the debris flow occurrence, and make the debris flow disaster forecasting model by the NN technique. The final work is to build the disaster early-warning systems with the computer techniques and network information techniques. 2.2 Torrent classification Based on Professor Aulitzky H index method for torrent classification (Aulitzky, 1988), combining with the conditions in mountainous area of Beijing, we worked out the complex index method of torrent classification in mountainous area of Beijing. The index for torrent classification is composed of six factors, including debris flow and flood disasters in the past, the potential one-day maximum precipitation, location and potential debris volume in the source area of the upper basin, potentiality of jam in torrent to the debris flows or flood, water-storage potential of the bedrock and surficial materials, the average profile grade of bed nearby. According to the intensity, each factor is divided into four classes with the maximum of 4 points. Each torrent complex index can be worked out, by the complex index calculated equation equal to the sum of every factor points divided number of considered factors. The type of torrent is judged by the complex index (CI). When CI?叟3.0, the type is of the serious debris flow torrent; when 2.7?變CI<3.0, the type is of debris flow torrent; when 1.9?變CI<2.7, the type is of bedload torrent; when CI<1.9, the type is of the debris flow flood creeks. 2.3 Mapping of the hazard zones Based on topographic map and the real topography, geomorphology, the locations of flood marks and obvious objects on the ground, several points on cone are chosen for being defined the hazard degree by a complex index, then the red zone, yellow zone and white zone can be determined according to the isopleths of complex index (Wang et al., 1998). The complex index (CI) calculated equation equal to total points of each factor divided number of considered factors. According to the real situations in Beijing mountainous area, such six factors should be considered, like the maximum grain volume of recently eroded material, and the maximum thickness of single debris layers that can be differentiated by the soil horizons or the textural breaks, and the inclination (gradient) of the debris cone domain under study, and the present vegetation cover, and the hydrographic situation on the debris cone. On every factor, the 4 points from 4 to 1 give to the 4 kinds of situations respectively. If CI is greater than 2.6, the area should be included in the most endangered "red zone" on account of possible destruction of solid houses and therefore danger for life and goods exists inside the houses; no building permit should be given. If CI is between 1.6 and 2.6, the area should be included in the "yellow zone"; certain buildings restrictions have to be imposed; if CI<1.6, the area is included in the "white zone", and is safe.

2.4 Ascertaining the debris flow disaster early-warning objects and the primary influencing factors Using the torrent classification methods and the hazard zone mapping methods, the debris flow torrent and serious debris flow torrent in Beijing mountain region can be made out, and the red zone and yellow zone of these torrents can be ascertained. According to the current research results, there are 273 debris flow torrents in Beijing mountain region, especially in the north and northeast of Beijing (Table 1). The debris flow disaster early-warning objects are shown in Table 2, the location of the early-warning objects is ascertained by mapping of hazard zone. According to the history of the debris flow disasters, the debris flows in Beijing mountain region is induced by storms. Based on the current research result, the rainfall of 15 days before the disaster day, the rainfall of the disaster day, the maximal rate of rainfall in one hour and ten minutes are the major factors causing debris flows. 2.5 The NN technique Artificial Neural Networks (NN) technique is the best methods to solve the non-linear incident such as debris flows and so on (Mctigue, 1982; Jin Fan et al., 1991). The back propagation neural (BP) networks is the method in the common use, with idiographic study process shown in Figure 1, and the Sigmoid Function (f(x) = [1+exp(-x+?兹)]-1) can be chosen as the relative function among these nodes. The key process for building the real-time forecasting model is conceiving the knowledge database for the NN model to study. The knowledge database is determined with the order of natural disaster events; therefore, the database is the debris flow disaster historical accident in this research. In our investigation, there are many storms in Beijing mountain region, of which more than 20 storms caused debris flows. Based on our research result, the rainfall of 15 days before the storm day, the rainfall of the storm day, the maximal rate of rainfall in one hour and ten minutes are the major factors causing debris flows. So the knowledge databases for NN study include the 18 factors in each time rain process of these storms. After building the knowledge databases, the input neural node is determined, which is the influencing factors causing the debris flows, so the number of the input neural node is 18. The output neural node is the forecasting content, if we care the possibility of debris flows and the critical rainfall when debris flows happen, the number of the output neural nodes is 2. The second step of work is choosing the number of implicit layer and