Smart Noise Monitoring Leeuwarden F16 Air Force Base in The Netherlands

Johannes D. KRIJNDERS[1]; Maarten REINDERS[2]
Nico FABER[2], Eize DRENTH[2]
INCAS[3], the Netherlands
Antea Group, the Netherlands

ABSTRACT

Noise monitoring is becoming more and more important. People that are annoyed by noise want to have on-line information about the actual noise situation. The only way to get this information is by monitoring the noise source that is responsible for the annoyance. But how to distinguish between the noise source responsible for the annoyance and other (background) noise sources?

INCAS3 and Antea Group developed a smart monitoring system to recognize and filter the noise source (audio) responsible. The system was applied at Leeuwarden Air Force base in the Netherlands. The system was not only equipped with sensors for monitoring noise but also with gassensors and sensors for weather conditions and a camera. The system was trained to recognize fighter jets by their typical time-frequency characteristics. All data was logged and is accessible by the remote on line application of Antea Group Analyse Platform©.

The next step will be to combine the noise data with on line reported annoyance from people living around the Air Base. People can report annoyance easily by an app on smartphone or tablet. Based on reported annoyance and real time noise monitoring the flight path can be adjusted to reduce impact of the noise and thus the annoyance.

Keywords: Aircraft detection, noise monitoring I-INCE Classification of Subjects Number(s): 13.1.2 Supersonic aircraft, 52.2.2 Military airfields, 71.8 Data acquisition systems, recorders and data storage devices, 74.4 Automated data processing and reduction.

1. INTRODUCTION

Noise monitoring will be increasingly used for measuring annoyance in the actual situation. Potentially annoyed citizens have an need for on-line information. To meet their needs. INCAS3 and Anteagroup developed a smart monitoring system to recognize and filter the noise source (audio) responsible for the annoyance. The monitoring system is capable of separating aircraft noise from other sound source. The system was applied at Leeuwarden Air Force base in the Netherlands.

In this paper at first the rules and regulations for aircraft noise are described. Secondly the methods and systems used at Leeuwarden Air force base are presented. Finally this paper gives the results and further planned developments.

2. RULES AND REGULATIONS AIRCRAFT NOISE

In the Netherlands two different measure units are used to characterize noise exposure from aircraft: for civil airports the Lden in dB[A] is used en for military airports the noise pressure B in “kosteneenheden” (cost-units), Ke is used. The Lden is an internationally standardized measure unit that is also used for measuring and calculating road and rail traffic noise. The noise pressure B is only used in the Netherlands and only for the military airports Volkel and Leeuwarden. Both measures Lden and B refer to the average situation over a whole year. To calculate Lden all Sound Exposure Level (SEL) of all aircraft need to be added and

[1] dirkjankrijnders@incas3.eu
[2] maarten.reinders/nico.faber/eize.drenth@anteagroup.com

averaged. For the B measure unit all LA,max values are added for all aircraft passing in a year.

For the airforce base Leeuwarden the following rules and regulations apply:
1. "Besluit van 3 mei 2013 tot vaststelling van een luchthavenbesluit voor de militaire luchthaven Leeuwarden (Luchthavenbesluit Leeuwarden).", Airport ruling Leeuwarden (1)
2. "Besluit militaire luchthavens", Ruling airforce bases (2)

The first governs the specific time frame in which the airforce base is open.
In the second maximum values are set for the maximum sound exposure (in Ke) in residences and other noise sensitive buildings. For Leeuwarden a map is made indicating the Ke-contours and indicating where buildings are required to have noise mitigation measures. The map is made based on modeling which requires a set for data to calculate the noise exposure. The model can calculate the exposure for any point in space and time and calculate the measure units (Ke, L_{den}, $L_{A,max}$, etc.) that result from that. The required input data are:
1. Number of starts and landings
2. Distribution of starts and landings over a day
3. Distribution of starts over the different distance classes
4. Types of aircraft
5. Operational flight procedure
6. Ground trace of the flight-paths
7. Distributions of starts and landing over flight-paths
8. Runway usage

These numbers are considered for a complete year.

3. METHODS

Data was gathered using the Antea Group Analyse Platform© and send via a local wifi connection. Thereby, the large audio and video files were stored locally and readout after the measurement had finished. Antea Group Analyse Platform© is a realtime event and analytics (big data) platform, a platform of tracking and analysing streams of information (data) about things that happen (events), and deriving a conclusion from them. The platform enables event processing that combines data from multiple sources to infer events that suggest more complicated circumstances. The goal of the processing is to identify meaningful events (or opportunities) and respond to them as possible.

The measurement mast was located in the garden of a private home, aligned with the main runway 06/24 of the airforce base, about 650 meters from the end of the runway. The location is shown in figure 1.

