CLUSTERING ACOUSTIC EMISSION ACTIVITIES IN CONCRETE USING UNSUPERVISED PATTERN RECOGNITION METHODS

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Abstract: Acoustic Emission (AE) is one of structural health monitoring methods used in different fields of engineering to detect defects such as cracks and leakages. The method is based on detection of elastic waves released from local sources in a stressed material. In civil engineering, by means of AE, location, type and orientation of the crack in concrete are obtained utilizing different algorithms. Pattern recognition, which is a subfield of artificial intelligence based on classifying objects, is also a proper tool for identifying types of AE activities. In this study, AE activities obtained from cracking sources of concrete material were clustered using two approaches of unsupervised pattern recognition: k-means and Gaussian Mixture Model. The results were evaluated and compared with each other to reveal effectiveness of these two processes.

Keywords: pattern recognition, acoustic emission, concrete testing, k-means, Gaussian mixture model.

Introduction

In the last century, reinforced concrete has been used for construction of different types of structures, particularly for bridges, tunnels, buildings and nuclear power plants. These structures have a certain lifetime. In addition, natural disasters (earthquakes, floods, etc.) as well as environmental effects (sulfate/chloride penetration, freezing-thawing, water penetration resulting in corrosion of the steel reinforcement etc.) shorten the lifespan of these structures. Accurate assessment of structures' health is crucial to maintain their service life safely. Identifying crack originations in RC structures have attracted researchers' attention (Jahanshahi et al, 2013). Nondestructive damage detection methods, which provide information about damages without any harming, are the safest and most common methods preferred in this field. Acoustic Emission (AE), which is one of the nondestructive damage detection methods, provides a good solution to monitor the formation time, type, growth and orientation of cracks in RC members by evaluating waveform parameters. The method also provides information on the type of the crack (A. Farhidzadeh et al,2013;2014).

In this study, in order to determine the type of crack such as tensile- and shear-type, AE activities obtained from three-point-bending of an RC beam were clustered using average frequency vs. RA value parameters. For this purpose, k-means and Gaussian mixture algorithms which are two of the unsupervised learning methods were used as clustering method and the results were compared.

Method

Acoustic Emission (AE) method is based on the propagation of elastic waves caused by an active source in a stressed material, detection them by sensors placed on the surface, conversion of these waves into signals and analysing them with various techniques (Figure 1.a). A typical AE signal has the parameters shown in Figure 1.b.

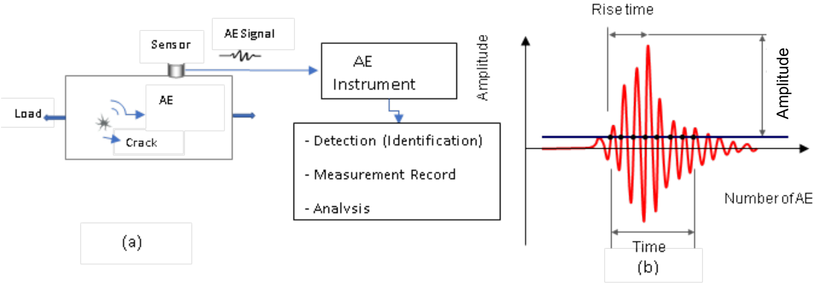

Figure 1. a) AE methodology b) AE parameters

With the aid of these parameters, crack type classification is made by using rise time, amplitude, AE count, and duration. In Figure 2, the ratio of rise time to maximum amplitude is called “RA value” and the number of AE counts per duration is called “average frequency”. With the aid of the distribution of the average frequencies versus the RA values, the cracks can be divided into two classes as shear and tensile. Hits with high average frequency and low RA value is defined as tensile, while the vice versa are defined as shear activity (JCMS-IIIB5706, 2003).

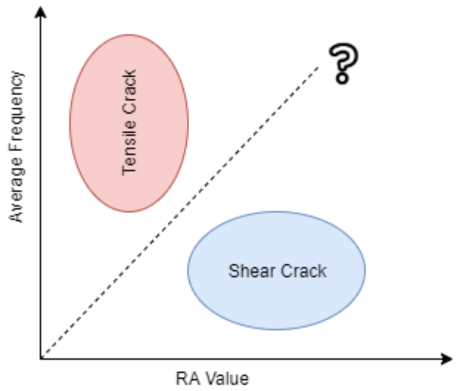

Figure 2. Crack classification according to JMCS IIIB 5706 (2003)

Since these data sets are not known, these activities should be clustered in accordance with the data characteristics. The algorithms used to solve such problems are called unsupervised learning algorithms. These algorithms enable us to classify and label the data according to unlabeled data characteristics. There are numerous unsupervised learning algorithms among which k-mean and gauss mix algorithms have been utilized in this study.

