

# Automated Tool for the Development of Noise Level Inspection Studies

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## Abstract

With the industrialization of cities, the automation of work processes in companies and the growth of the population, one of the most relevant environmental pollution factors is noise, which has a direct impact on people's health and is caused to a greater extent by sources such as means of transportation and work activities. In this sense, it is essential for government authorities to assess the impact of the noise level on the population of cities, in order to make decisions related to urban planning. According to the above, companies in charge of conducting acoustic audits and research centers need to have tools and systems that allow the conduction of inspection studies and that enable the statistical analysis of noise levels, taking into account the levels recommended by the World Health Organization and the relevant authorities. Based on the above, in this paper we proposed as a contribution the construction of an automated tool for the development of environmental noise level analysis studies in different application contexts. The automated tool was implemented in the Python programming language and allows loading an audio file, extracting the samples that make up the signal and calculating the noise level in dBs associated with each sample. This tool is intended to support the conduct of acoustic inspection studies within cities, in order to determine the environmental impact of noise captured in buildings, public places, roads, on citizens.

**Keywords:** ambient noise, noise level, noise inspection, noise pollution.

## I. INTRODUCTION

With the growth, development and industrialization of cities, as well as the increase in population and the automation of work processes, one of the polluting factors that has a direct impact on the well-being and health of the population is environmental noise, which can originate from different sources such as means of transportation and work activities [1]–[8]. In this sense, according to the World Health Organization, there is a direct and exponential relationship between the level of development of a country and the noise pollution that affects its population [9], [10].

Taking into account the above, since 1972 when the WHO classified noise as a pollutant, industrialized countries have enacted laws regulating noise levels [11]. Nowadays,

environmental noise inspection studies have gained significant importance, taking into account the effects that noise has on people's health and the economic and labor implications it represents [7], [12]. In accordance with the above, people who are continuously exposed to high levels of noise experience physiological disorders such as loss of hearing, alteration of brain, cardiac and respiratory activity, gastrointestinal disorders, among others [6]. In this regard, the World Health Organization has recommended keeping indoor noise levels down to 30 dB, while at the level of noise generated by vehicular traffic, it has been recommended to keep it below 53 dB [13], [14].

Based on the above, companies in charge of conducting acoustic audits and research centers need to have systems and tools that make it possible to conduct noise level inspection studies in the different sites of a city, in such a way that these systems are not only responsible for the timely capture of noise levels, but also for the statistical analysis and analysis based on machine learning methods on the captures made [15].

In this article we propose as a contribution, the construction of an automated tool for the development of noise level analysis studies in different application contexts. The automated tool was implemented through the Python programming language, specifically using the Python libraries pydub, tkinter, matplotlib and numpy. The proposed tool allows loading an audio file, extracting the samples that make up the signal and calculating the noise level in decibels associated with each sample. Similarly, from the noise levels obtained, the tool allows a statistical and graphical analysis to obtain the percentage distribution of the noise levels that make up the analyzed audio file. In order to evaluate the usefulness of the proposed tool, an acoustic inspection study was conducted in which an audio file published on YouTube was analyzed with ambient noise captured during a 30-minute period at an international airport. The tool presented in this article is intended to serve as a support in conducting acoustic inspection studies within the cities, in order to determine the environmental impact of noise captured in buildings, public places, roads, on the citizens.

The rest of the article is organized as follows: Section 2 presents the methodology considered for the development of this work. Section 3 describes the results obtained in this research, which includes the description of the design and implementation of the proposed automated tool, as well as the conduct of a case study through the use of the constructed tool.

Finally, section 4 presents the conclusions and future work derived from this research.

## II. METHODOLOGY

For the development of this research, 4 methodological phases were defined: characterization of noise levels, selection of tools and technologies, design and implementation of the analysis tool and finally case study (see Figure 1).

