# INEXPENSIVE DAMAGE DETECTION OF CABLE-STAYED BRIDGES BY USING SIGNAL PROCESSING AND MACHINE LEARNING

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Nowadays, with the help of the structural health monitoring methods, it is feasible to identify the occurrence of damage at the very early stages and to prevent from the financial and human losses. However, one of the main obstacles to the prevalence of such methods in the country is the high cost of health monitoring systems. The purpose of this study is providing and identifying an inexpensive method for damage of bridges using signal processing and machine learning techniques. In order to reduce the costs, the number of sensors for monitoring the structure vibration has decreased. Since the reduction of the sensors number might reduce the accuracy level of the structural health monitoring, the most up to date signal processing methods are used. In the first step of the paper, several time-frequency signal processing techniques are compared. In the next step, after decomposition of signals by time-frequency techniques, a new damage index is introduced based on cross wavelet transform (CWT) and then calculated damage indexes are classified using support vector machine (SVM) to be able to distinguish healthy and damage states. The results indicate that the above method with high accuracy can identify the damages in the structure.

In this study, the structure of Yonghe Bridge was used to identify the damage. The bridge is one of the first cable bridges built in the center of China, with a central span of 260 m in length.

In the section of comparing of the signal processing methods, instantaneous frequency-time methods were used to enhancing the frequency resolution of signal processing. However, although the extracted modes by these methods are more sensitive to damage detection than other time-frequency methods, the corresponding frequency of these modes still has a high fluctuation that makes it difficult to detect the damage. This problem occurs due to their immediate properties of these methods. On the other hand, the extraction of frequencies by adding Hilbert also increases the above-mentioned fluctuations. Conversely, the wavelet transform method has a lower frequency resolution, but the frequencies extracted by this method are more stable. Therefore, the extracted modes are processed instead of Hilbert transformation by wavelet transformation due to reduce the oscillations of the processors.

In the previous section, an efficient signal processing method was selected for extraction of vibrational modes. In the following steps, a method for identifying damages has been introduced:

At first, using the NExT method, the free vibration area is separated from the total vibration of the structure so that the frequency fragmentation accuracy level continues to increase.

Then vibration modes are extracted using EWT analysis. To calculate the damage index, the first extracted mode is calculated by the analyzed cross-wavelet transformation and the average of the coefficients.

Although in the previous stage, the healthy and the damage modes are distinct. However, in order to automatically detect the damage, the SVM method is used to classify the data in this stage. Since this method is a method of learning under monitoring, it is first necessary to practice the data. For this work, 100 first pieces have been used. The healthy mode data is considered as a positive category and the mode of damage is considered as a negative category. In the ROC chart, the higher the curve is tilted up and to the left side of the page, the better the classification has been made. Here the level below the curve is 0.93, the false positive rate is 0.00 and the true positive rate is 1.00.

For verifying the performance of the practiced SVM for other data, the next 100 pieces are used.

In order to increase the accuracy level of the signal characteristics extraction, four new signal processing methods were first studied and the best method was selected. Then, by defining a damage index and using the machine learning method, the data were classified to identify the damage mode. In general, the results can be summarized as follows:

1. Among the compared signal processing methods, the two newer methods (EWT and EMDOS) have a comparative advantage over the EMD method. Both of these methods have identified the frequencies transmission more uniformly in the damage mode. Meanwhile, the EWT method indicated that there was less dispersion in the extraction of frequencies due to this fact that the EWT method takes advantage of the both wavelet transformation and EMD method strengths.
2. Although the reduction of sensors can reduce the system reliability in identifying the damage, it can greatly compensate this problem by combining modern signal processing techniques. Although these methods also exhibit great fluctuations, by using the data classification methods, distinguishing between the healthy and the damage mode can be easily possible.