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Displacement Prediction of Landslide Influenced by the Periodic Precipitation, Reservoir Level and Groundwater Level Fluctuations

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Abstract. Since the initial impoundment of the Three Gorges Reservoir in June 2003 and approximately 30 m of reservoir level fluctuation, numerous preexisting landslides have been reactivated. To mitigate disastrous landslides, the Baishuihe landslide in the Three Gorges region was selected as a case study in predicting such displacement using the monitoring data and a radial basis function-support vector machine (RBF-SVM) model. The landslide displacement was strongly influenced by periodic precipitation, reservoir level and groundwater level fluctuations. Primary landslide influencing factors were used as independent variables to predict the displacement using several kernel function types including polynomial function, sigmoid function, and RBF based on SVM model. Prediction results demonstrated that the RBF-SVM with the optimal parameters , and of 170, 0.05 and 0.04 can

provide the best predictive accuracy, with the maximum and minimum absolute error values of 9.84 and 0.47mm, respectively.

Keywords: Landslides, Displacement prediction, Support vector machine (SVM), Three Gorges

1 Introduction

Landslides are a major natural geological hazard in the Three Gorges Reservoir area threating the normal operation of the Three Gorges Dam and even causing damage to both property and lives [1].Especially the high reservoir impoundment of the Three Gorges Reservoir beginning in June 2003, the frequency and magnitude of landslides are expected to increase with the reactivation of old landslides and triggering of new ones. Old landslides began to noticeably deform, including the Baishuihe landslide, Baijiabao landslide, and Shiliushubao landslide [2], [3]. These landslides are primarily located along the Yangtze River and its tributaries, and their deformation characteristics are closely associated with the seasonal precipitation, reservoir level and groundwater level fluctuations. Statistics indicate that approximately 2,490 landslides are present in the Three Gorges region and that 200 landslides occur each year [4].The potential risk posed by these landslides is substantial. The extent of potential disasters may be minimized by understanding their mechanisms and developing predictions, hazard assessments, early warning systems, and risk management of the landslides. Predicting the displacement of an active landslide is of great importance

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in preventing landslides and reducing their occurrence in the Three Gorges Reservoir area. To achieve this objective, a landslide displacement prediction was applied to the Baishuihe land slide using a radial basis function-support vector machine (RBF-SVM) model and 5years of monitoring data.

In recent years, different approaches have been carried out on displacement prediction of landslides. Li et al. in [5] summarized many landslide deformation prediction studies, which can be grouped into three categories: deterministic, statistical, and computational intelligence methods. Deterministic models are primarily applied for physical mechanisms of the rock and soil mass and can provide a clear physical explanation [6], but they require comprehensive data of the material parameters. Statistical models have been widely used in deformation prediction of landslides. The results of such models are relatively easy to explain [7], but they are inherently linear and lack data from complex landslide systems. Intelligent methods have recently been widely applied formining patterns by identifying the underlying rules and features in a nonlinear landslide system, including artificial neural networks (ANNs) and SVMs. The ANN model can be used to identify the complex nonlinear relationships between landslide displacement and the major conditioning factors [8], [9], [10], although it is prone to over fitting. SVM model is becoming increasingly popular, as it offers one of the most robust and accurate methods among well-known algorithms and ranks among the top 3 data-mining algorithms identified by the IEEE [11]. The method is also well suited to nonlinear high-dimensional data modeling problems and shows promise in predicting landslide displacement [12], [13]. Micheletti et al. in [14] concluded that SVM models can be used effectively in landslide studies due to their capability in dealing with high-dimensional spaces. Min and Lee in [15] stated that a search for optimal parameters in an SVM model plays a crucial role in building a landslide prediction model. To develop an efficient SVM model, kernel functions and the corresponding parameters must be carefully predetermined [16], [17], [18].

2 Description of the BaishuiheLandslide

The Baishuihe landslide, which is a large, active ancient landslide, occurred on the south bank of the Yangtze River (31º01′34″N, 110º32′09″E),in the village of Baishuihe, ShazhenxiTown, Zigui County, Hubei Province, China. The landslide is approximately 56 km west of the Three Gorges Dam (Fig. 1).The bedrock geology of this landslide is mainly composed of sandstone and mudstone, which is an easy slip stratum. The slope is of the category of bedding slopes, and borehole monitoring data indicate that average thickness of the landslide is about 30 m. The landslide lies at an elevation of 75to 390 m. The landslide covers an area of approximately 0.42km^2 and has an estimated volume of $1,260\times10^4$ m^{3}and maximum length of approximately780 m. The transverse width is approximately 700 m parallel to the Yangtze River. The Baishuihe landslide was reactivated after the initial impoundment of the Three Gorges Reservoir. The fluctuation of the reservoir level was a crucial influencing factor in the recent landslide displacement. The5yearsof monitoring data between January 2004 and May 2008indicate that the seasonal precipitation and groundwater level fluctuation are also significant factors in the landslide deformation. Superficial cracking and distinct ground displacements were observed on the ground, as shown in Fig. 2 and Fig. 3.

