SoundMeterPlat - Aircraft Noise Monitoring Platform

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Abstract— **It is estimated that more than 400,000 people in Lisbon and neighboring municipalities are affected by noise from Humberto Delgado International Airport of Lisbon. The WHO recommends noise levels: for air traffic, they should not exceed 45 dBA in the weighted average of the day, evening, and night (Lden). For the nighttime (Ln), when noise sensitivity increases, the WHO recommends levels below 40 dBA. However, average noise levels (Ln) above 45 dBA and peak levels (LCpeak) of around 103 dBC are frequently recorded. Chronic sleep disruption due to aircraft noise has been associated with medium to long-term health problems, including cardiovascular problems, increased stress, and mental health. As part of noise monitoring and awareness, ISEL's Audio and Acoustics Laboratory (LAA) is developing a pilot platform, SoundMeterPlat, to collect, analyze, store, and present acoustic parameters from a network of sound acquisition and processing stations located throughout urban areas. The platform aims to provide an integrated view of the urban acoustic landscape, allowing users to access relevant data in real time to support decision-making. With the help of interactive dashboards, sound data can be visually explored, making the information accessible and actionable for different user profiles. The data is available for download via the platform in CSV format. Monitoring noise events in urban environments represents an essential pillar for the development of Smart Cities, promoting not only public safety—through the early detection of emergency situations such as accidents, disturbances, or risky behavior—but also the efficient management of urban resources, allowing, for example, the optimization of the dispatch of intervention teams or the adjustment of public service operating hours based on sound patterns. Furthermore, it contributes to improving citizens' quality of life by identifying areas with excessive noise levels, enabling mitigation measures in residential, school, and hospital areas. The SoundMeterPlat project proposes the development of a solution for sound monitoring in urban environments, focusing on data privacy, modularity, and ease of use. The architecture integrates sound analysis stations with a sound traffic light approach and a platform for storing and visualizing results. This platform uses an architecture based on the MQTT protocol, processing with Node-RED, storage in InfluxDB, and visualization in interactive dashboards via Grafana, accessible through a web application. Remote reconfiguration and display capabilities allow the solution to be adapted to different clinical scenarios. Additionally, the system performs non-intrusive identification of sound event types, automatically classifying sounds such as voices, screams, alarms, music, or equipment noise using AI models. The AudioSet dataset has been quantitatively evaluated with a purpose-built database and real-time testing. The system performs inference efficiently on devices such as the Raspberry Pi mini-computer, storing the results with confidence indicators..**

Keywords— **Noise in urban environments; continuous sound monitoring; online platform; Smart Cities, Sound Event Detection, IoT.**

I. INTRODUCTION

Airport noise pollution has become a critical issue for urban environments, particularly around major airports near big cities which significantly impacts the surrounding population. The constant activity of aircraft takeoffs, landings, and ground operations contributes to elevated noise levels, affecting public health, quality of life, and community well-being. Several research studies points that aircraft noise will damage people's hearing [1-4], increase level of worries [5,6], interfere with people's sleep [7,8] and affect their mental health [9].

In addition, aircraft noise will increase the probability of attention deficit hyperactivity disorder among children [10] and even increase the risk of cardiovascular diseases such as hypertension and coronary heart disease [11,12].

Over 200 organisations, including climate justice groups, neighbourhood associations, and NGOs, have signed a joint declaration condemning the harmful impacts of night flights on health and the climate, describing them as "unnecessary and avoidable." Building on this momentum, groups from 10 countries took united action on 13th September—marking the second annual observance of the International Day for the Ban of Night Flights at Airports—to demand an immediate end to night flights at airports [13]. One of the priority of implementing a long-term noise monitoring system is to conduct with great concern to the involvement of all the parties (government, elected bodies, air transporters and residents).

Traditional monitoring methods often lack the capacity to provide real-time, granular data needed for effective management. Advances in sensor networks and data visualisation offer new opportunities for dynamic acoustic monitoring, enabling targeted mitigation strategies.

