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An image-based method for non-contact and dynamic room acoustics analysis

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ABSTRACT

Noise is defined as "unwanted" sound and the workers in industrial workroom are often exposed to noise. Acoustics analysis helps to evaluate and improve noise absorption of the reflecting surfaces. Acoustics treatment aims to control sound reflections within the room. This study investigated a method of dynamic room acoustics analysis in industrial workrooms which was developed using image processing and MATLAB software. This method can be used for collecting data and calculating the noise absorption surface area, and may help to identify the acoustics index of buildings more accurately on the basis of the existing conditions.

The proposed method was compared with the classical method through 82 dimensional measurements. The required tools including camera, targets, and checkerboard were installed in the site of experiment. Taking into account the distance between the camera and the fittings of interest, the required data were gathered along the two directions of the hall in order to calculate the length, width, and the height of the fittings. The captured photos in jpg format were saved on a computer and processed using suitable algorithms. To collect the data via the classical method, the data collection stage was repeated using a Laser distance meter Tajima Model F02.

Based on the results obtained from dimensional analysis in the Industrial settings, the average sound absorption index measured using the new and the classical method, respectively, was 4.15 and 4.39 Sabin·m^2. The intra class correlation coefficient between these two methods was 0.989 (R^2 = 0.994).

The proposed method as a measurement and monitoring instrument was accurate enough to be used for acoustic analysis of buildings and can be considered as an alternative for the classical method. This method requires less time to be performed and provides more accurate calculations, thus, it can be used to make the right decision regarding the building acoustic condition; moreover, as it is a non-contact analysis method, it can significantly protect evaluator person against the risk of accidents caused by industrial machinery.

1. Introduction

Workers in industrial workrooms are often exposed to noise and occupational exposures can be associated with excessive negative health outcomes. Noise may have both auditory and non-auditory effects [1]. According to a report by the WHO, it is estimated that 10% of the world population are exposed to high levels of noise pressure which can lead to hearing loss [2]. Despite the utilization of standards to protect hearing ability and decrease occupational exposures in developed countries, noise is still among the causes that induce hearing loss (NIHL) [3]. Based on the results of studies, increased systolic and diastolic blood pressure, changes in heart rate and body metabolism, and the release of stress hormone are among the problems caused by excessive noise exposure [4]. Reliable acoustic analysis and estimation methods should be utilized to protect people's health and security. Industrial sittings have complex systems which require accurate control

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and monitoring methods in order to maintain healthy and safe conditions in the workplace [5]. In such places, people may be exposed to different levels of noise caused by two sources one of which is the noise emitted from the noise source and the other one is the noise reflected from the building inner surfaces [6]. The main goal of noise control and monitoring plans is to decrease the exposure to noise at working stations; such plans and interventions can be implemented through making changes in noise source, noise route, and receiver (working station), or in a combination of them [7]. Acoustics treatment is an important and applicable method for conducting an acoustic analysis; the result of an accurate analysis can be used solely or in combination with other noise controlling methods to make a significant and effective reduction in noise exposure. Among the input parameters for room acoustic analysis, we may note length, width, and height of the objects in the room, and type of internal surfaces [8]. These parameters can actually determine the level of noise reflection in a room. As a result, it is of great importance to calculate and determine exact details on the absorption and reflection, because the application of any computational changes in the mentioned factors can result in a change in the absorption surface and acoustic properties of the environments under the study. In closed industrial workrooms, due to the existence of numerous obstacles such as machinery, product storage, and work tables, platforms, and equipment, sound waves behave differently, as compared with empty environments.

