Utilization of AI in Safety Management of Dams --- Development of Dam Management Support Technology to Enhance the Quality of Maintenance

(Research period: FY2020 to FY2022)

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Keywords: dam, safety management, abnormality detection, AI, LSTM, Isolation Forest

1. Introduction

With such a large number of dams having been constructed during the high-growth period and now in service for a such a long period of time, there is concern about the shortage of skilled personnel with extensive experience in safety management who monitor the condition of dams through patrols and measurements to ensure that there are no abnormalities. It is typical of dams that safety management is based on various types of measurement data, yet some on-site workers have commented that it is difficult to clearly determine the presence or absence of abnormalities even by analyzing reliable data. Therefore, we examined an abnormality detection method using AI, which has been used in many fields in recent years, as a technology to assist dam managers in judging the presence or absence of abnormalities based on various measurement data acquired on site for safety management.

2. Anomaly detection method

Measurement data acquired for the purpose of dam safety management includes leakage volume, pumping pressure, deformation (displacement), and seismic motion (acceleration waveform) (**Fig. 1**).

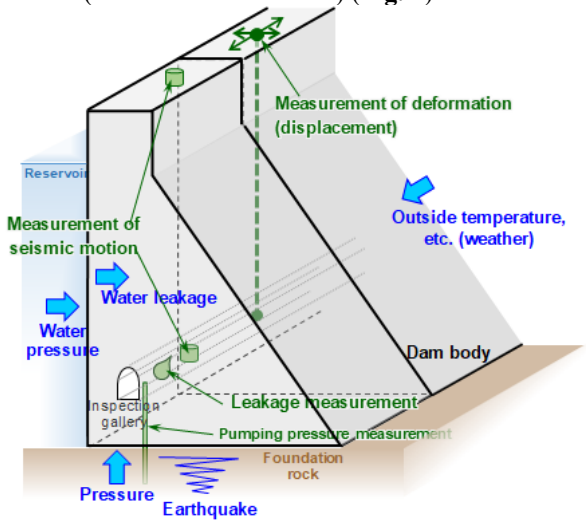


Fig. 1: Main measurements for dam safety management (Example of concrete gravity dam)

Of the foregoing, we examined the possibility of detecting abnormalities with AI technology using data on deformation of the dam body (relative displacement of the dam foundation and crest; hereinafter, the "amount of dam body deformation") and seismic motion (acceleration waveform observed at the crest of the dam). They are common in that they are obtained as time series data.

For concrete dams, it is known that the amount of dam body deformation is generally affected by the reservoir water level and temperature, and that cyclic changes are repeated. Therefore, to detect abnormalities based on the deviation between predicted and measured values taking into account the reservoir level and outside temperature, we tried to apply LSTM (Long Short Term Memory, **Fig. 2**), a neural network algorithm applicable to regression problems of time series data, which can make predictions by treating past data as long-term memory.

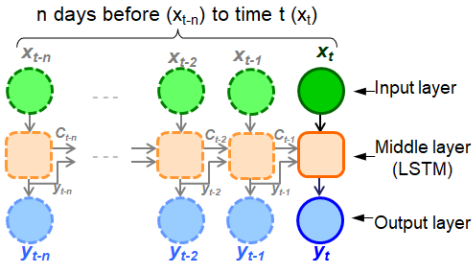
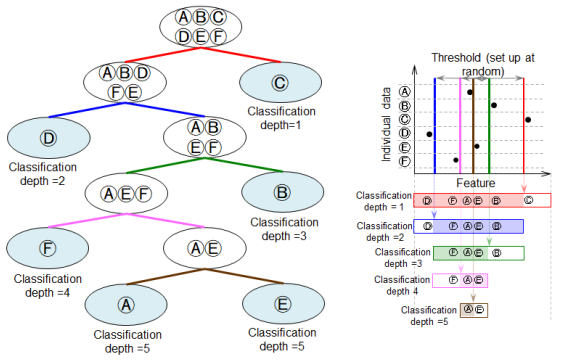


Fig. 2: Outline of LSTM model

On the other hand, the seismic motion data observed in the dam body will reflect the response of the dam. For this reason, we considered abnormality detection from changes in seismic response, which could be due to structural damage. However, actual damage cases are limited in dams. Therefore, as a machine learning algorithm that can detect abnormalities from normal data, we attempted to apply an Isolation Forest (IF, **Fig. 3**), which determines isolated data as abnormalities at an early stage by repeatedly dividing (classifying) the data using decision trees.