K-Means

K-means is one of unsupervised clustering algorithms. The "K" in the name of the algorithm represents the number of clusters the data will be divided into. First of all, we decide to how many clusters should be divided according to the characteristics of the data. The center point is tried to be found. Then, the closest points are gathered around the determined center point and the cluster members are brought together. This process is repeated until the clusters formed with the common points become the most efficient. In Figure 3 clustering stages of K-means algorithm are given.

Gaussian Mixture Model

The Gaussian Mixture Model (GMM) is a probability distribution. It is used to detect normally distributed sub-data sets within a general data set. GMM does not need to know which classes the subsets belong to. It learns by itself which sets belong to the data distributions. Since the labels are not subset, GMM is also known as unsupervised learning. Figure 4 shows the parameters needed by GMM algorithm for clustering.

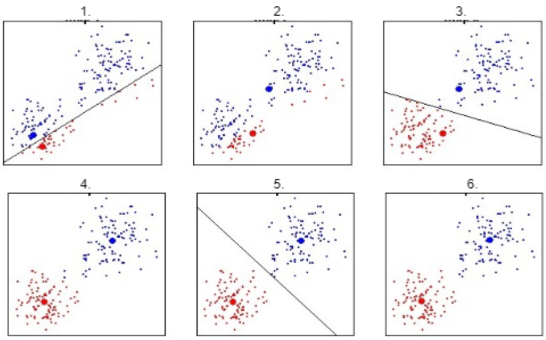

Figure 3. Stages of k-means clustering

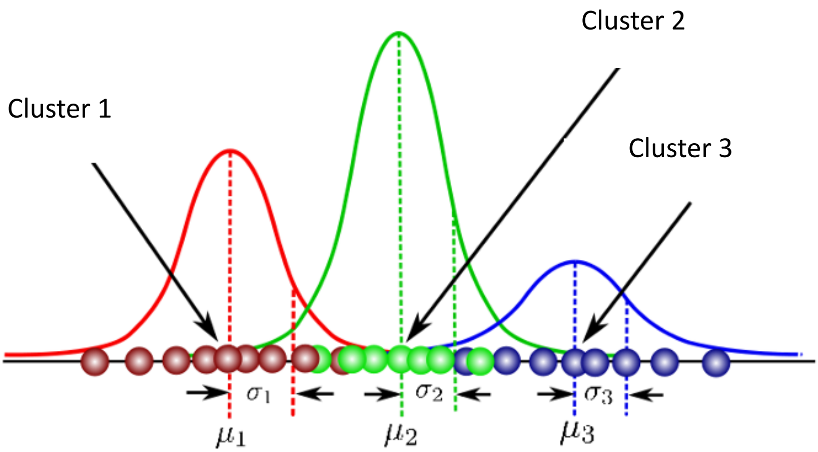

Figure 4. Parameters used in GMM

Experimental Study

In the experimental study, three-point-bending test was applied to the reinforced concrete beam specimen having properties given in Figure 5. Mix design of concrete used for production of the specimen is also presented in Table 1.

During the mechanical test, AE activities were recorded by eight piezoelectric sensors having resonance frequency of 150 kHz. They were attached on the surfaces of the beam with a silicon grease to provide a good detection. Threshold was set as 40 dB to eliminate ambient noise and eight preamplifiers were also used with 40 dB gain. Recorded AE activities were filtered and meaningful AE hits were extracted.

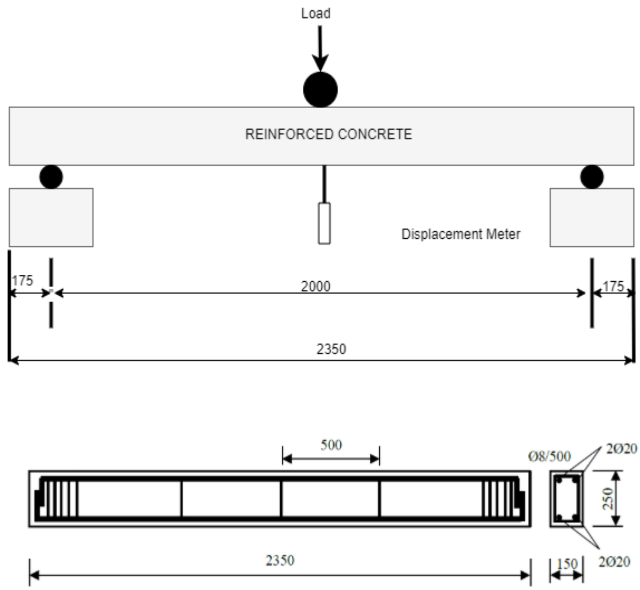

Figure 5. Geometric and reinforcement details of test specimen and test setup

Table 1. Mix design of concrete (kg/m³)