Today, a number of sound monitoring platforms are on the field. Actually, large airport infrastructures (more than 50,000 movements recorded annually) are legally required to maintain a continuous noise monitoring system for activities in the areas

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surrounding the airport, in order to implement Noise Maps. However, the sound data is not generally made available to the public, only the global reports. Nevertheless, there are examples of systems that are accessible to the public. The Bruitparif is a non-profit environmental organization responsible for monitoring the environmental noise in the Paris agglomeration. It was founded in 2004. Bruitparif monitor continuously a network of 45 long-term measurement stations named "Rumeur" [14]. The S.U.R.V.O.L (SUrveillance sanitaiRe et enVironnementale rOissy-orLy-le bourget) is a system developed by the French government has decided to set up a system to monitor the health and environmental impact of air, road and rail traffic around the three airports in Greater Paris: Roissy-Charles de Gaulle. [15]. The ANOMS system at Warsaw Chopin Airport integrates 10 distributed monitoring sites, combining meteorological sensors and ADS–B (Automatic Dependent Surveillance–Broadcast) data to accurately correlate noise events with specific flights [16]. Other commercial systems are: the Sonitus System- Real-time noise monitoring with web-based dashboards; SMS/email alerts and Long-term data storage and reporting. Cirrus Research – Noise-Hub Live noise data streaming; Remote device control; Cloud reports and alerts. NTi Audio – NoiseScout- noise monitoring via a secure cloud interface; Automated reporting and compliance logging; Smart city integrations. Ecosystem Noise Monitoring (Barcelona)

Public project showing environmental noise: https://noiselevel.barcelona. Real-time noise across city zones. Real-time dashboards; Threshold alerts (email, SMS); API access for integration; Historical data download; Automatic report generation; Public vs private access controls. NoiseScout Portal.

II. Overview

This paper introduces SoundMeterPlat, an innovative low-cost IoT platform designed to collect, analyse, and visualise airport noise data through a distributed sensor network, supporting smarter, data-driven decision-making in noise management within smart city frameworks. The SoundMeterPlat concept uses an IoT architecture based on the MQTT communications protocol; processing with Node-RED; data storage in InfluxDB; and visualization in interactive dashboards via Grafana, accessible through a web application. Remote reconfiguration and display functionality allow the solution to be adapted to different clinical scenarios. Additionally, the system performs non-intrusive identification of sound event types, automatically classifying sounds such as voices, screams, alarms, music, or equipment noise using AI models, such as the YAMNet, using the AudioSet dataset. This was quantitatively evaluated using a purpose-built database and real-time testing. The system performs inference efficiently on devices such as the Raspberry Pi minicomputer, storing results with confidence indicators.

III. Development

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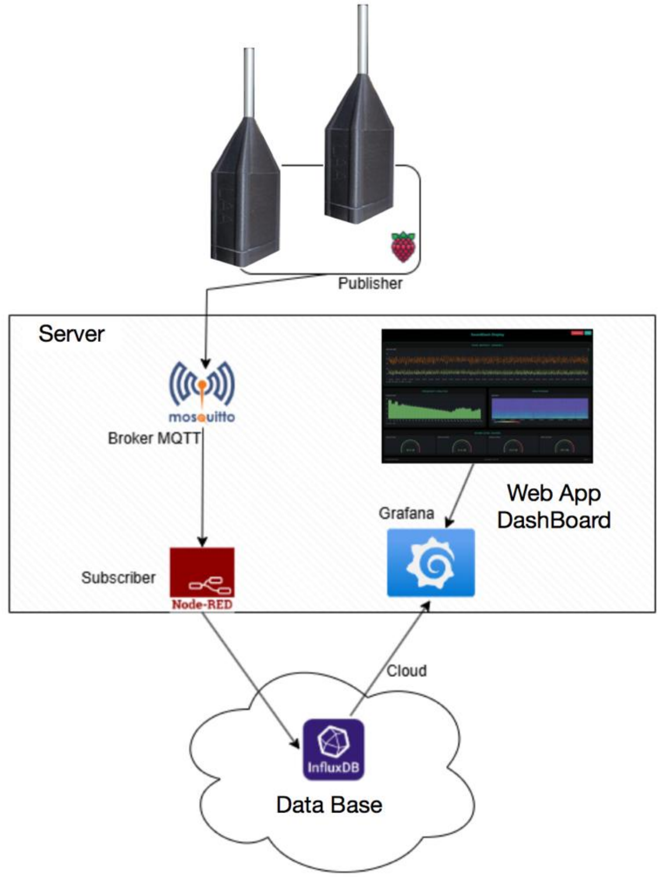