Figure 1 – Location of the measurement mast. Directly under flight path of runway 06/24 of Airforce base Leeuwarden which can be seen in the lower left corner.

3.1. Recording

Acoustic data was gathered using an ESI-121-24[3] with internal harddrive and two weather proofed Beringher ECM8000 class II measurement microphones. Recordings were made uncompressed at 48 kHz, 32 bits. During the two weeks of the Frisian-flag event 168 hours of data were gathered. Besides the audio a number of weather related parameters were measured, see table 1 for a full overview of the gathered data.

During two days a Bruel and Kjaer 2260 sound level meter was added to the setup to verify the calibration of the recordings and a video camera was added to allow visual verification of detections. The camera was looking in line with the runway away from it. Table 1 shows a summary with the devices used for the monitoring.

Table 1 – Measurement devices used and duration of data gathered

Parameter	Device	Duration
Audio	INCAS[3] ESI-121-24	14 days
SPL	BK 2260	4 days
Wind	Thies	14 days
Video	Mobotix	14 days

The airforce base did not provide lists of starts and landings during the period, so a ground truth is not available. Also not all passages are starts or landings, some are touch-and-go where at the end of the runway the aircraft turns 180 degrees. This makes it impossible to make reliable, numerical performance estimates.

[3] http://www.incas3-solutions.com/en/technologies/ethernet-sound-interface/

3.2. Event detection

The detection of airplanes from the audio has been done in two stages, first a threshold of 95 dB was used to pre-select the events and in the second step a frequency based filter was used to reduce the number of false positives. False negative are very unlikely due to the location of the sensor.

For the first step the audio data was filtered using an A-weighting filter and integrated to get L_A-values. These were compared to the results of the BK 2260 where available and the difference was neglectable. The threshold of 95 dB was applied and 10 seconds of audio before and after were saved. A histogram of the $L_{A,max}$-values is shown with the red bars in figure 2.

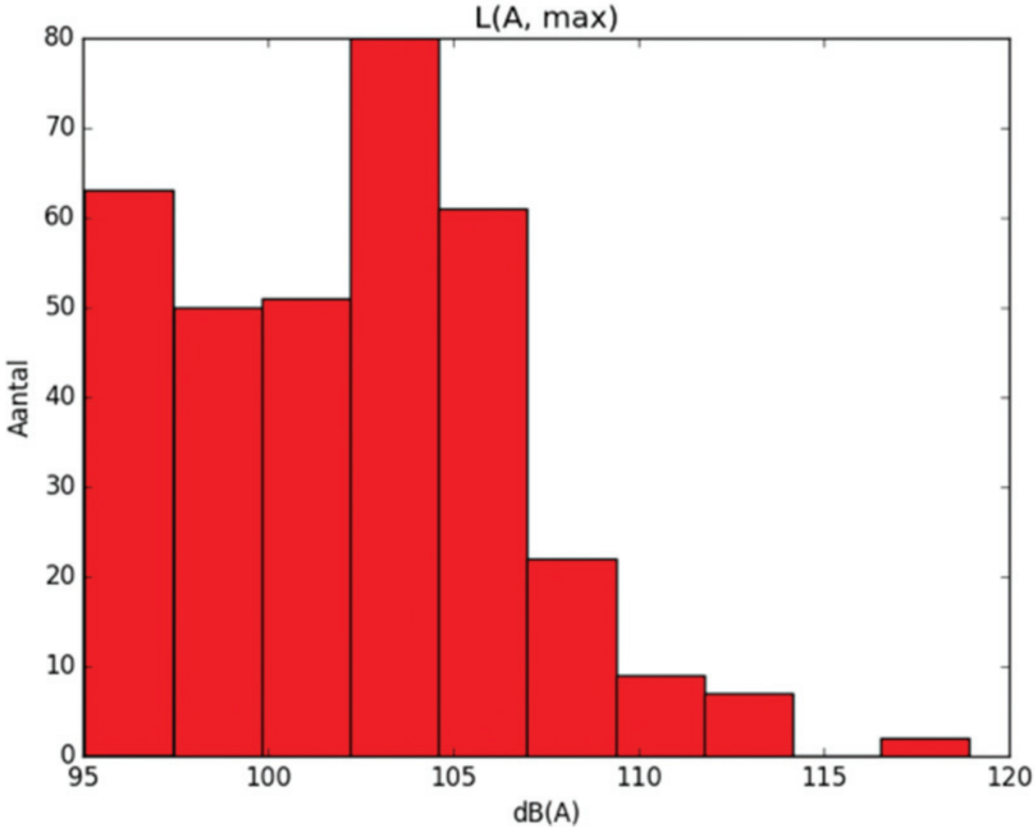

Figure 2 – Histogram of the LA,max-values

For the first day all results were listened to and annotated, 36 aircraft were heard. Four noise events could not be positively identified as aircraft by audio alone and were considered false positives.

