An accident notification system in concrete pouring using sound analysis

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Abstract –

In this study, a sound analysis-based detection and reporting system for accidents that occur during concrete pouring is proposed. First, the process of the existing monitoring system was examined and problems were noted, and studies and technical approaches to sound analysis were analyzed. Pouring sound samples were then collected from construction sites, the frequencies and patterns were identified, and accident sound patterns were created by superimposing leakage and other noise onto pouring sound samples. Finally, logic and an algorithm to identify accidents were proposed based on the results of patterns retrieved from the above datasets. In the future, it is expected that accident notification systems using the sound analysis proposed in this study will be useful not only for the prevention of accidents but also for safety management throughout construction sites in general.

Keywords –

Sound analysis; Accident notification; Concrete pouring

1 Introduction

1.1 Background and purpose

Accidents due to the collapse of forms and struts occur frequently while concrete is being poured. It is necessary to monitor the status of both the inside and outside of the concrete and formwork during pouring because concrete leaks due to formwork collapse pose a great threat to the quality of a structure as well as human and material loss during the project.

Direct, manual inspection by a project manager is the best case scenario, but condition management of formwork is typically performed using surveillance cameras and measuring sensors due to the unpredictable nature of pouring sites and safety issues. However, surveillance cameras cover a limited range of vision and require numerous installations in order to monitor the project area. Moreover, the measuring sensors require attachment at each formwork and are not economical. For that reason, constructing a monitoring system that covers a wide construction area economically is necessary.

1.2 Method of research

In this study, sound analysis-based detection and a reporting system for accidents during concrete pouring are proposed. First, the process of the existing monitoring system was examined and problems were noted, and studies and technical approaches to sound analysis-based monitoring systems in the construction industry were analyzed. Pouring sound samples were then collected from construction sites, the frequencies and patterns were identified, and accident sound patterns were created by superimposing leakage and formwork rupturing sound patterns onto pouring sound samples. Finally, logic and an algorithm to identify accidents were proposed based on the analyzed sound patterns retrieved from the above datasets.

2 Literature review

Sound is a wave transmitted by the vibration of an object, and an accident may be detected using the sound pattern of a unique frequency. Women scream at a frequency of 1,000–2,000 Hz, while men scream at a frequency of 500–1,500 Hz. Studies using the frequency and pattern differences of sound have been performed in many different areas.

Existing studies using speech analysis are mainly conducted in humanities by analyzing the characteristics of rhyme change, intonation, and the rate of accentuation. The biomedical field aims to develop a medical system for laryngeal cancer detection and voice therapy. In the field of information and communication, techniques for matching the facial expression and voice of a character in an animated game are being developed. This is also seen in artificial intelligences such as Siri in the form of speech recognition. It may be used to detect a situation around a car, identify diseases and anomalies through the cries of livestock, and determine whether a person is the guilty party during the investigation of a crime. Speech analysis technology has also been applied to disaster response by judging human emotions or reactions.

Figure 1. Sound analysis of vehicle road[10]

Figure 1 shows an analysis of sound in an intersection. Though it is typically in the frequency range of 30–40 dB and 5,000 Hz or less, the sound of a skid occurs in the range of 1 kHz–3 kHz[10]. An accident notification system for tunnels is being developed using the frequency differences taken from the road, as above. An automatic accident detection system in the transportation sector installs CCTV in the designated area and analyzes the data in real time to automatically detect an accident in the tunnel while also providing information for the prevention of secondary accidents [3][4]. However, since this study is applied to a tunnel, which is a linear space, its application to a construction site in a three-dimensional space is limited.

Studies for detecting accidents have been steadily carried out in the field of construction. In recent years, many studies have monitored risk situations in real time using miniaturized equipment. In an existing study on accident monitoring using advanced equipment, real-time monitoring based on USN was performed with various measurement sensors (ultrasonic, load, slope) in formwork construction [6][9]. However, there are limitations with installing measurement sensors at a construction site, and there are economic problems regarding their application to a large-scale construction site.