(a) Isolation tree (b) Division by features

Fig. 3 Outline of Isolation Forest

3. Attempt to detect abnormalities using measurement data at the dam

(1) Detection of abnormality in the amount of dam body displacement using LSTM

We used LSTM to make it learn historical measurement data on the amount of dam body deformation (upstream and downstream components) for a domestic concrete gravity dam (about 120 m in height). Time-series data on reservoir water level and temperature (outside temperature and dam body temperature) were input as data corresponding to explanatory variables in the input layer of the model shown in **Fig. 2**. A comparison of the predicted data obtained from the output layer and measured data on the amounts of dam body displacement is shown in **Fig. 4**. The figure also shows the results of multiple regression analysis, which is a conventional method, but since the LSTM prediction represents well the actual measured values, it is expected to be used for abnormality detection by setting an appropriate threshold for the deviation from the actual measured values.

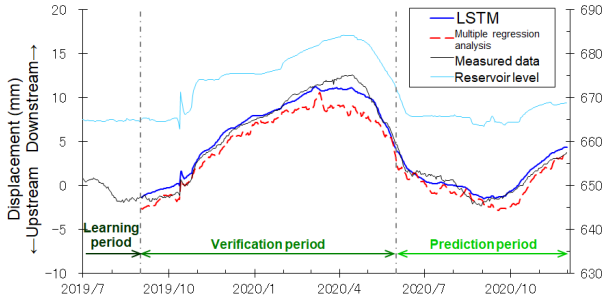
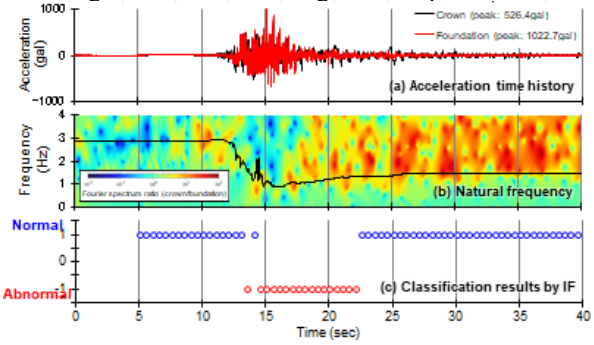


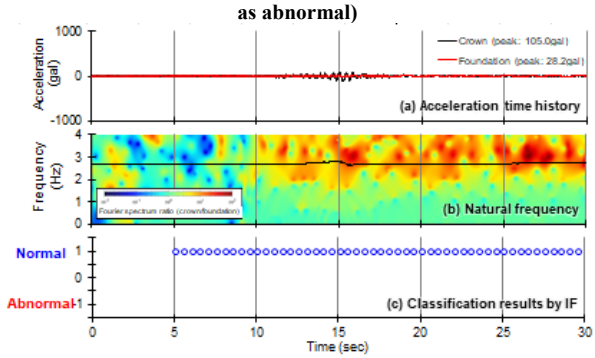
Fig. 4: Prediction of the amount of dam body deformation (LSTM)

(2) Detection of abnormalities in seismic response using an Isolation Forest

From the seismic motion data (acceleration waveform) and its frequency characteristics data during large and small earthquakes observed by seismometers installed at the crest of a rockfill dam (about 75 m high) in Japan, we identified various statistics, etc., as features, and implemented machine learning by IF (classification of normal and abnormal). As a result, of the data in which the acceleration level was large and a decrease in the dominant frequency, which is considered to correspond to the natural frequency of the dam, was found, the data during the time period in which the change occurred was determined to be abnormal (**Fig. 5**). Since a decrease in natural frequency has been observed in foreign dams where structural damage was reported at the time of an earthquake, this method is expected to be used for detecting abnormalities during an earthquakes.



(a) Data showing a decrease in the dominant frequency (judged as abnormal)



(b) Data showing no decrease in the dominant frequency (judged as normal)

Fig. 5: Example of abnormality detection in seismic motion data (IF)

4. Conclusion

The results showed significant potential for using AI-based methods in dam safety management to assist in determining the presence or absence of abnormalities based on measurement data. Although visual confirmation and other investigations and analyses are necessary to determine whether or not the dam actually has abnormalities, if this method can be used for screening large amounts of data and determining the need for further analysis, it is expected to help rationalize the safety management of dams. In the future, we would like to further expand the target data and create practical support tools that can be used in the field.

☞See the following for details.

KOBORI Toshihide, SATO Hiroyuki, NIKAIDO Ryohei, Bin Fu, and KONDO Masashi: An Attempt to Use AI for Abnormality Detection by Measurement Data for Dam Safety Management, Civil Engineering Journal, Vol. 64, No.1, pp. 38-41, 2022.