THE COLORS OF URBAN NOISE - A NEW CONCEPT OF MONITORING

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Abstract

The new European directive puts pressure on noise policies in cities. Measuring urban noise is not an easy task. The paper describes a new approach to the problem. It is based on a dense network of simple and independent measuring stations. Each station is connected to an area server via a Hertzian link. The area servers sort and transfer data to a processing system (database archiving, web sites, particular calculations...). The stations pre-process the signal and only relevant and pertinent information is transferred. For example, neural network based algorithms are implemented in the stations to automatically identify noise sources. The low price of the system (a small fraction of the current market price) makes possible a mesh density compatible with the complexity of sound propagation and problems to solve. An actual urban implementation is shown in real time. Applications and development options are discussed.

Introduction

Measuring noise in a city is a necessary step towards the reduction of noise in the city. The need for urban noise reduction inspired the European Union (EU), and a new directive shows the direction in which the EU is heading..

Measuring noise -almost everybody can do it today. Even if we make it more difficult, by asking for spectra or some finer descriptors (like loudness), many contemporary instruments deliver the requested values.

Measuring urban noise is another story. Some important requirements make the problem quite difficult to solve. The measurement has to be long enough to allow the comparison of situations (eg before and after the construction of a new road). Measurements have to cover a large territory, leading to a high number of measuring stations, and thus to increased costs, usually out of the reach of cities. The duration and the geographical spread of the measuring stations complicate the maintenance of the system. Last, but not least: the processing of a huge amount of data is a Herculean task.

The new expectations of people living in large cities make all this even more complicated. A modern European wants to know in what environment he lives and so public access to the measurement data is necessary.

Importance of noise sources

The measurement is a step towards reduction of noise – a measurement should thus give pertinent information about noise sources. Existing techniques of identification of sources are too expensive or not accurate enough for urban noise. The recognition of sources from the recorded signal, although very useful in shorter measurements and/or in a lower number of points, would lead to the recruitment of an army of trained listeners to review the recordings from all the measuring stations.

We come here to another “de facto” requirement: the urban noise measurement system must be able to identify sources automatically.

Measurement data

Measuring an averaged 1/3 octave spectrum, plus a few global levels (different frequency weightings, different time constants), plus some statistical values, requires about 100 bytes per sample. Storing the data every second leads to a memory need of about 9 Megabytes of space per day, over 3 Gigabytes per point per year. Moreover, all this data is to be transmitted between the measuring point and a central storage site. The choice of relevant data and its organization becomes a crucial point.

The processing of the noise data is just one of the tasks of a city’s management. In other words, the measuring system has to be compatible with other, more general tools used by the municipal technical services. Maybe the most obvious example is compatibility with the geographic information system, also related to the EU directive. However, other requirements exist which cannot be neglected.

New concept

What we need is a measuring system with the following main features:

- Inexpensive
- Accurate
- Easy to install
- Easy to maintain
- Automatically detecting noise sources
- Filling an intelligent and compatible database
- Calculating requested indicators
- Publishing results.

The outline of the system is shown in fig. 1.

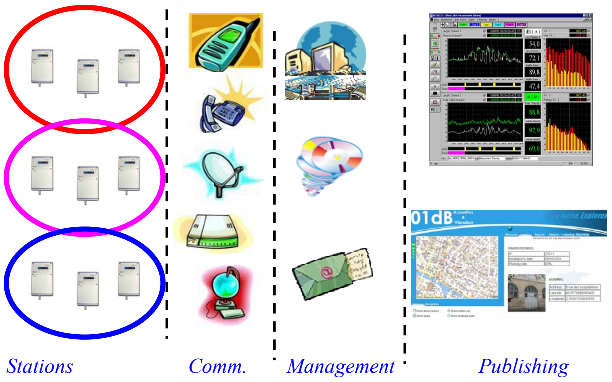

Figure 1. The urban noise measurement system

The system presented is composed of:
- Independent intelligent outdoor measuring units
- Gathering and controlling stations
- Communication devices and protocols
- Central data storage and processing.

