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An information processing method for acoustic emission signal inspired from musical staff

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A B S T R A C T

This study proposes a musical-staff-inspired signal processing method for standard description expressions for discrete signals and describing the integrated characteristics of *acoustic emission* (AE) signals. *The method maps various AE signals with complex environments into the normalized musical space.* Four new indexes are proposed to comprehensively describe the signal. Several key features, such as contour, amplitude, and signal changing rate, are quantitatively expressed *in a normalized musical space*. The processed information requires only a small storage space to maintain high fidelity. The method is illustrated by using experiments on sandstones and computed tomography (CT) scanning to determine its validity for AE signal processing.

1. Introduction

The Acoustic emission (AE) technique is an effective non-destructive method that analyzes the characteristics of elastic waves that are caused by microscopic damage in the concrete member [1–3]; hence, the AE technique can be applied to different fields, such as rock masses failure monitoring [4], quality control of metal processing [5,6], and structural fatigue testing [7,8]. In the aforementioned fields, parameter analysis methods are often adopted to cope with the diversity and uncertainty of the generated signals [9]. The characteristic parameters describing AE signals include peak amplitude, event duration, rising time, event count, ring-down counts, and energy consumption [10–15]. The definitions of these parameters are shown in Fig. 1. These parameters can describe one certain feature but have difficulty in describing the integrated characteristics of AE signals within a wide time domain. For example, Aggelis et al. [16] predicted the fatigue damage of metal plates by the rising time parameter of acoustic emission signal. Kasashima et al. [17] measured the sensitivity of the built-in AE sensor via the AE energy consumption parameters. The rising time parameter reflects the AE signal changing rate, and the energy consumption parameter reflects the energy level of the AE signal. The common features of these parameters are as follows: they describe a certain feature of the AE signal within a short time and are unable to reflect the global integrated characteristics, such as signal contour and changing trends within a wide time domain. Furthermore, the aforementioned parameters lack the standard description expressions of discrete signals. However, the standard description expressions and global integrated characteristics within a wide time domain are the supporting technologies for establishing the characteristics database of an AE signal and for achieving the pattern recognition of AE sources. Thus,

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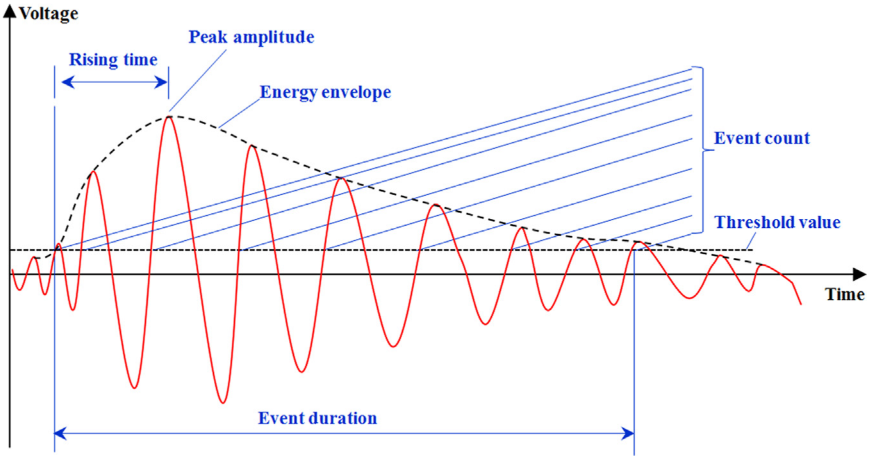

Fig. 1. Definition of the AE characteristic parameters in a simplified waveform.

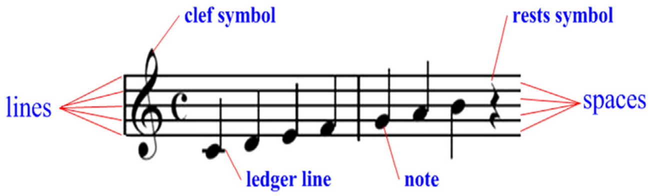

Fig. 2. Knowledge structure of a musical staff.

establishing the characteristics database of an AE signal is still challenging work because of the lack of corresponding technologies for AE signal description.

For the abovementioned issues, some researchers integrated multiple features of AE signals to solve a number of industrial problems. For example, Keshtgar and Modarres [18] assessed the AE signal properties for identifying the presence of a small initial crack to provide the presence of the onset of a potential growing crack. Woo et al. [19]conducted post-failure observations to correlate the multiple features in the acoustic emission signal that corresponds to the specific types of damage mechanisms. Griffin [20] integrated several features of the AE signal to fast compression and investigated the correlations of force and distance. In this study, the authors considered that the AE signal envelope contains abundant information, such as signal contour, magnitude, changing rate, and changing trend within a wide time domain, which can represent the integrated characteristics of an AE signal. However, the AE signal envelope currently has a few analyzing technologies, such as an energy consumption method, and lacks a fine description model for the integrated characteristics of an AE signal.

This study proposes an AE signal processing method inspired from musical staff. The proposed method introduces new indexes in a uniform model and can comprehensively describe the AE signal. Several key features, such as contour, amplitude, and signal changing rate, are quantitatively expressed. The processed information can easily be stored on a computer and only requires a small storage space. Furthermore, the AE signal, which is usually within inaudible ultrasonic frequency, is mapped to the audible musical space; thus, the proposed method creates a new way to analyze AE signals, which provides supporting technology for future works on the establishment of the characteristics database of an AE signal within a wide time domain.

2. Knowledge structure of staff

In standard Western musical notation, a musical staff is a set of five horizontal lines and four spaces that represent different musical pitches [21]. Appropriate music symbols are placed on the staff according to their corresponding pitch or function. Musical notes are placed by pitch, and rests and other symbols are placed by convention. The absolute pitch of each line is determined by the placement of an appropriate clef symbol at the appropriate vertical position on the left-hand side of the staff. The lines and spaces are numbered from bottom to top, i.e., the bottom line is the first line and the top line is the fifth line. Notes outside the range of the staff are placed on or between ledger lines (outlines the width of the note needed to be maintained) above or below the staff [22–24]. The knowledge structure of a musical staff is shown in Fig. 2.