Fig. 1. Functional block diagram of SoundMeterPlat.

A. *Sound analysis*

The system provides a set of analyses of sound parameters, which are sent to the local database:

- TimeStamp: date and time of the measurement, essential for chronological organization and data correlation;

- LAF (or LAEA): equivalent continuous sound level, A-weighted, energy over time (rms value) – represents an average of the sound energy during the measurement interval of each ¼ second (or other value);

- LCpeak: instantaneous peak value with C-weighted filter – indicates the loudest sounds, including impulsive noises. Refers to one of the most important parameters indicated in the RGR;

- LCpeakT: maximum LCpeak value over time during a measurement session;

- LAFmax: maximum sound pressure level with A-weighting and fast response (Fast) – reflects the noisiest moments within the measurement range;

- LAFmaxT: maximum LAFmax value over time during a measurement session;

- LAFmin: minimum sound pressure level with A-weighting and fast response – useful for assessing the contrast between silence and noise;

- LAFminT: minimum value, over time, of the LAFmin during a measurement session;

- LAeq: A-weighted continuous equivalent average level – often used in environmental noise assessment standards, it represents a weighted average of the received noise. It refers to one of the most important parameters, indicated in the RGR;
- BTxx: sound levels by frequency bands of thirds of an octave. Allows for the identification of tonal, impulsive, and low-frequency sounds;
- EventAlarm: binary indication of the occurrence of a sound event due to exceeding the detection threshold relative to the background noise level;
- SoundEventsDetect: identifies a set of sound types grouped into families – impulsive, music, screams, siren, snore, speech, waterfall, wheels, and whistle – using a statistical AI model.

These parameters allow a detailed characterization of the sound environment, enabling, for example: the identification of anomalous acoustic patterns and behaviors, the distinction between continuous sources and sudden noise events, and the evaluation of the effectiveness of implemented noise mitigation measures.

B. Sound events detection and identification

The platform includes an intelligent system called SoundEventsDetect for the detection and classification of sound events in hospital environments, especially for aircraft environments. The solution integrates pre-trained artificial intelligence models, such as YAMNet (Yet Another Mobile Network), trained with the AudioSet dataset of Google (more than one million annotated sounds extracted from Youtube videos), and it is quantitatively validated using a custom audio database and realtime tests. The system performs efficiently on devices like the Raspberry Pi 4 B+, 1 GB, and stores results with prediction confidence scores. Additionally, a mapping was created between the 527 AudioSet classes and 10 semantic families relevant to city noise environments, enabling easier human interpretation of the acoustic context.

The YAMNet model showed the best classification performance for this project (and was used in the final system). This model performs inference on 1-second audio segments at 16 kHz, converting samples into mel-scaled spectrograms, and produces a distribution of scores for 527 classes. The scores are values from 0 to 1 distributed, with the number of different values equal to the number of classes. The score at each index of the list corresponds to the score of the class of the same index in AudioSet, YAMNet Google Research (2020).

The main advantages of YAMNet:
- Lightweight and efficient (suitable for local execution);
- Well-trained with real examples from YouTube;
- Easily integrateswith the Python Tensorflow library (version 2. x).