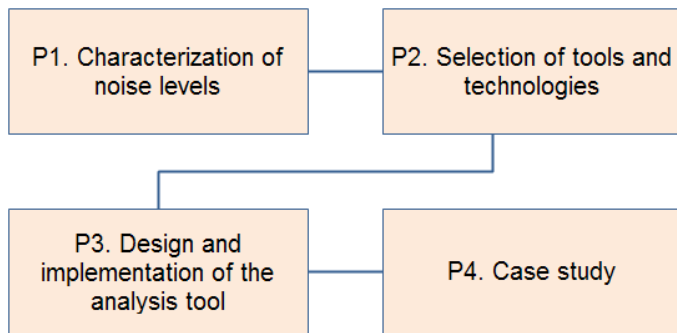


Fig. 1. Methodology considered

In phase 1 of the methodology, a literature review was conducted in order to identify and determine the classification of noise levels to be considered in the implementation of the automated tool for noise level analysis, so that the noise levels defined in [16], [17] were taken into consideration. Once the noise level ranges were defined, in phase 2 the exploration and selection of technologies and libraries to be considered for the construction of the tool was carried out, from which the Python language libraries pydub, tkinter, matplotlib and numpy were chosen. In phase 3 of the methodology, the design and implementation of the tool was carried out, taking into account the advantages provided by the tools selected in phase 2. Finally, in phase 4 of the methodology, the performance and usefulness of the developed tool was evaluated within a case study, in which the noise levels of an audio file published on Youtube with the ambient sound of an international airport for 30 minutes were analyzed. The case study allowed both a statistical analysis and an analysis of the percentage distribution of the noise levels considered in phase 1 within the airport audio signal samples.

## III. RESULTS AND DISCUSSION

This section presents the results obtained in this research, which includes the definition of noise levels from the literature review, as well as the design and implementation of the noise level analysis tool and the case study developed from the proposed tool, on an audio file with the recording of the ambient sound of an international airport published on Youtube.

Based on the above, Table 1 shows the noise levels considered in the development of the tool, which were obtained and adapted according to what is presented in [16], [17]. The

ranges presented in Table 1 were used to calculate the percentage distribution of noise levels in the audios analyzed.

Table 1. Defined noise levels

Noise Level	Range (dBs)
Low	Level≤30 dBs
Normal	30 dB<Level≤50 dB
Considerable	50 dB<Level≤75 dB
High	75 dB<Level≤100 dB
Very High	100 dB<Level≤120 dB
Pain threshold	Level>120 dB

Once the noise levels to be considered in the construction of the analysis tool were defined, the design of the tool was approached, so that Figure 2 shows a flowchart illustrating the different sequential processes performed by the proposed tool.

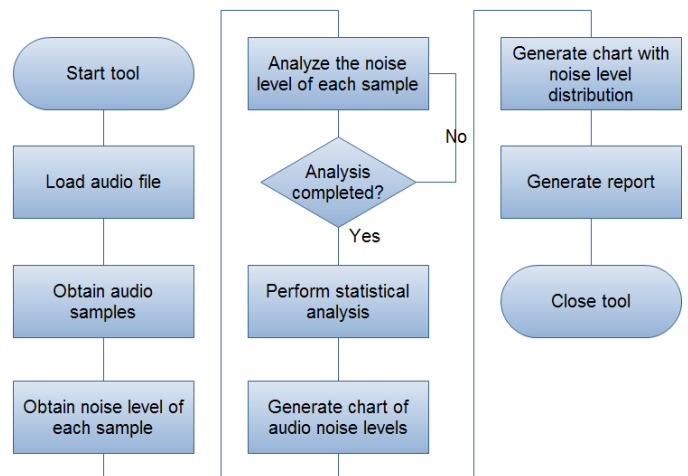


Fig. 2. Flowchart of the proposed tool

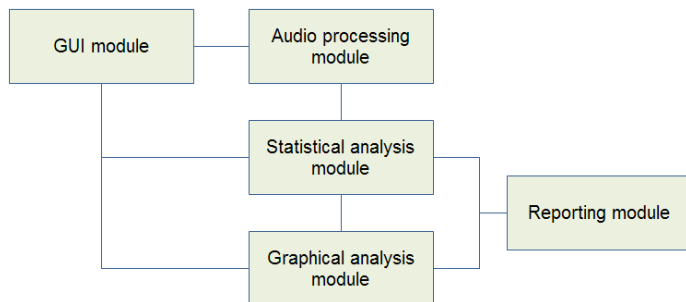
Thus, once the analysis tool is started, it is possible to load the audio file to be analyzed in wav format, so that once the file is loaded, the tool obtains in an array of floating numbers the samples that make up the signal, which are in a range from -1 to 1. From the obtained array, the tool proceeds with the calculation of the noise level in decibels of each sample of the array, using equation 1, for which the absolute value of each audio sample is taken. In case the audio sample contains a value equal to zero, this value is replaced by the minimum value of the array signal, taking into account the logarithm restrictions.

$$Noise\ Level = 20\log_{10}\left(\frac{abs(audio\ sample)}{reference\ level}\right) \quad (1)$$

Each of the noise levels obtained and associated to each sample of the audio signal is stored in another floating array, so that once the processing of the samples is finished, the tool performs a statistical analysis on the data of this array in order to obtain:

the mean, the median, the standard deviation and the variance. Similarly, the automated tool allows a graphical analysis by obtaining a chart showing the noise levels along the signal and another one showing the percentage distribution of noise levels in the audio signal, taking into account the levels defined in Table 1. Finally, the tool enables the generation of a report with the statistical results obtained, as well as the percentage distribution of the noise levels belonging to the signal samples.

