INSTRUMENT FOR SOUNDSCAPE RECOGNITION, IDENTIFICATION AND EVALUATION: AN OVERVIEW AND POTENTIAL USE IN LEGISLATIVE APPLICATIONS

C Karatsovis ISVR Consulting, University of Southampton, Highfield, Hants, SO17 1BJ, UK
S J C Dyne ISVR Consulting, University of Southampton, Highfield, Hants, SO17 1BJ, UK

1 INTRODUCTION

Latest technological advances in hardware design and microelectronics may mean that it will become feasible to develop a sound instrument that would not only define a sound field solely by the measurement of the overall *effect* of its contributing sound sources, but could also identify, classify and localise these individual sound sources. This type of instrument could ultimately enable stakeholders, such as engineers, planners and developers to have a better understanding of the potential impact of existing sound sources on new developments, or the introduction of new sound sources in an existing environment.

This paper provides an overview of an EPSRC funded research project named ISRIE (Instrument for Soundscape Recognition, Identification and Evaluation). The main objectives of this research work are four-fold: (a) to develop a sound monitoring hardware platform based on an advanced network system array, (b) to develop advanced signal processing techniques for automatically identifying and characterising different sounds in a mixed sound environment through a combination of time and frequency domain techniques and pattern recognition methods, (3) to consider applications and the way in which such an instrument could be used to influence legislation associated with environmental noise impact assessments, and (4) to integrate all the elements of the project into a practical instrument.

Particular emphasis is placed upon the potential use of such an instrument in specific legislative applications in the UK, such as PPG 24, BS 4142 and noise nuisance.

Stakeholders might directly or indirectly benefit from such an advanced sound instrument since it could enable them to characterise the ambient noise climate in terms of the relative contribution of different sources, for instance road traffic, train traffic, aircraft traffic, birdsong and industrial noise in complex sound environments. It should also enable them to deduce the location and/or direction of audible sources of sound in a given measurement position. Furthermore, such an instrument should enable them to identify infrequent transient sounds that cause great annoyance to communities despite their relative small contribution to the overall level. Also, this type of instrument should enable stakeholders to consider both ‘positive’ and ‘negative’ sounds in existing or planned environments. However, the characterisation as ‘positive’ and ‘negative’ sounds is not part of the objectives of this research work.

2 WORK OVERVIEW

The research programme consists of various work packages associated with key elements and tasks of this project. The output of each package informs the other work packages in order to keep the work focused and to assess the feasibility and practicality issues of certain aspects of this work.

2.1 Sensor Network Array Platform

Projects partners at the University of Newcastle are currently developing a wireless sensor network platform for sound measurement and localisation. This network consists of a number of acoustic sensors and sensor arrays in a specific geometric configuration in order to maximise the beam forming capabilities for localising different sound sources. A preferred measurement platform for this type of application is the existing 3D Soundfield microphone probes for 2D and 3D sound source localisation. The ultimate plan is to integrate the measurement microphone arrays into a wireless network module system that can be used for remote sound measurements. Data synchronisation and time references are significant issues that are being addressed in the development of a successful wireless network measurement platform.

2.2 Source Separation and Development of Real-Time Module

Projects partners at the University of York are currently considering source separation through three different techniques – blind, semi-blind and non-blind, where the latter method uses an *a priori* knowledge of the discriminating attributes. Other techniques are also being explored, such as a method using Time Domain Signal Coding (TDSC) and Self-Organising Feature Mapping. The signal processing techniques will then be part of a dedicated microcontroller-based module. The outcomes of this work will be integrated with the work of the wireless sensor array system in order to provide a single platform for sound measurement and instrumentation.

2.3 Signal Analysis and Classification

Project partners at the University of York are also developing methods for classifying different sounds. The methods involve the use of TDSC, wavelet analysis and FFT techniques. Clearly, the ultimate form of classification will depend upon the feature characteristics that have been selected for sound source separation. Also, a syntactic pattern recognition system is currently under development by utilising the temporal structure of the monitored sounds.

2.4 Applications

ISVR Consulting are currently reviewing existing noise legislation and planning guidance, and are considering which stakeholders could benefit from such a sound instrument. Through consultation with these stakeholders, parameters are being identified to enable the instrument to assist in dealing with legislative control measures, planning and guidance.