The weatherproof measuring units are simple, reliable and inexpensive. They measure the noise with the required accuracy, process the signal and transfer the processed data.
The outdoor units are grouped into clusters. They are connected to the central point via either a wireless link or a cable (fig. 2)

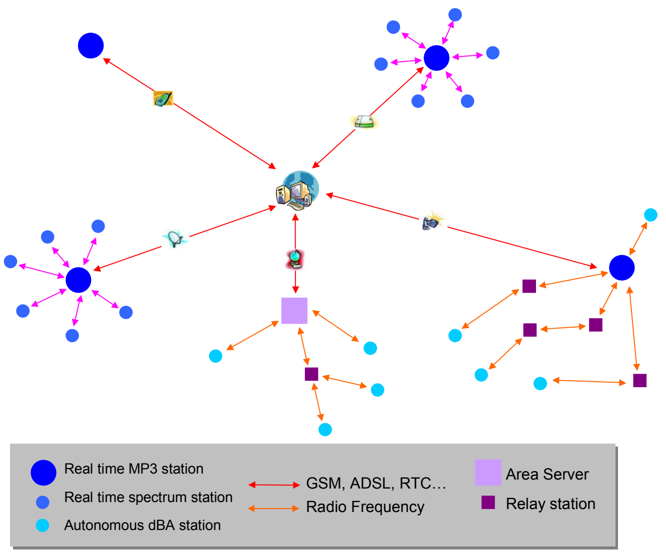

Figure 2. Clusters of measuring points

Three types of measuring stations have been developed.
The main one (Real time MP3 Station) is the most advanced of all measuring stations. They are connected directly to the central processing unit. The speed of this connection is significantly higher (starting at 9600 bytes per second for a GSM phone, up to several megabytes per second for a specific network connection like ADSL line). These “fast” stations are used for more complex measurements (multi overall values, third octave...) with a very short integration time (100ms), and they are able to transfer the audio signal (MP3 compressed if necessary). These stations include also a radio modem area server and they can receive data coming from other stations.
The second types measure spectra and overall weighted levels with a short integration time (500ms). They are connected through the area server of the real-time MP3 station via a radio frequency link. All data are transferred in real-time to the main stationand it is possible to publish all data on a web site in real-time. These stations must be close to the main one (less than 600metres)
The last type is the dB(A) station which permits mainly LAeq measurement with a longer integration time (1 min). These stations also use a radio frequency link but they can send the data through the main station (MP3 station) or through an independent area server (without measurement features). If the dB(A) station and the area server are too distant, it is possible to use relay stations to transfer the data. The data flux is about 100 bytes per second, making the system reliable even in difficult urban conditions.
Each area server scans (using the radio modem) the information from the remote stations of one cluster. The server is equipped with the appropriate hardware for Internet/Ethernet connection.

Detection of noise events

Besides the obvious acoustic processing, the processor of the station can be programmed to apply algorithms of noise source detection and identification. In many actual urban situations a simple observation of the overall level and its comparison with a predefined threshold is not sufficient (due for example to different background levels between day and night). The detection used here is based on the observation of the difference between a “short” descriptor and a “longer” descriptor, as shown schematically on figure 3:

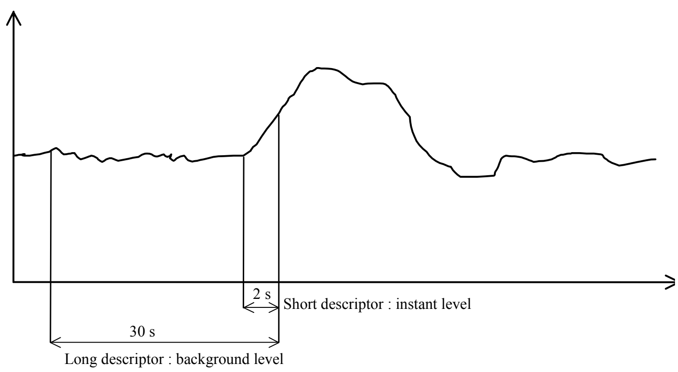

Figure 3. Principle of source detection

In a steady state situation the short and the long descriptors are relatively close. An event is detected when the “short” descriptor exceeds the “long” one by a given number.