C. Dashboard

The online platform was developed using the Bootstrap responsive web framework, allowing compatibility with different screen sizes and mobile devices. Grafana graphs were incorporated into the application via iframes, keeping them updated in real time as configured in the original platform.

The extracted data is sent to the cloud via the MQTT protocol, commonly used in communication with IoT devices, and stored in the Influx database. The Grafana module manages user searches, data formatting, and graph presentation. Finally, the Flask platform allows for browser-based presentation and supplementary analysis of sound parameters.

The web platform shown in Figure 4, developed in Portuguese, was designed to manage all information generated by the S2MS sound station. It enables the analysis, visualization, and download of sound data, as well as remote control of the S2MS station.

The home page (Figure 2, in Portuguese, as are Figures 3 to 11) provides a brief description of the project and navigation to the two main sound data analysis modes: Real-Time Monitoring (Figure 7) and Period Monitoring (Figure 8). It also offers access to sound level information displayed on a map (Figure 4).

In addition, the Detected Events page (Figure 9) allows users to view and download alarms detected within a selected time period, while the Technical Access page (Figures 10 and 11) enables authorized personnel to configure and maintain the system.

Fig.2. SoundMeterPlat system main room panel.

Fig. 3. DashBoard displaying the S2M sound station on a map.

The Real Time Monitoring mode (Monitorização em Tempo Real, in Portuguese) allows to show, in separate figures, the following analyses: i) continuous sound levels, for several time windows ii) Spectrogram iii) Spectrum by frequency bands, thirds of an octave iv) sound levels at the moment and v) Event Types, showing the scores for the 10 families, over time, and the top 3 classes among the 527 given by YAMNet model.

Fig. 4. Real-Time Monitoring DashBoard.

The Monitoring by Period mode (Monitorização por Período, in Portuguese) shows, in separate figures, the analyses for the time period defined by the user: i) sound levels ii) Spectrogram iii) Spectrum by frequency bands, thirds of an octave iv) average sound levels and statistics for the period and for the shifts of the last day.

Figure 5 shows the dashboard for the list of Detected Events during a period of time defined by the user. The set of events can be downloaded.

A. Performance Analysis of Requests to InfluxDB and Grafana

The performance of queries made directly to InfluxDB and via Grafana, comparing response times over different time intervals was analysed. The goal was to identify potential bottlenecks in response time and see if the total request time is being impacted by processing done by Grafana or by queries to the database system itself.

We found that the average time for a direct query to InfluxDB, with data collected every 5 minutes, is 548 ms. When expanding the analysis to longer periods, a query for 1 hour takes about 1953 ms, and for 3 hours, the total time rises to 3747 ms.

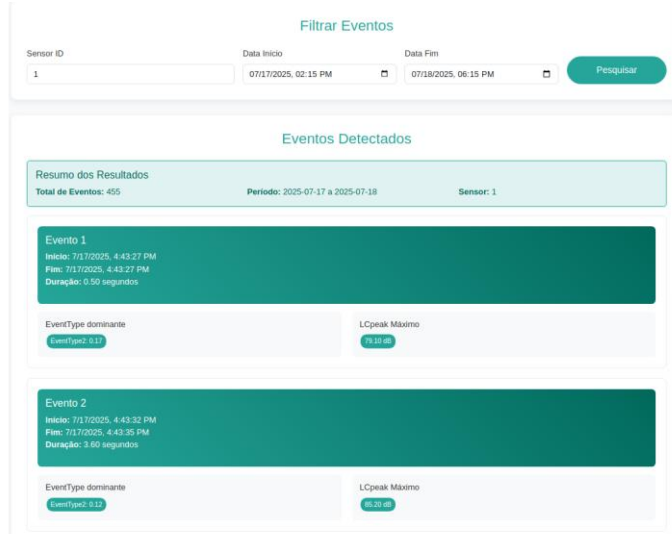


Fig. 5. DashBoard of Detected Events in list.

