Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2017-87-AC2, 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

Interactive comment on "Landslide displacement prediction using the GA-LSSVM model and time series analysis: a case study of Three Gorges Reservoir, China" *by* Tao Wen et al.

Tao Wen et al.

tanghm@cug.edu.cn

Received and published: 10 July 2017

Response to Interactive Comments The authors thank the reviewer and the Editor for their comments. We have addressed all the comments in the revised manuscript. The following includes our point-by-point responses to the comments and the locations in the manuscript where the corresponding revisions appear.

Interactive Comments

1.The reviewer suggests verification of or discussion on why "The trend displacement and the periodic displacement are predicted by polynomial function and the GA-LSSVM

Printer-friendly version

Discussion paper

model, respectively."

Response: Thank you for the careful reading and constructive comment. We have revised the text accordingly. Please see Methodology: Pg 2_line 37-46 in this revision.

Cumulative displacement of landslides is caused by the combined effects of internal geological conditions (lithology, geological structure, topography, etc.) and external environmental factors (rainfall, reservoir water level, groundwater, etc.). The landslide displacement caused by internal geological conditions increases generally with time, which reflects the trend in cumulative displacement. Landslide deformation exhibit long-lasting and continuous movements under gravity loads that is affected by the creep characteristic. Geological structure and topography cause result in monotonic displacement through time. Because the curves of the trend component displacement versus time have quasi-linear and incremental characteristics, we use polynomial functions to fit these curves and provide the best-fitted results. However, the landslide displacement induced by external environmental factors is approximately periodic. The LSSVM model yields good performance in pattern recognition and nonlinear function fitting. The genetic algorithm (GA) is a global optimization algorithm that uses highly parallel, random and adaptive searching based on biological natural selection and optimization. In this paper, the GA is selected as the method of parameter optimization in the LSSVM due to its advantages in determining the unknown parameters that are consistent between the predicted data and the measured data. By introducing the GA, some key parameters of the LSSVM model can be derived automatically. Therefore, considering the characteristics of the periodic displacement and the relational grades between variables, we select the combination of the LSSVM model and the GA to predict landslide periodic displacement.

2.The Section 3.2 (Monitoring data and deformation characteristics of the landslide) describes the monitoring data used in this study. The reviewer suggests validate these sampling data for landslide displacement prediction in the very beginning; i.e. are those continuous and mutually dependent landslide data applicable or feasible to the statistical method, such as the least squares support vector machine (LSSVM), basically dealing with independent sampling data.

Response: Thank you for the careful reading and constructive comment. We have revised the text accordingly. Please see Introduction: Pg 1_line 31-32 and line 38-39 in this revision. It is well known that the evolution process of landslide is a complex non-linear process that is caused by the complex interaction of different factors, e.g. the complicated geological settings, varying hydrological conditions. Displacement time series are generally appreciated as the direct representation of the complex and non-linear dynamical behaviour of landslide. However, the landslide displacement induced by the exteral factors is approximately periodic. Therefore, a landslide displacement sequence is an instability time series with a periodic episodic movement characteristic. Because the integrity of the data collected at monitoring points has an effect on the displacement prediction, the monitoring data from July 2003 to October 2013 are selected to explore landslide deformation. The SVM is a machine learning model based on the knowledge of statistical learning for small samples and structural risk minimization. With the rapid development of theory and technique, Least Squares Support Vector Machines (LSSVM) have been proposed for overcoming the defects of the SVM with high computational complexity due to quadratic programming. Compared with SVM, LSSVM runs faster and exhibits more adaptability because the quadratic optimization problem of SVM is transformed into a linear system of equations, and it has been widely used in the automatic and efficient monitoring of landslide safety.

3.In the text there are 8 monitoring stations with GPS, in figure 4 stations appear. The 8 stations only appear in figure 6, but in the work and in the other figures and in the tables only appear data of 3 GPS stations.

Response: Thank you for the comment. In this submission, about the reason for exhibiting 3 GPS stations in the work and in the other figures and in the tables were provided. Please see Landslide displacement prediction: Pg 11_Line 3-5.

In the text there are 8 monitoring stations with GPS, in figure 4 and figure 6 stations appear. 8 monitoring stations were used to analysed deformation characteristics of the landslide. But in the work and in the other figures and in the tables only appear data of 3 GPS stations, GP85, GP86, GP87. Because ZG85 in the head scarp areas, ZG86 in the middle areas and ZG87 in the back scarp areas were all from longitudinal section A-B and they represented different regions. Thus, due to the limited space, we just selected 3 GPS stations to validate the predicted performance of the proposed model. Based on the analysis of the deformation characteristics of Shuping landslide and the GA-LSSVM model and due to the obvious nonlinear and episodic movement deformation characteristics of monitoring stations ZG85, ZG86 and ZG87, we select only these stations along longitudinal section A-B to verify and establish the prediction model.

4.Abstract section should contain important numerical figures such as relative error or RMS error figure.

Response: Thank you for the comment. In this submission, some important numerical figures were provided. Please see Abstract section.

5.Numerical improvement in some circumstances may not be the core technology and sometimes it may be redundant, leading to the suggestion of redirection and emphasis on why we need such a model analysis in real applications perhaps included in the Introduction section.

Response: Thank you for the careful reading and constructive comment. We have revised the text accordingly. Please see Introduction.

As is well known, it is difficult to predict the displacement of a landslide accurately using a mathematical model. This is mainly because the landslide is characterized by complex nonlinear-dynamic behavior involving many uncertain geological and engineering factors. Recently, numerous models have been proposed and widely used for landslide displacement, such as functional regression, Artificial Neural Network

Printer-friendly version

Discussion paper

(ANN), and Support Vector Machines (SVMs). All those models tried to find the complex non-linear relationship between a training set of input vectors and corresponding output. However, ANN has its own drawbacks such as arriving at the local minimum, over fitting, slow convergence speed that limit its predictive performance. The SVM is a machine learning model based on the knowledge of statistical learning for small samples and structural risk minimization. Therefore, SVM becomes a more advanced method for dealing with the nonlinear problems in predicting landslide displacement. With the rapid development of theory and technique, Least Squares Support Vector machines (LSSVM) have been proposed for overcoming the defects of the SVM with high computational complexity due to quadratic programming. To improve the predictive performance, Genetic Algorithm (GA) was introduced to optimize the parameters of model for obtaining better predictive performance in recent achievements. Therefore, the present paper proposes a landslide displacement prediction model based on the GA-LSSVM with time series analysis.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-87/nhess-2017-87-AC2-supplement.pdf

---

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2017-87, 2017.