To accomplish the different processes presented in Figure 2, the tool was designed and organized in 5 functional modules: GUI, audio processing, statistical analysis, graphical analysis and report generation, as shown in Figure 3.

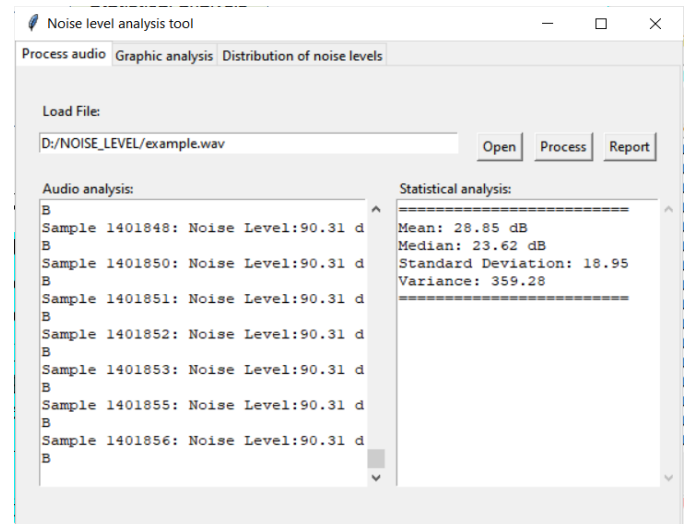


**Fig. 3.** Functional modules of the tool

The GUI module was implemented using the Python tkinter library and is responsible for managing the graphical interface of the tool, which includes the management of interface events and the presentation of statistical and graphical results in the tabs that make up the tool. The audio processing module was implemented in the tool using the Python pydub library and is responsible for obtaining the audio samples of the signal and calculating the noise level of each sample using equation 1. The statistical analysis module was implemented through the use of the Python numpy library and is responsible for obtaining the mean, median, standard deviation and variance of the noise levels calculated for each of the audio signal samples. The graphical analysis module was implemented through the use of the Python matplotlib library and allows the generation of a chart with the noise levels along the audio signal and a chart with the percentage distribution of the noise levels, taking into consideration the ranges presented in Table 1. Finally, the reporting module allows the generation of a CSV file with the results of both the statistical analysis of the noise levels and the percentage distribution of the noise levels obtained in the analyzed audio file.

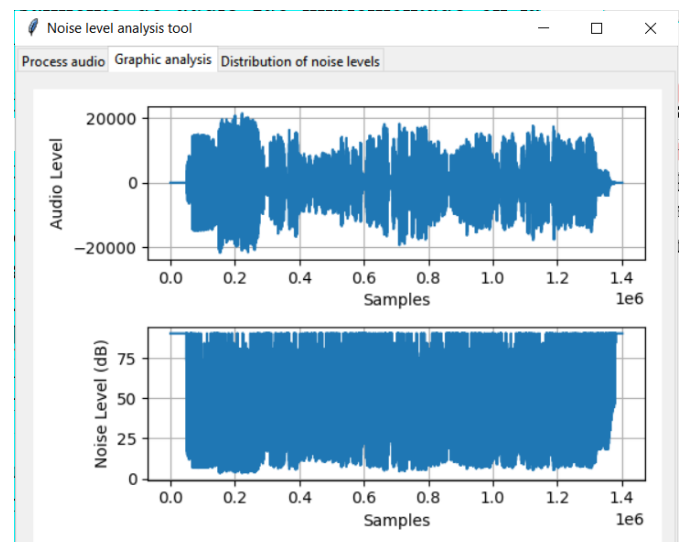
Taking into account the processes presented in Figure 2 and the functional modules of the tool shown in Figure 3, Figure 4 presents the graphical interface of the noise level analysis tool, which consists of three tabs: "Process audio", "Graphic analysis" and "Noise level distribution". In the "Process audio" tab, the tool allows both to attach an audio file in .wav format through the "Load" button, and to start processing the loaded file by pressing the "Process" button, so that internally the samples are obtained from the audio signal and the noise level associated with each of the samples is calculated, while the results are displayed in the graphical interface of the tool. Similarly, once the analysis of the noise level in the different audio samples that make up the signal has been completed, the

tool calculates and displays the statistical analysis of the noise levels (average, median, standard deviation and variance) in the graphical interface. On the other hand, once the noise levels have been calculated and the statistical analysis has been completed, the tool allows the generation of a .CSV report file, with the results of the analysis, by clicking on the "Report" button. As an example, Figure 4 shows how the audio file "example.wav" obtained a total of 1401856 samples, to each of which the noise level was calculated according to equation 1, obtaining as a result a mean value of 28.85 dB, a median of 23.62 dB, a standard deviation of 18.95 and a variance of 359.28.