The requests made by Grafana for an LAEA metric, with sensor selection, shown that for a 5-minute interval, the total request time is 732 ms, with an internal processing time of only 0.300 ms. For 15 minutes, the request takes 1.21 seconds, with a processing time of 0.000 ms. For 1 hour, the request takes 2.13 seconds, with data processing at 0.100 ms, and for 3 hours, the total time is 3.53 seconds, with processing also maintained at 0.100 ms.

This data indicates that response times are very similar between direct queries to InfluxDB and visualizations made via Grafana. The difference is minimal, and the data processing time done by Grafana is practically zero. This suggests that the main performance bottleneck lies in the InfluxDB requests themselves, and not in the graphical or analytical processing done by Grafana.

Although the observed times do not indicate serious problems in the current scenario, it is important to emphasize that the system depends on a database hosted in the cloud (InfluxDB Cloud), and that it is dealing with large amounts of data per second. This architecture introduces a significant dependency on internet connectivity and cloud service stability, which can become a critical bottleneck as the number of sensors increases or users request longer time intervals. These limitations may not only compromise the scalability of the system and its ability to provide real-time data, but also negatively impact the user experience. Delays in loading dashboards or occasional failures can generate frustration and demotivation, leading to the abandonment of users who expect quick and interactive responses.

The file is published to a separate MQTT topic for the sensor to retrieve; the sensor must be restarted to apply the new settings.

IV. Results and Discussion

The analysis of acoustic conditions around Lisbon airport begins with the predictions, using acoustical propagation models, presented by noise maps available online, as shown in Figure 6, and by the Lisbon City Council.

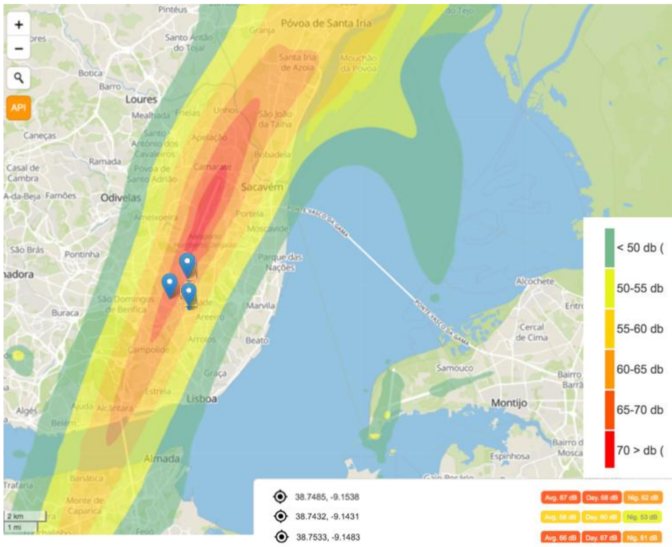


Fig. 6. Map of zone of Lisbon International Airport with (from https://noise-map.com/).

It is observed that the highest ambient noise values, LAF, for the monitored area (Alvalade Leste, Lisbon), are sometimes greater than 70 dB(A) for Lden and greater than 60 dB(A) for Ln.

Additionally, actual sound levels were measured using the SoundMeterPlat at specific locations. The measurements were taken at the same location for both aircraft taking off and landing, given that these maneuvers depend on atmospheric conditions, such as wind direction.

Figure 7a shows the typical temporal noise profile for the LAF, LCpeak and LAeq sound levels (flatter brown curve) for the night period between 6:00 am and 7:00 am, takeoffs. An average periodicity of about 3 minutes is observed. It is also observed that the maximum levels are quite high, around LAF = 74 dBA and LCpeak = 95 dBC.

As an example, Figure 7b shows a typical case of the noise profile of an airplane taking off. This event is characterized by having an average duration of 12 seconds.