nodes in the implicit layer. The number of implicit layer is more, and the precision is better, and the time of NN study is longer, so we choose the 2 layers NN. The number of nodes in the implicit layer is more or smaller, the astringency of the system must be unsatisfactory. Taking Matlab (5.3) to count the networks iterative error graph of different node numbers in hidden layer (Zhou, 2001b), we find when the number of nodes in implicit layers is 10, the error is the smallest and the NN systems is in good work, therefore, we choose the number is 10, and the study efficiency is 0.5 can be accepted commonly. When these works end, the model of debris flow real time forecasting can be built (Figure 2). The principium of calculation includes six steps of work. The first step of the work is taking the 18 factors divided 500 to make them unitary before regarding as the input node. After the node in input layer determined, the second step work is calculating the input value of the first implicit layer by formula 1: Net= WX (i = 1…10) (1) Then calculating the output value of the first implicit layer by formula 2: Net= (i = 1…10) (2) The fourth step of work is calculating the input value of the second implicit layer by formula 3: Net = WNet (i=1…10) (3) The fifth step of work is calculating the output value of the second implicit layer by formula 4: Net= (i=1…10) (4) The sixth step of work is calculating the output node of the output layer by formula 5: Y = WNet (i=1…10) (5) The seventh step of work is outputting the result of debris flow disaster. If the storm has caused the debris flows, the output value is 1, and else if the storm has not caused the debris flows, the output value is 0. The other output node is the value the critical rainfall divided 500. When using the model to forecast the debris flows, we can judge by the rule: if the output value of the model is close to 1, we can judge it is possible the debris flows will occur; if the output value of the model is close to 0, the debris flow is impossible. 2.6 The debris flow disaster early-warning system (DFDEWS) Based on the above research, combined with rainfall monitoring in the rainy season, the debris flow disaster early-warning system is built. In this system, the GIS technique, the advanced international software and hardware are applied, which makes the system´s performance steady and its expansibility good. The system is a visual information system that serves management and decision-making. It can serve timely inspect of the variation of the torrent type and hazardous zone, the torrent management, the early-warning of disasters and the di saster reduction and prevention, including data management sub-systems, function of query sub-systems, debris flow disaster real time forecasting sub-systems, figure and table making sub-systems and the information promulgating sub-systems. The DFDEWS is developed using Visual Basic5.0 and GIS (Arcinfo 7.11). It serves not only as a general management tool of database (such as the functions of data storing, editing, inquiring, sorting and statistics), but also provides multi-media function, with sound files and image files in special fields in databases. Furthermore, the debris flow disaster real time forecasting sub-systems can ascertain the possibility of the debris flows, and can automatically make figure and table for the early-warning object information (including the location), and through the information promulgating sub-systems, these information can accurately reach the protection objects on time, so the loss of disaster can be reduced or avoided completely (Wang and Yu, 2001). 3 The application of DFDEWS in Beijing mountain region 3.1 Obtaining the weighting matrix of the neural networks model We choose the 18 influencing factors of 60 storms in Beijing mountain region including 20 storms causing the debris flow disaster as the neural networks knowledge database to input the debris flow disaster real time forecasting sub-systems (Figure 2), after one million times calculation and taking 13 hour on the PII computer, the weighting matrix of probability of debris flows happens and the critical rainfall (Formulas 1, 3 and 5) is determined (Table 3). 3.2 Forecasting probability of debris flows occurrence and the critical rain Based on the torrent classification, there are 273 debris flow torrents in Beijing mountain region, especially in the north and northeast of Beijing. Therefore, we build 273 rain observation stations in these debris flow torrents. When the rainy season is coming, we record every day´s rainfall information. If there is a storm forecast, the forecaster must pay more attention to the storm, and record rainfall information every 10 minutes, and take the 18 factors like the rainfall of 15 days before the storm, the current rainfall, the maximal rate of rainfall in one hour and ten minutes of the current storm day up to the time of prediction as the input neural node to input the debris flows disaster real time forecasting sub-systems after obtaining the weighted matrix. The probability of debris flow occurrence and the critical rainfall will be worked out rapidly. From 1998 to now, we use the DFDEWS to predict the debris flow disasters in 273 debris flow torrents, and the prediction result accords with the fact, and it is satisfying. Meanwhile, we have taken two historic disasters unused in building the systems to test the DFDEWS. The first event is on August 3, 1950, and the rainfall of the day reached 190.1 mm, leading to debris flows. When testing the DFDEWS, we input the 190.1 mm, the rainfall of 15 days before and the maximal rate of rainfall in one hour and ten minutes as seen in Figure 3, the DFDEWS can draw the conclusion that the disaster would definitely occur and the critical rainfall will reach 216.7 mm. Another event is on August 3, 1956, the forecasting conclusion is that the debris flows would difinitely occur and the critical rainfall is 194.6 mm. From the application efficiency in Beijing mountain region, the probability can be forecasted exactly, and the critical rainfall is close to the real rainfall, therefore, the system can be used in Beijing mountain region for debris flows disaster early-warning. 