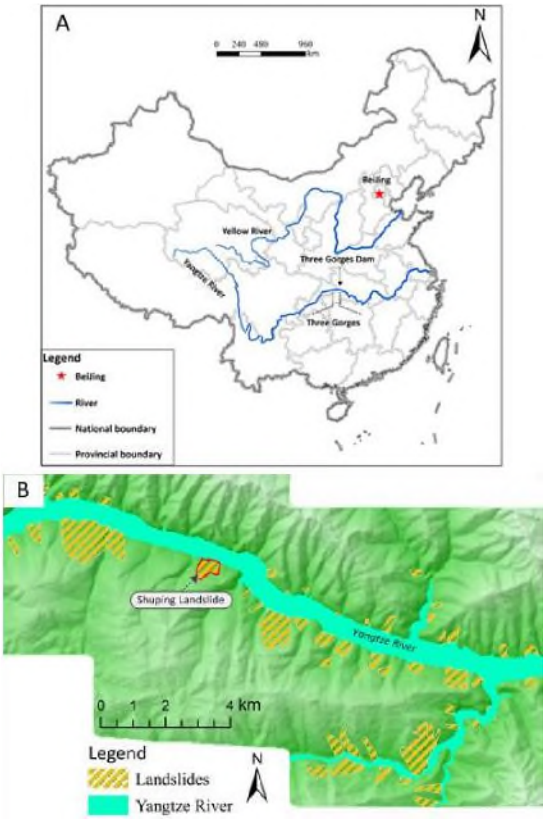

Fig. 1. Location of the Three Gorges Dam and the Shuping landslide in China (A) map of China, (B) map showing location of Shuping landslide.

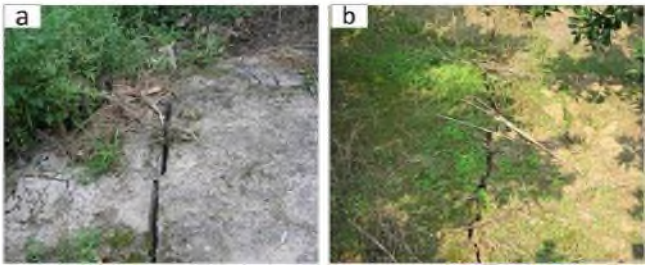

Fig. 2. Photographs of the ground cracksin the frontal and middle part of the eastern landslide in September 2005.

Fig. 3 Photographs of the ground cracks in the middle part of the eastern landslide in July 2007.

Fig. 4 shows the monitoring data of landslide accumulative displacement at six monitoring points.

Table 1. Locations of the six GPS monitoring points in the warning zone of Baishuihe landslide.

No.	Elevation (m)	Locations
ZG93	214.55	North east
ZG118	209.26	Middle and lower
DX-01	216.16	North east
DX-02	187.61	North east
DX-03	189.52	North east
DX-04	192.63	North west

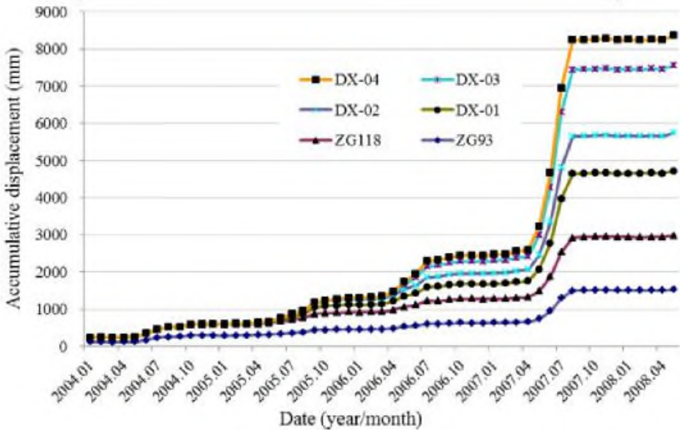

Fig. 4. Cumulative displacement versus time at six GPS monitoring points.

A landslide is a nonlinear, dynamic, and uncertain system controlled and influenced by geologic, topographic, and other conditioning factors. Correlating the deformation of an active landslide with environmental factors is significant in an understanding of the complexity and random characteristics of landslide displacement. Landslide evolution and deformation in the Three Gorges Reservoir is closely related to the seasonal precipitation, reservoir level and groundwater level fluctuations. There are 53 groups of measurement data from the period January 2004 to May 2008.Each time step represents one month. There is no exact mathematical rule to determine the required minimum size of training samples and test samples. But some suggestions for the portions of these samples are given in the literature [22]. Considering these suggestions,80%of the measurement data were randomly selected as the training samples for training models, and the remaining 20% were used for validation testing.

5 Conclusions

Landslide displacement prediction is of great significance for preventing landslides and reducing the risk in the Three Gorges Reservoir area. This paper presents the prediction of landslide displacement of the Baishuihe landslide using 5 years of monitoring data and RBF-SVM model. The cumulative displacement versus time shows a step-like pattern that is related to the precipitation, reservoir level and groundwater level fluctuations. Precipitation is a major driving factor and has a positive correlation with the displacement rate.

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