Table I shows the summary of the acoustic data obtained in this study regarding the measured sound levels and statistical parameter values. In addition to the sound levels indicated in section A - Sound analysis of chapter III. DEVELOPMENT, the following parameters related to the acoustic environment were analyzed or calculated:

Lden: Indicator of daytime-dusk-nighttime noise, associated with overall annoyance.

$$L_{den}=10\times log\frac{1}{24}\left[13\times10^{\frac{L_d}{10}}+3\times10^{\frac{L_e+5}{10}}+8\times10^{\frac{L_n+10}{10}}\right]$$

Ld: the average long-duration sound level during the daytime period from 7 am to 8 pm;

Le: the average long-duration sound level during the daytime period from 8 pm to 11 pm;

Ln: the average long-duration noise level during the daytime period from 11 pm to 7 am;

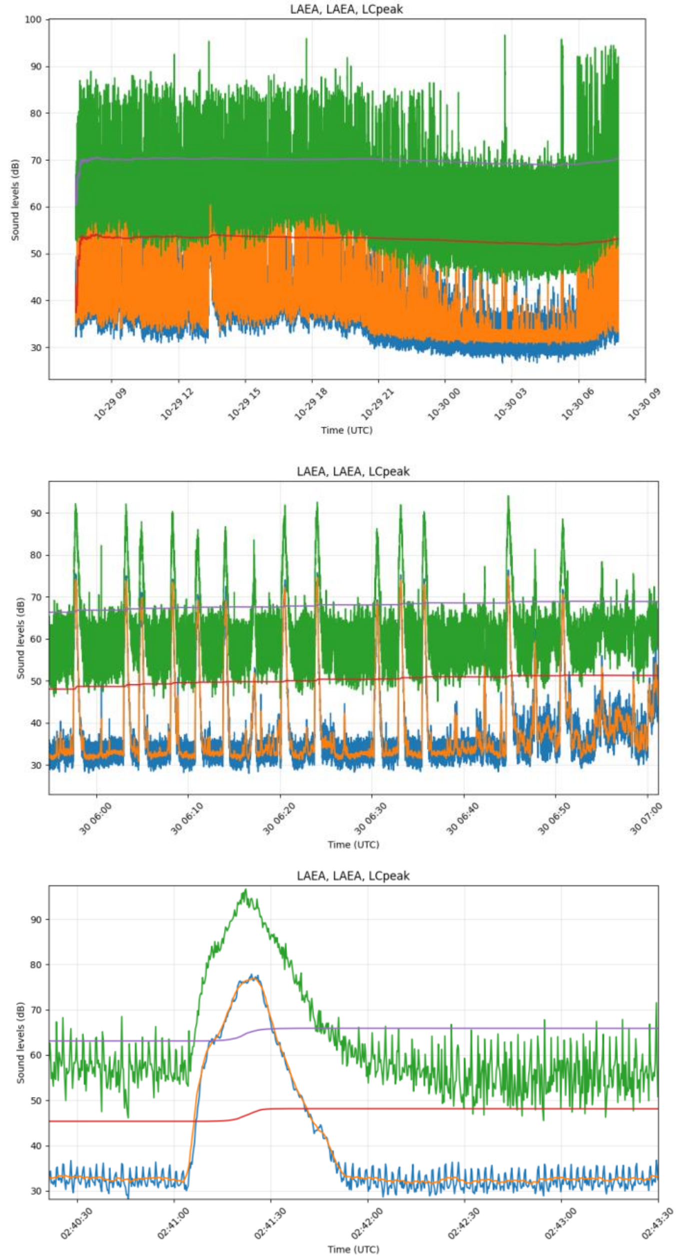


Fig. 7. Sound levels of LAEA, LCpeak, LAeq and LCeq at night period near the International Airport of Lisbon. Time series for one day (upper image) one hour (middle image) and a sound event example of an aircraft (lower image).