3.3 Predicting the information about the potential hazardous objects When the systems provide the probability of a storm causing debris flows, the systems can offer the detailed information about the potential hazardous objects like the number of people and their names, house, building and the location of disaster at once (Figure 3). Therefore the potential harm people can be informed by telephone or broadcasting network or Internet by the forecaster in time, and take some protective measures to reduce the loss. 4 Conclusions The research result showed there are 273 debris flow torrents in Beijing mountain region, through researching all the 2280 torrents in Beijing by torrent classification and hazard zone mapping techniques and the early-warning objects can be made sure in the hazard zone of 273 debris flow torrents; therefore, the early-warning work for protecting object will reduce and locate the 273 torrents, and can save a wealth of economy and labor and material. There are 50,143 people, 62,549 houses, 37,985 roads and 359 other establishments and so on threatened by the debris flows in Beijing mountain region. The storm is the key influencial power causing the debris flow disasters, and the rainfall of 15 days before the disaster day, the rainfall and the maximal rate of rainfall in one hour and ten minutes of the disaster day are the major factors causing debris flows. Artificial Neural Networks (NN) technique is the best method to solve the non-linear incident such as debris flows. Using the back propagation neural (BP) networks methods, the debris flow disaster early-warning NN model structure and knowledge database and the weighting matrix are gained. The application and test of the model showed it is efficient to predict the disaster, and the forecasting result is very accurate, so the model can be applied in Beijing mountain region and worthy spreading. Based on the torrent classification and hazard zone mapping and debris flow disaster early-warning NN model, combined with rainfall monitoring in the rainy season and Internet technique and GIS, the debris flow disaster early-warning system is built. In this system, the advanced international software and hardware are applied, which makes the system´s performance steady and its expansibility good. The system is a visual information system that serves management and decision-making, which can serve timely inspect of the variation of the torrent type and hazardous zon e, the torrent management, the early-warning of disasters and the disaster reduction and prevention. This research was awarded by the Beijing Committee of Science and Technology, for the social and economic benefits in combating disasters. References Aulitzky H, 1988. Vorlaeufige Zweigeteilte Wildbuch-Klassifikati Ketion. Interpraevent 1998. Band 3, 233-236. Jin Fan, Fan Junbo, 1991. Estimation on the graveness of debris flow ditches using neural networks. In: Proceedings of the International Symposium on Debris Flow and Flood Disaster Protection (Vol.A). Beijing: Seismological Press, 282-288. (in Chinese) Shi Changxing, Zhangdian, 2000. Analysis of impact of sedimentation of flood disasters in China. Acta Geographica Sinica, 55(5): 627-636. (in Chinese) Mctigue D F, 1982. A nonlinear constitutive model for granular materials: application to gravity flow. Appl. Mech. ASME, 49(2): 291-296. Wang Lixian et al., 1998. Torrent classification and hazard zone mapping information system on GIS. Journal of Beijing Forestry University, 7(1): 51-57. (in Chinese) Wang Lixian, Yu Zhiming, 2001. The Flush Flood and Debris Flow Disaster Forecasting. Beijing: China Forestry Press, 76-100. (in Chinese) Xie Baoyuan et al., 1993. The Result Assemble of Torrent Classification and Hazard Zone Mapping of Beijing Mountain Area in China-Austria Scientific and Technical Cooperation. Beijing Forestry University, 3-5. (in Chinese) Zhang Shijun, 1991. A brief description about the debris flow of Beijing district. In: Proceedings of the International Symposium on Debris flow and Flood Disaster Protection. Beijing: Seismological Press, 345-350. Zhou Jinxing, 2001a. Technique of space prediction on flush flood and debris flow disaster. Journal of Soil and Water Conservation, 15 (2): 112-116. (in Chinese) Zhou Jinxing, 2001b. Study on the flush flood and debris flow disaster early-warning technique. In: Doctoral Dissertation of Beijing Forestry University, 67-90. (in Chinese) Zhou Jinxing, Wang Lixian, Xie Baoyuan et al., 2001. A review on the technique of forecasting and alarming flush flood and debris flow disaster. Journal of Mountain Science, 19(6): 527-532. (in Chinese)

关键词： debris flows; disaster early-warning technique; torrent classification; mapping of the hazard zones; the neural networks technique

 