**Fig. 4.** "Process Audio" tab of the tool

On the other hand, in the "Graphic Analysis" tab, the tool displays a graph with the audio signal corresponding to the file loaded in the first tab and another graph representing the different noise levels calculated throughout the audio file (see Figure 5). Thus, as an example, the graphs presented in Figure 5 correspond to the graphical analysis of the "example.wav" file loaded and shown in Figure 4.



**Fig. 5.** "Graphic analysis" tab of the tool

Finally, in Figure 6, the tool obtains graphically the percentage distribution of the noise levels in the audio loaded in the "Process Audio" tab. As an example, Figure 6 shows that for the file "example.wav" loaded in the first tab, about 65% of the audio signal samples have a low risk level, while about 20% of the samples have been classified in the normal level. Similarly, it can also be observed that about 5% of the audio samples are found in the levels: considerable and high. Also, it is possible to observe from the example in Figure 6 that the "Very High" and "Pain Threshold" levels do not have audio samples.

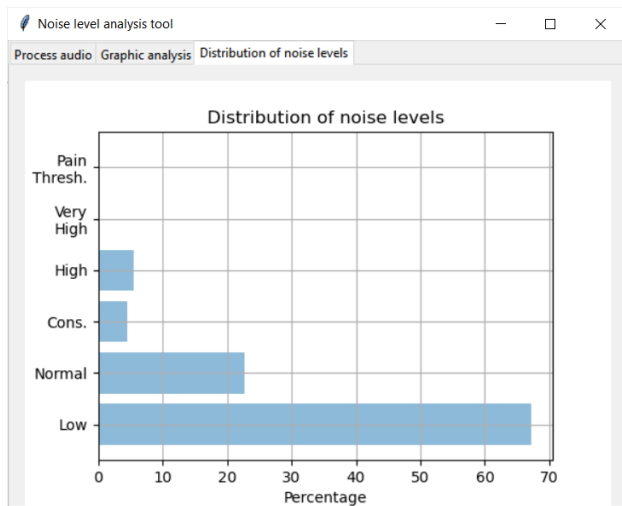


Fig. 6. "Distribution of noise levels" tab of the tool

Once the different tabs of the proposal tool were described, we proceeded to perform the noise level analysis on an audio that includes the ambient sound of an international airport for a period of 30 minutes [18]. Thus, when analyzing the audio file considered by using the proposed tool, the statistical results presented in Table 2 were obtained, which were calculated on a total of 86402752 audio samples.

Table 2. Statistical analysis performed

Measure	Value
Mean	32.05 dB
Median	30.14 dB
Standard Deviation	10.09
Variance	101.77

From the results presented in Table 2, it is possible to observe that the mean and median noise levels of the case study can be classified within the "Normal" level of Table 1. On the other hand, Figure 7 shows the charts with the input audio signal of the case study and the noise levels obtained throughout the analyzed audio file.

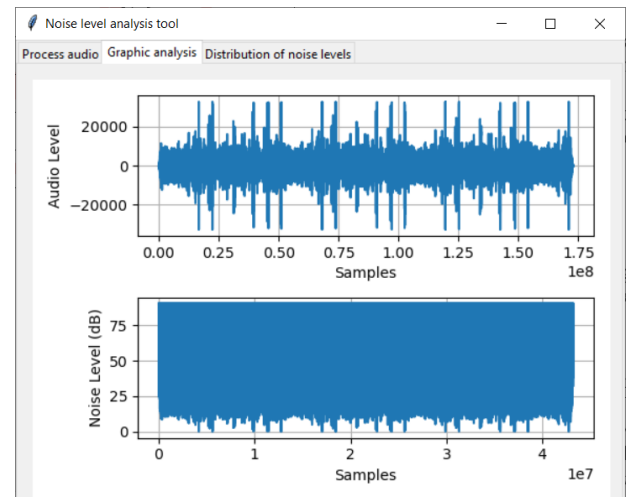


Fig. 7. Noise level of the case study audio signal

Finally, Figure 8 shows the percentage distribution of the noise levels obtained for the case study. Thus, according to Figure 8, it is possible to observe that about 50% of the audio signal samples have a noise level that has been classified in the "Low" level, while about 45% of the samples were classified within the "Normal" noise level. Similarly, 5% of the audio samples are within the "Considerable" noise level. Additionally, it is possible to observe that there were no samples classified in the "High", "Very High" and "Pain Threshold" levels.