All selected audio segments were processed automatically using a linear transmission-line cochlea model from (3) with 128 segments and a maximum frequency of 8000 kHz. This results in time-frequency plots like the one in the left panel of figure 3.

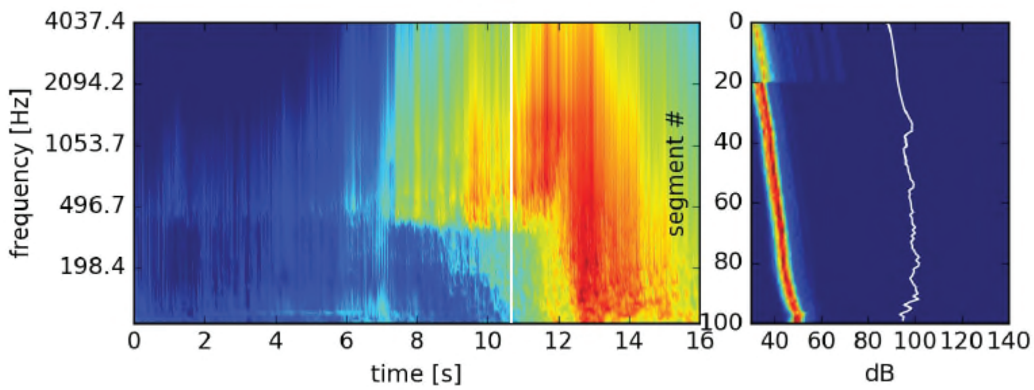

Figure 3 – Left panel shows the cochleogram of an aircraft passage. The white line indicates the manual annotation point. On the right is a histogram of the background of the hour around the event on the left. The white line here is the maximum energy in the passage.

Using the annotations a spectral filter was calculated and this was matched against all detected events. This filter is the average, normalized spectrum at the annotated time in the event. Application is done by taking the in-product of the filter and the normalized spectrum.

Because of the lack of a ground truth the threshold on the match was chosen such that the four false positives were discarded while none of the true positives were. From the 345 detections 330 were accepted.

3.3. Background estimation

Besides the aircraft events we were also interested in the background levels and their frequency distribution. For this we ran a background model (4), this model follows slow changes in energy and ignore rapid changes. The model for example does follow the noise levels caused by the rush hour, but not of individual cars.

The result can be seen in the right panel of figure 3, which is the histogram of the 1 minute averages of the half hour before and the half hour after the event (white line).

4. RESULTS

In this paper we presented a system capable of running unsupervised, for several weeks (only two presented in this paper) recording and uploading many environmental parameters. Automatic, embedded, detection of target sounds makes that the system can communicate over low bandwidth channels. The current, preliminary, analysis focuses on the noise produced by military fighters jets. The lack of ground truth data prevents proper scientific validation, but randomized visual and listing checks found no wrong detections.

5. CONCLUSIONS AND OUTLOOK

With the lack of a ground truth the combination of sensor modalities will need to create a consistent and reliable detection of military jets. Future work will include research in this direction. Also still more information about the flight in the measured period is becoming public, this will also be included.

With the arrival of the F-35 fighter more interest in the monitoring of these jets will be generated, an additional measurement campaign will be performed. During the introduction flights more information may be present to get a better measure of the performance.

As in the end we’re not interested in the noise per se, but in the annoyance cause by it, we looking to extent the project with annoyance reporting app on smartphones. This should be as simple as possible, allowing people to react quickly. People would only be asked what they were doing at the time and whether they were inside or outside. This should give an overview of the area, time and activities where the annoyance is happening.

Another development is the application of the system to other sources of noise. The mobile nature of the system and the quick configuration allows for rapid deployment in case where for example industrial is measured. Here the combination with gas concentrations, fine particulate matter (PM) and/or very local weather conditions can provide clear insight in what is happening at the site. The audio recognition would than provide information about the machinery in use at different times. Other possible applications areas would be road traffic noise monitoring.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. W. Dijkstra for providing the opportunity for this measurement campaign.

REFERENCES

1. Luchthavenbesluit Leeuwarden. http://wetten.overheid.nl/BWBR0033411/2013-06-17
2. Besluit militaire luchthavens. http://wetten.overheid.nl/BWBR0025302/2014-12-12
3. van Hengel PWJ., Krijnders JD. A Comparison of Spectro-Temporal Representations of Audio Signals. Audio, Speech, and Language Processing, IEEE Transactions on. 2014;22(2):303–313.
4. van Hengel PWJ, Andringa TC. Verbal aggression detection in complex social environments. 2007. pp. 15–20.