When determining the dimensional characteristics of the environment and fittings, the classical method is used to analyze the acoustic conditions. Classical dimensional measurements in the acoustic field are performed using meters and manual methods. When using these methods, error is inevitable, and sometimes incorrect results from building acoustic analysis may be obtained because of collecting incorrect data about the space or due to incomplete calculations. Thus, it is of great importance to develop new methods through designing operational algorithms. In addition, the presence of large and bulky objects in industries and in some cases the high risk of exposure to physical, chemical, and ergonomic hazards make it difficult and challenging to use classical method of the acoustic analysis in closed industrial workrooms. The results of the building acoustic analysis, which are obtainable through using a new image processing method, can be utilized for noise estimation and other applications [9]. In a study by Golmohammadi et al. which was conducted to estimate occupational exposure to noise, the acoustic characteristics of the space were evaluated [10]. The accuracy of the quantitative and qualitative results can have a significant impact on the estimation of the risk of noise exposure and help to provide accurate calculations for noise control. On the other hand, it is necessary to consider the unsafe behaviors of the computing operator who may approach working machines (moving, compaction etc.) to calculate acoustic and structural factors. Therefore, it is essential to pay attention to new methods to replace the old ones. It should be noted that in industrial halls the dimensions of barriers (machinery, equipment, materials etc.) are constantly changing and the use of such methods for data acquisition can be helpful for instantaneous acoustic analysis and industrial workrooms monitoring on the basis of existing conditions; they may be also used for the introduction of continuous monitoring systems and identifying the noise exposure risk while considering all the effective factors.

Today, with increasing utilization of various discrete data acquisition methods and tools such as scanners and digital cameras, image processing is widely used. One of the areas of interest in image processing is the image analysis by the machine which deals with the ways in which the meaning and content of the image can be understood [11]. There has been a remarkable progress in image processing and it has been used in many fields of science. Tati et al. and Dutta et al. conducted comprehensive investigations about the existing sensors used in image processing for monitoring and controlling the advanced machining processes [12]. This intelligent technology has been used in engineering, medical sciences, estimation of body posture, and different areas of food industry [13–20]. Many studies have been performed in identifying material surfaces and analyzing their texture using various image processing techniques [21–24]. As one of the advantages of using digital image processing, it applies no loading on the surface under the study. This non-contact technique can speed up the analysis and evaluation procedure especially in risky industries with high risk exposure while simultaneously allows dynamic evaluation in building acoustic analysis.

A study has also been carried out by Yahya et al. regarding the application of image processing for identifying absorption coefficient of surfaces, dimensions, and the reverberation time. In this research, estimating the surfaces dimensions of the room was done using stereo vision technique and the dimensions of the surfaces and various objects in the room were measured by analysis of obtained images [25]. Since the special conditions need to be provided for the installation of stereo vision system and stereo image data collection, the implementation of this system is quite difficult in the existing complicated conditions of industrial environments due to the wide area of the halls, high equipment density, and process complexity. Although using more cameras allows measuring the dimensions of the objects, it may not be highly efficient in special circumstances like in the industrial environment. In addition, this system increases the cost and the analysis of images takes more time. Therefore, in the present study, the application of image processing in acoustic analysis of industrial environments was investigated by 2D optical image-based method using mono camera system so that the image capturing can be easily provided from various directions. Then the innovative image processing method was utilized to perform the acoustic analysis in closed industrial workrooms.

2. Describing the methodology of non-contact image-based system

In this study, the dimensions of fittings were calculated and measured using the new image processing method. The images were analyzed using GUI in MATLAB and the obtained results were used to estimate the sound wave behavior through calculating the Sabin index, and performing the building acoustic analysis. Moreover, the index was calculated via classical (static) method and the results obtained from both methods were compared and analyzed in the real industry. In the static method, Laser Distance Meter Tajima F02 model was used to determine the real dimensions of the fittings.

In the current method, a non-contact image-based methodology was developed to identify and measure the dimensional variables. Fig. 1 presents the steps of the non-contact image-based dynamic method of acoustic analysis.

Based on the proposed methodology (Fig. 1), the details of each step of the non-contact image-based system are described in the following.

2.1. Camera placement and target installation

At first, the required equipment including camera, targets, and checkerboard were prepared and placed at the right location. Taking into consideration the existing conditions including the position of the installation of fittings and the distance between the camera and fittings, the appropriate location for the camera was determined for data collection. The characteristics of camera are presented in Table 1. It should be mentioned that in this study, one camera was used for image data collection.

A black circular target on a white background with the diameter of 15 cm was also used as the measurement target in this study. To prevent accidental events such as camera shake which have a destructive effect on image quality, the camera was placed on a tripod.

2.2. Image data gathering

After the preparation of the required equipment and installation of the targets, the image acquisition is started by capturing the calibration