LA10: sound level exceeded 10% of the time. It is useful for evaluating high intensity events or noise spikes;

LA50: sound level exceeded 50% of the time, representing the median noise level;

LA90: sound level exceeded 90% of the time, indicating background or residual noise level;

Range: dynamic range of the value of this parameter;

Noise Pollution Level: This term adjusts the mean value to account for the variability or fluctuations in noise levels, emphasizing peaks and dips - LNP = LAeq + (L10 - L90)/4

Duration (>60 dB): indicates the total duration the airplane's passage events, for the period;

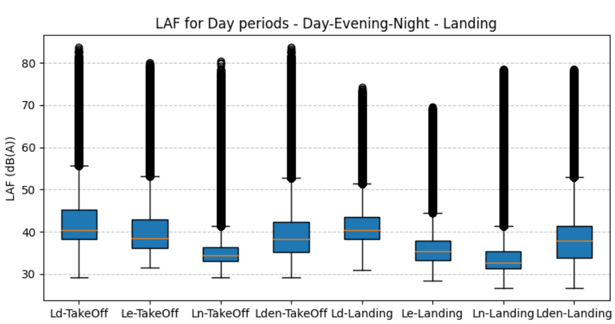
Event count (> 60 dB): number of events related to an airplane's passage, for the period.

TABLE I: AVERAGE SOUND LEVELS AND STATISTICS FOR TAKEOFF AND LANDING AIRCRAFT ACTIVITIES

		Lday			Levening			Lnight			Lden		
		TakeOff	Landing	Diff	TakeOff	Landing	Diff	TakeOff	Landing	Diff	TakeOff	Landing	Diff
	N	172700			43100			115099			331099	345500	
LAF (dBA)	Max	83.7	74.3	**-9.4**	80.1	69.7	**-10.4**	80.5	71.2	**-9.3**	83.7	75.5	**-8.2**
	Min	29.2	30.9	1.7	31.4	28.3	-3.1	29.1	27.7	-1.4	29.1	26.6	-2.5
	Mean = LAeq	**61.3**	**53.3**	-8	**59.3**	**49.9**	-9.4	**52.9**	**42**	-10.9	62.3	53.2	-9.18
	Range	83.7	74.3	-9.4	80.1	69.7	-10.4	80.5	79.2	-1.3	83.7	78.5	-5.2
	LA10	61.5	50.9	-10.6	52.8	42.5	-10.3	39.9	40.1	0.2	53.9	45	-8.9
	LA50	40.5	40.3	-0.2	38.4	35.3	-3.1	34.3	33.8	-0.5	38.3	37.8	-0.5
	LA90	35.7	35.6	-0.1	34.2	31.3	-2.9	32	31.1	-0.9	32.5	30.6	-1.9
	Noise Pollution Level (LNP)	67.5	56.9	**-10.6**	63.8	52.6	**-11.2**	54.7	46.1	**-8.6**	64.6	54.1	**-10.5**
	Duration >60 dB (s)	**2880**	**3108**		**456**	**396**		**396**	**576**		**3732**	**3900**	
	Event count (> 60 dB)	**240**	**259**		**38**	**33**		**33**	**48**		**311**	**325**	
LCpeak (dBC)	Max	100.6	92.9	**-7.7**	98.7	86.5	**-12.2**	97.1	86.6	**-10.5**	100.6	91.6	**-9**
LAFmax (dBA)	Max	84.3	74.9	-9.4	81.2	70.1	-11.1	81.6	71.2	-10.4	84.3	75.2	-9.1
	Min	29.9	31.3	1.4	32.2	29.5	-2.7	30.3	27.7	-2.6	29.9	27.7	-2.2
	Mean	62.1	54.1	-8	60.2	50.6	-9.6	53.8	45	-8.8	60.3	50.8	-9.5
LAFmin (dBA)	Max (dB)	83.2	73.4	-9.8	79.2	69.4	-9.8	79.9	74.1	-5.8	83.2	80.1	-3.1
	Min (dB)	25.5	29.8	4.3	30.1	26.9	-3.2	27.3	25.1	-2.2	25.5	23.1	-2.4
	Mean (dB)	60.4	52.6	-7.8	58.3	49.3	-9	51.8	44.8	-7	58.5	52.4	-6.1