	Materials						
Amount	Cement	Water	Aggregate (mm)			Plasticizer	Fly ash
			0-3	5-15	15-25		
	255	167	934	429	485	4.24	84

Results

RA value and average frequency parameters of these 4298 AE hits were used to cluster concrete cracking activities by k-means and GMM. Clustering results were visualized by scattering both clustered activities in Figure 6 and Figure 7.

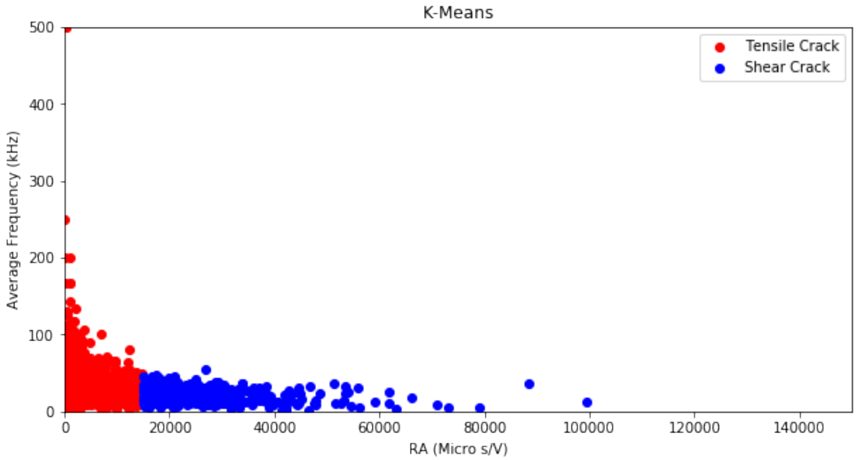

Figure 6. Clustering of AE activities attributed to concrete cracking by k-means.

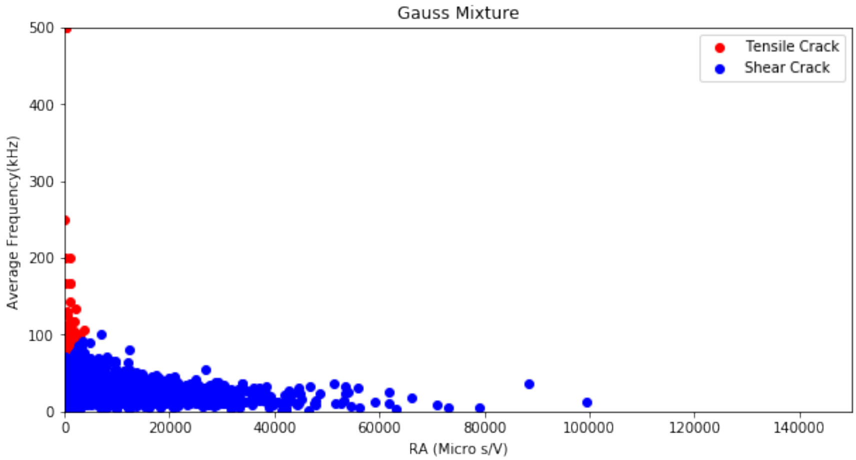

Figure 7. Clustering of AE activities attributed to concrete cracking by GMM.

The k-mean algorithm yielded theoretically expected results. Separation by such a sharp line is proof that the k-mean only looks at the distant intimate relationship, not according to the data characteristics. The Gaussian mixture algorithm, on the other hand, is a more flexible algorithm than the k-mean since it classifies the data according to the probability of statistical values. Therefore, the clustering in the segregation zone is separated as shown in the standard and as we have foreseen.

Conclusion and Suggestions

By evaluating literature findings and results obtained from this study, it is seen that GMM algorithm gave more suitable clustering results for crack type classification. One of reasons of this situation is directly center calculation in k-means algorithm. However, as the actual types of the activities are not known exactly, these current results are not precise.

Studies in this field have been developing and investigation of appropriate signal parameters for clustering has been continued. For the studies in future, it is recommended to use and investigate different waveform parameters. In addition, it is envisaged that the development of supervised learning algorithms using specific labeled data would be more appropriate for the solution of this problem.

References

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