A landslide monitoring system in the civil engineering field detects the change in water temperature with a temperature meter and analyzes the sound when the ground is pushed out to predict risk in advance. However, since it is necessary to perforate the ground and detect the accident sound in a state where external noise is blocked after perforation, it is difficult to apply due to the characteristics of the construction site since such a wide variety of sounds are generated. Studies monitoring the work status and productivity of heavy equipment through sound analysis seem to have improved the problems of monitoring through the attachment of existing sensors [1][2]. However, since heavy equipment monitoring only analyzes single machine activity at a distance from external noise, sound analysis is not performed for the construction site.

An accident detection system that analyzes the frequency and pattern of the sound can detect a wide range if it is installed at a single point rather than attached to individual members. Therefore, it can be combined with noise management in the construction site in an economical and efficient fashion.

3 An accident notification system

3.1 The process of accident notification based on sound analysis

It was found that most of the causes of collapse occurred while concrete was being poured. Therefore, it is necessary to understand the accidents that may occur during concrete pouring and to propose a process to detect and respond to these accidents.

While concrete is being poured, the form or the shore may break down due to the side pressure of the concrete, resulting in loss of life or material damage. Even if there is no collapse at the construction site, if a gap is created due to the weight, a concrete leakage accident will affect the structural quality of the building.

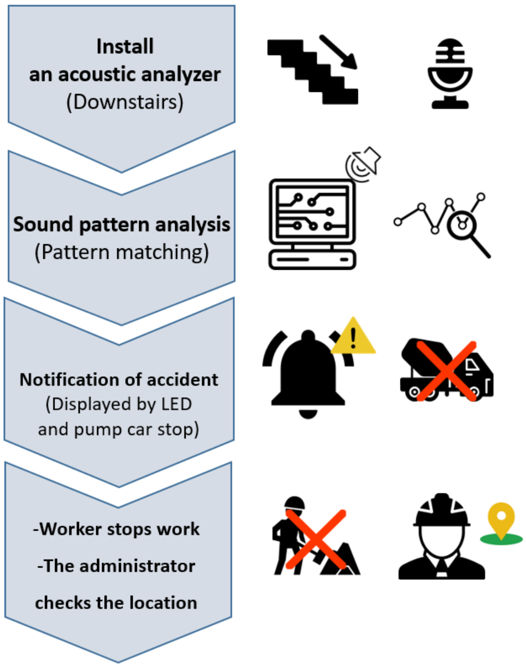

Figure 2. Accident notification process

Accidents that occur while concrete is being poured require quick action, but this is generally not possible. The problem with accidents is that when concrete is being poured, an accident in the lower layer goes completely unnoticed by those pouring concrete in the upper layer. In order to solve these problems, we propose a process to detect an unexpected situation while monitoring the downstairs situation through sound analysis during concrete pouring

First, a portable sound analyzer is installed under the concrete pouring layer. In the next step, the sound collected by the sound analyzer is sent to the server in real time. When a pattern that is similar to previously collected accident sounds is detected by the server, the installer's LED indicator warns of danger. When this sign is displayed, the pump car automatically stops and the worker is forced to stop as well. The administrator knows that the sound is coming from the server, finds the exact location, and takes action.

3.2 Sound analysis in concrete pouring

A A basic experiment was conducted to propose an accident detection process using sound analysis. Before the prototype of the portable sound analyzer was developed, a basic experiment was conducted to determine if it would be possible to distinguish between noise and accident sounds at a construction site.