The statistical indicators for LA50 show relatively low values when compared to LA10 and LAeq, a difference of approximately 25 dB for Lden and approximately 18 dB for Ln. This fact shows that sound has very high oscillations and intermittences, which is typical of aircraft noise. In fact, by the Duration parameter (or by the Event count and the exposure of the event of an aircraft passing (~12 s)), we see that during a full day approximately 60 minutes correspond to aircraft noise, and during the night period it is approximately 7.5 minutes. Considering that the passage of an aircraft generates high noise levels, LAeq, of approximately 80 dBA and LCpeak of approximately 100 dBC, the degree of annoyance caused is high, especially during the night (between 23:00h and 7:00h).

These conclusions are consistent with the results presented in Figure 8. It can be seen that the average values vary little (IQR = Q3 - Q1 - interquartile range, shows a narrow box) and the whiskers (1.5 × IQR) follow the same trend. However, the range of variation of the Outliers (black circles) is large (corresponding to sudden transient sounds, such as aircraft movements).



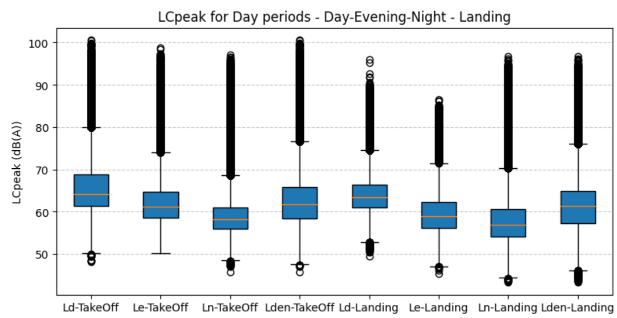


Fig. 8. Statistics of LAF and LCpeak noise levels for TakeOff and Landing aircraft activities.

As expected, during the night period these values decrease given the lower density of aircraft passing by (as seen in Figure 7 – upper image). Moreover, Noise Pollution Level parameter shows a significant increase of overall noise levels, of about 5 dB, because it considers the typical behavior of intermittent sound of aircrafts.

V. CONCLUSION

The SoundMeterPlat project addresses a real and relevant problem in environment noise near airports. The proposed solution consisted of a modular platform for sound monitoring, based on open-source technologies and designed for environments with privacy and reliability requirements.

By integrating sound sensors with the MQTT protocol, processing in Node-RED, storage in InfluxDB, visualization in Grafana, and developing a dedicated application, it was possible to build a complete, functional system that is adaptable to different airport areas settings. The designed IoT architecture allows not only real-time visualization of collected data, but also temporal querying, data export, and remote reconfiguration of sensors, for an affordable price.

The preliminary study carried out near the Lisbon International Airport showed interesting results about the aircraft movements of approaching and leaving the airport.

The overall noise levels, LAeq, registered are considered high for residential areas. In fact, Lden sound levels exceeds 63 dBA and Ln sound levels exceeds 52 dBA. This situation worsens during the night (between 11:00 PM and 7:00 AM) with peak sound levels reaching 97 dBC.

An interesting finding relates to people's exposure to noise. If the sound events due to passing airplanes were compressed into just one event, it was found that residents in the areas surrounding Lisbon International Airport were bombarded with noise levels of approximately 60 minutes during the day and 7.5 minutes in night period. Therefore, considering that the passage of an aircraft generates high noise levels, LAeq, of approximately 80 dBA and LCpeak of approximately 100 dBC, the degree of annoyance caused is high, especially during the night (between 23:00h and 7:00h), causing severe disturbances in sleep quality in people, with harmful consequences for their health.

These results demonstrate the importance of continuous noise monitoring and visualization, combined with raising awareness about the malicious effect of excessive noise levels to the populations living and using these areas of the city.

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