GIS and ANN model for landslide susceptibility mapping

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Abstract: Landslide hazard is as the probability of occurrence of a potentially damaging landslide phenomenon within specified period of time and within a given area. The susceptibility map provides the relative spatial probability of landslides occurrence. A study is presented of the application of GIS and artificial neural network model to landslide susceptibility mapping, with particular reference to landslides on natural terrain in this paper. The method has been applied to Lantau Island, the largest outlying island within the territory of Hong Kong. A three-level neural network model was constructed and trained by the back-propagate algorithm in the geographical database of the study area. The data in the database includes digital elevation modal and its derivatives, landslides distribution and their attributes, superficial geological maps, vegetation cover, the raingauges distribution and their 14 years 5-minute observation. Based on field inspection and analysis of correlation between terrain variables and landslides frequency, lithology, vegetation cover, slope gradient, slope aspect, slope curvature, elevation, the characteristic value, the rainstorms corresponding to the landslide, and distance to drainage line are considered to be related to landslide susceptibility in this study. The artificial neural network is then coupled with the ArcView3.2 GIS software to produce the landslide susceptibility map, which classifies the susceptibility into three levels: low, moderate, and high. The results from this study indicate that GIS coupled with artificial neural network model is a flexible and powerful approach to identify the spatial probability of hazards.

Key words: GIS; artificial neural network model; landslide susceptibility mapping

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1 Introduction

The population growth and the expansion of settlements and life-lines over hazardous areas exert increasingly great impact of natural disasters both in the developed and developing countries. In many countries, the economic losses and casualties due to landslides are greater than commonly recognized and generate a yearly loss of property larger than that from any other natural disasters, including earthquakes, floods and windstorms. Landslides in mountainous terrain often occur as a result of heavy rainfall, resulting in the loss of life and damage to the natural and/or for human environment. Potential sites that are prone to landslides should therefore be identified in advance to reduce such damages. In this regard, landslide hazard mapping can provide much of the basic information essential for hazard mitigation.
through proper project planning and implementation.

Earth sciences, and geomorphology in particular, may play a relevant role in assessing area at high landslide hazard and in helping to mitigate the associated risk, providing a valuable aid to a sustainable progress. Tools for handling and analyzing spatial data (i.e. GIS) may facilitate the application of quantitative techniques in landslide hazard assessment and mapping\(^{11}\).

Landslide hazard was defined by Varnes\(^{21}\) as the probability of occurrence of a potentially damaging landslide phenomenon within a specified period of time and within a given area. The probability of landslide depends on its geographical environment around it, that is, the geographical factors determining the landslides and their intensity. Dai\(^{3}\) has grouped the factors which determine the landslide hazard of an area into two categories, the quasi-static and dynamic variables. The spatial distribution of the quasi-static variables within a given area determines the spatial distribution of the landslide susceptibility in the region\(^{1}\). Up to now, most of the studies have focused on the indirect mapping of landslide susceptibility rather than on landslide hazard as defined by Varnes (1984). These studies have been largely based on the general principle that “the past and the present are the keys to the future”, i.e. future slope failures will be more likely to occur under those conditions which led to past and present landslides\(^{1,4,5}\).

Many methods and techniques for assessing landslide hazards have been proposed or tested. Statistical models were used in the statistical determination of the combinations of variables that have led to past landslides. Quantitative or semi-quantitative estimates are then made for areas currently free of landslides, but with similar conditions. Both simple and multivariate statistical approaches have been widely used in such an indirect mapping of landslide susceptibility\(^{1,5,11}\). Statistical techniques are generally considered as the most appropriate approach for landslide susceptibility mapping at scales of 1:20,000 to 1:50,000, because at such a scale range it is possible to map out in detail the occurrence of past landslides, and to collect sufficient information on the relevant variables that are considered to be relevant to the occurrence of landslides\(^{11}\). GIS has provided various functions of handling, processing, analyzing, and reporting of geo-spatial data\(^{12}\). The overlay operation commonly applied within GIS is useful in both heuristic and statistical approaches\(^{1,8,10,13-15}\). An important aspect of the statistical methods is the capability to supply probabilistic forecasts. However, there are several difficulties with the method such as the identification of all the relevant triggering factors that will be used as ‘explanatory’ variables for each landslide.

An artificial neural network (ANN) is believed to process information in a manner similar in some ways to that of the human brain, although their processing capability is much lower than that of the human brain. The artificial neural network consists of a set of simple processing units arranged in a defined architecture and connected by weighted channels which act to transform the environmental factors into a susceptibility level. An artificial neural network model use a small training sets and, once being trained, it is rapid computationally, which will be of value in processing the large dataset.

According to French\(^ {15}\), there are several advantageous characteristics of the neural network approach to modeling, designing, or problem solving as follows: (1) the problem or task addressed may be either poorly defined or understood, and observations of the process may be difficult or impossible to perform; application of a neural network does not require a priori knowledge of the underlying process; (2) one may not recognize all of the existing complex relationships between aspects of the process under investigation; through a training procedure the neural network incorporates the role of all necessary relationships controlling the process; (3) a standard optimization approach or statistical model provides a solution only when being allowed to run to the completion; the neural network always converges to an optimal (or suboptimal) solution and need not run to any prespecified solution condition; (4) neither constraints nor an a priori solution structure is necessarily assumed or strictly enforced in the NN development. These characteristics eliminate, at least to some degree, the difficulties concerning regression-based methodologies: primarily the need for the forecaster to select the explanatory variables and the dependence on an understanding of the local conditions.

We introduce the geographical environment of the Lantau Island and provide descriptive statistics of