Article

A combined landslide displacement prediction model based on variational mode decomposition and deep learning algorithms

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S1. Establishment of LSTM, GRU and CNN models for periodic and random displacement prediction

Based on the deformation analysis of the Baishuihe landslide in Section 3.2, multivariable LSTM, GRU and CNN models were developed to forecast both periodic and random displacements. After conducting a series of trial-and-error tests, a three-layer LSTM and GRU neural network architecture was adopted, with the inclusion of a Dropout layer to enhance generalization capability and accelerate convergence. Specifically, the architectures of the LSTM and GRU models at sites ZG118 and XD01 consisted of three layers: the first two layers were LSTM (or GRU) hidden layers, followed by a Dense output layer. The optimal CNN structure consisted of two Conv1D layers, a MaxPooling1D layer, and a Dense connected layer.

The GS method was used to search for the optimal hyperparameters through cross-validation on the training dataset to achieve the best performance. The search ranges for the neurons number, input sequence length, and dropout rate in the LSTM and GRU models were [20, 240], [6, 36] and [0, 0.5], respectively. Meanwhile, the ranges of convolution kernel number and kernel size in the CNN model were set to [4, 64] and [1×1, 1×7], respectively. During the data preprocessing stage, all selected input variables, periodic and random displacement were normalized to the range [-1, 1]. The optimal parameters determined by the GS method are listed in Table S1.

Table S1. Optimal parameters of LSTM, GRU and CNN prediction models.

Monitoring station	Displacement componence	LSTM and GRU models				CNN model	
		Neurons of Layer1	Neurons of Layer2	Input length	Dropout rate	Kernel number	Kernel size
ZG118	Periodic term	140	60	12	0.2	24	1×3
	Random term	140	80	6	0.1	24	1×3
XD01	Periodic term	160	60	12	0.2	24	1×3
	Random term	160	80	6	0.2	24	1×3