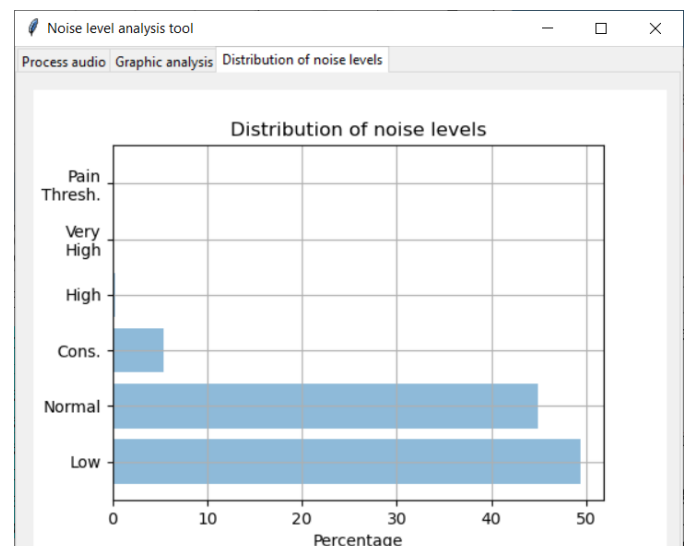


Fig. 8. Case study noise level distribution

Through the above results, it is possible to conclude that the acoustic insulation of the airport analyzed is adequate for the health of passengers, given that the noise levels determined by the tool and perceived in the airport waiting rooms are within the normal noise level. It is also possible to mention that the audio file analyzed was recorded indoors at the airport, so this study can be enriched by analyzing the noise level outdoors or in areas close to the airport.

#### IV. CONCLUSIONS

As a consequence of the growth, development and industrialization of cities, one of the key factors that can have an impact on the health of the population is the noise generated by different sources, such as means of transportation. Based on the above, one of the technological challenges is to have systems and tools that allow conducting acoustic inspection studies in different sites of a city. Thus, in this article we proposed as a contribution, the construction of an automated tool for the development of noise level analysis studies, which takes as input an audio file in .wav format with the ambient sound of a particular place or area of a city, and obtains as output the percentage distribution of noise levels associated with the samples that make up the audio signal.

From the statistical and graphical results provided by the proposed tool, it is possible to conclude that the tool can support the development of acoustic inspection studies, which effectively contribute to decision making by the relevant authorities in terms of sound insulation and city planning. Thus, although the case study in which the tool was applied was the analysis of noise levels at an airport, the tool can be used, for example, to analyze the impact of vehicular traffic in residential areas, in school zones or in hospitals and medical centers.

The libraries associated with the Python language and used in the development of the tool, allowed to adequately process and analyze the signal samples of an audio file in wav format. In this way, through the use of the pydub library, it was possible to obtain the audio signal samples in an array. On the other hand, the numpy library allowed the calculation of the noise levels along the audio signal, as well as the statistical analysis and percentage distribution of these levels. Finally, the matplotlib library allowed to obtain the charts corresponding to: the original audio signal, the noise levels of the audio signal and the percentage distribution of the noise levels.

The case study developed on the audio file with the ambient sound of an international airport for a period of 30 minutes, allowed to determine that the average of the samples was classified in the "Normal" noise level. Similarly, when the samples were counted and classified, it was found that the noise levels that presented the highest percentage in the samples analyzed were the "Low" and "Normal" levels, with respective percentages close to 50% and 45%. Based on the above, it is possible to conclude that the noise level inside the airport waiting rooms is within the appropriate range for the health of passengers and workers.

As future work derived from this research, we intend to complement the present study by analyzing noise levels in areas surrounding the airports or in areas outside the waiting rooms. In the same way, it is intended to carry out different studies of noise level analysis from audio signals obtained from security cameras or traffic control cameras. Finally, the tool can be enriched through the inclusion of unsupervised learning models for cluster analysis on the noise levels calculated from the audio signal samples.

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