Processing of detected events: Identification of the sources

The station starts a more intricate task when an event is detected: identifying the origin of the noise.
Several different groups of algorithms may be applied to identify the detected events. In the tested system the algorithms developed in the frame of the MADRAS European project have been used. These algorithms are based on a hierarchy of classifiers (neural networks, statistical classifiers, shape detectors…), leading to the required level of selection.
The direct connection between the station and the central units makes all interactive tasks easier and diminishes the probability of an error. A learning session based on a known population of events of a given type is carried out in situ, adapting the coefficients to the particular environment of a particular point. Correction and improvement of the algorithms are made possible by remote downloading of the firmware.

Remote stations

As the declared target is to make the stations inexpensive, the outdoor microphone quickly appears as one of the key elements. Development in this field is continuing, and the first significant results are expected later this year.

The embedded signal conditioning comes from type I approved instruments. The precision of the system depends then on the sensor (microphone), provided the communication is sufficiently reliable. As a consequence, the microphone determines the price of the unit.
Although miniaturized (fig. 4), each station contains several operating components such as the acquisition front end, DSP (24 bits, 96 kHz), radio modem or cable link, GPS module…

Figure 4. Remote station (size approx. A4 sheet)

Data processing

The abovementioned quantity of data and the human resources necessary for its processing make data storage and processing one of the most important features of the system.
Figure 5 gives an idea of the data storage system. The measurement data are stored as they enter the first raw database. This base is archived and emptied at regular periods. The second database is a noise warehouse. It contains the information necessary for global processing, reporting, web publishing, decisions, etc. Important work is being carried out on the tools which extract data from the raw base and transform them into pertinent packages stored in the warehouse.

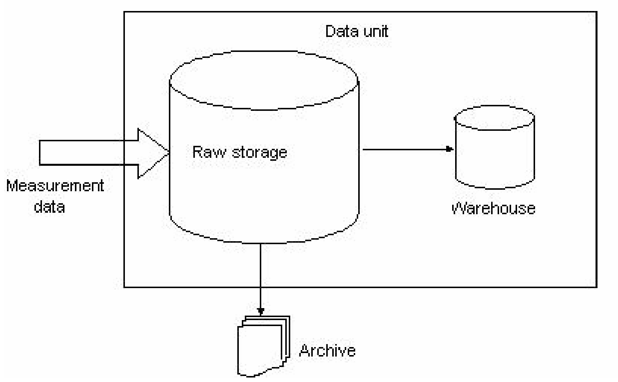

Figure 5. Central server data storage

Current state & development

The system has already been tested in real locations and several cities worldwide have already been running it for several months. An inexpensive, precise and reliable form of outdoor microphone protection has been developed, in order to permit the use standard type 1 or even type 2 microphones capsules. The aim was to reduce the cost compare to that of a standard outdoor microphone while keeping accuracy to a similar level, and affording the possibility of remotely checking the microphone. The system also includes a heating preamplifier with built-in desiccating system (fig. 6).

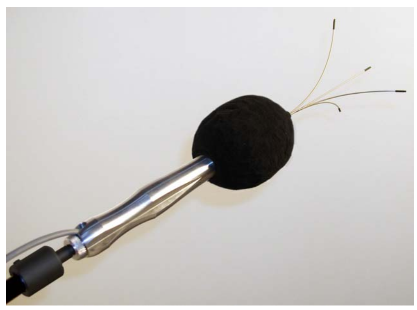

Figure 6. Outdoor microphone protection

Current development aims to establish the limits of the wireless communication, especially when using WiFi Standard 802.11g. This would lead to the formulation of simple operational installation procedures.
However, the main development at present concerns the software, and in particular the post processing. This work does not concern only acoustics, in particular at the data warehouse level. This data processing is a logical part of the whole system, and it encapsulates the link between measurement and its exploitation. The EU directive processing is carried here, and the measurement and the predicted (calculated) results meet at this level.

Conclusions

We have presented in this paper an innovative solution to enable cities to comply with the requirements of the EU directive. Existing classical noise monitoring stations, primarily designed for airport noise monitoring stations were not evaluated (on both size and price bases).
The platform presented here was accordingly designed to comply with the needs of city councils.

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