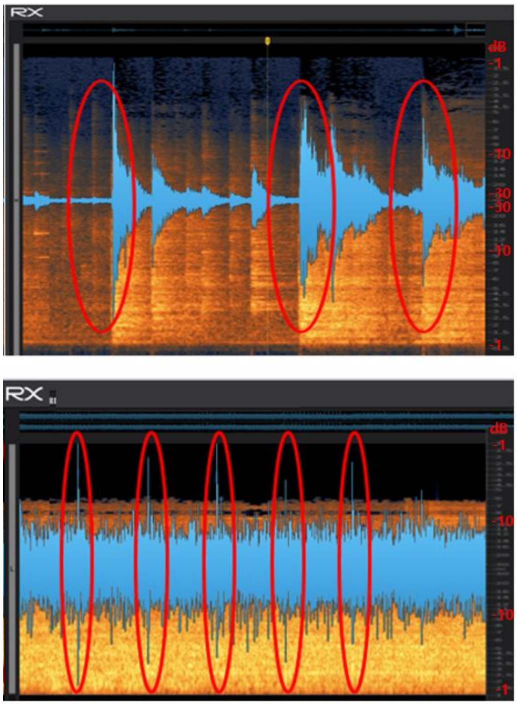

Figure 3. Sound analysis of concrete pouring

The upper picture in Figure 3 shows the analysis of the pattern created by generating impact noise among the noise of a general construction site. In the lower part of Figure 3, the pattern of the impact and plosive sounds during concrete pouring were analyzed. It can be seen that the upper picture clearly distinguishes the impact sound. High impact sounds and plosives are clearly visible in decibels because of the low ambient noise.

In the lower picture, a very loud noise was generated during concrete pouring. At the time of direct recording, the putting noise was too large to check other sounds with the ear. However, frequency analysis showed that the impact sound and the plosive sound were distinguishable by their unique pattern and size even in a loud noise situation. It was confirmed that the impact noise and the plosive sound have different threshold values from general noise, as found in previous studies that classify work noise at the construction site. It was judged to be possible to use sound analysis monitoring in the concrete pouring section.

3.3 An algorithm to determine an accident

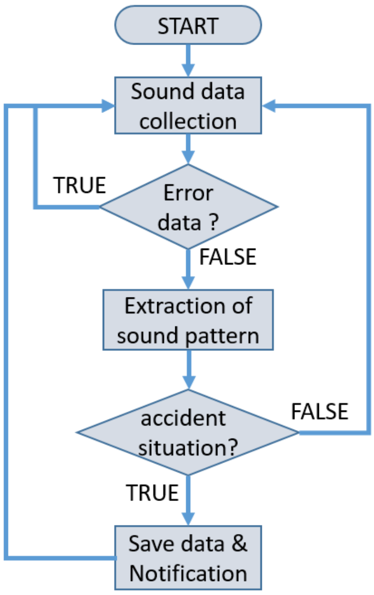

Figure 4. An accident detection process

An accident detection process based on data analysis using an sound collector was designed. Analog signals of accidental sounds and various noises in the field were digitized and converted into data. The more data is collected by applying the Big Data Analysis Theory, the higher the accuracy of the judgment algorithm. The algorithm works by probing and filtering the data collected, generating an accident sound data pattern interval, and examining the similarity between the real time sound data and the accident sound pattern. Data collection and filtering implement logic to filter error data because there is the possibility of collecting noise and error data. The similarity between the generated accident section pattern information and the currently collected sound pattern is examined, and when the value of the currently collected sound deviates from the threshold value, it is judged to be an out-of-sight condition.

4 Conclusion and Future research

This study investigates the current status of sound analysis research through literature review, and a process for an accident notification system based on sound analysis was proposed. Through a basic experiment in which the system was applied, the noise pattern was analyzed at a concrete pouring site and the validity of the system's application was confirmed.

A sound analysis-based accident detection system is a field of interest and research in transportation. So far, accident detection has been dependent on CCTV, but the present limitations of image reading have been reached. However, it is possible to identify and prevent many accidents using the immediate and wide range advantages of sound.

The following is the future directions for this study's sound analysis. First, a significant amount of sound data is required to apply an accident notification system using sound analysis in the field. There is also a need for data not only regarding the mechanical sounds and noise of a construction site but also of actual accident sounds. To design a program using a Neural Network or Deep Learning, accuracy is improved when many data points are collected. Collecting ample noise and accident sound data through case studies at various sites will contribute to the detection rate of the system in the future.

In addition, it is necessary to know the positioning of the sound's source. According to the patent registered by Samsung Electronics, each of the input sound source signals inputted through two or more microphones are combined to generate output signals, and the generated microphone output signals are calculated. The distance to the sound source may then be calculated using the distance between the calculation result and the frequency of the input sound source signal. Using this technique, the system can create a map of the source and determine the direction and distance of the source. When applied to accident monitoring, an accurate location for accident sound in the field can be obtained.

An accident notification system based on sound analysis will increase the accident detection rate by fusing various sensors, deep-running technology, and wireless network technology. In addition, accurate positioning and the immediate response of the system will contribute greatly to the field of safety management.

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