2.5 File Transfer Protocol Resource

ISVR Consulting has commissioned an FTP server capable of storing a large number of calibrated sound recordings primarily carried out in the field and in laboratory conditions. In this way, audio recordings of a variety of sound sources and environments are accessible to all project partners and to the broader acoustics community as part of a large database of recordings of soundscapes. Over the course of this research work, the main use of these sounds will be to develop and test the signal processing techniques associated with source separation, analysis and classification.

2.6 Instrument Deployment

The wireless network measurement platform along with the source separation, signal analysis and classification techniques will be integrated into a single instrument. This platform will provide the

basis of ISRIE. Measurements in the field will be carried out with ISRIE and with conventional sound level meters to enable the utility and practicality issues to be addressed.

3 USES OF ISRIE IN LEGISLATIVE APPLICATIONS

Stakeholders are being consulted in order to deduce what parameters are required from such an instrument. Currently, the L_{Aeq} seems to be used almost exclusively when measuring environmental noise sources, such as road traffic noise. However, the L_{Amax} and SEL, in addition to the L_{Aeq} measurements, are sometimes used when there are distinct or impulsive events to the measured noise in question [1] and the L_{A90} is the preferred parameter for the measurement of background noise in the UK.

In a long-term, stable situation, 'dose-response' relationships are used to relate the level of the noise to the degree of annoyance in a community. Meta-analyses of attitudinal survey data have been developed over the past 50 years for this purpose [2]. Such dose-response relationships have also been developed from the European Commission and guidelines have been produced on the relationships between transportation noise emanating from air, road and rail, and community annoyance [3]. Recommendations suggest the percentage of persons annoyed (%A) or the percentage of highly annoyed (%HA) should be a function of the Lden level. The latter level is defined in terms of the 'average' levels during daytime, evening and night-time and by applying a 5 dB penalty to noise in the evening and a 10 dB penalty to noise in the night.

In the first instance, ISRIE will focus on the use of such an instrument in legislative applications that deal with short-term, complaint-type problems, such as industrial mechanical noise affecting existing dwellings nearby, rather than dealing with long-term, stable circumstances.

There is an extensive list of legislative tools for the assessment of noise in the UK as described in BS 9192 [4]. However, we focus our attention on two legislative tools in the UK dealing with the impact of noise on existing or proposed residential developments; Planning Policy Guidance (PPG) 24 [5] and BS 4142 [6]. Attention is also placed upon statutory noise nuisance, which is normally dealt by specialist local authority officers, through the use of number of legislative Acts, such as the Environmental Protection 1990 [7].

An instrument that could enable stakeholders, such an engineering practitioners, developers and planners to approach problems in a more objective and robust manner is clearly beneficial.

3.1 The Potential Use of ISRIE in PPG 24

PPG 24 is used for the evaluation of noise exposure of proposed noise sensitive developments. In particular, for new dwellings, PPG 24 recommends the use of four Noise Exposure Category (NEC) bands (A, B, C and D). These bands are designed to assist local authorities in evaluating applications for residential development near existing noise sources. Each NEC is defined by a range of free-field noise levels. The latter ranges are dependant upon four noise source categories; road traffic, rail traffic, air traffic and 'mixed' noise sources.

The potential use of ISRIE in this planning application guidance could be multiple:

- The NEC categories have different noise level ranges depending on the type of the assessed noise environment, as mentioned earlier. So, in order to decide upon the appropriate representative noise source category, the soundscape should first be characterised in terms of the contribution of the different noise sources present in the mixed sound environment.

  At the moment, the contributing sources to a soundscape are not easily quantifiable with existing technology. Under current practice, if the individual noise sources cannot be

determined either by measurement and/or calculation, then the mixed noise source category is normally used. However, the mixed noise source category should only be used if there are no individual dominant noise sources. According to the guidance note in question, a noise source is considered to be dominant if its level lies within 2 dB(A) of the overall value.

Therefore, an advanced sound meter that could enable practitioners to quantify individual noise sources in terms of their relative contribution would be beneficial. It could enable acoustic consultants to decide objectively on the most representative noise source category in which the noise environment should be assessed.

- According to the guidance tool, individual events that exceed 82 dB $L_{Amax,S}$ occurring several times in any hour should place the proposed development site as being in NEC C irrespective of whether the overall noise level might define the site as being in lower NEC categories. The guidance indicates that planning permission should not normally be granted when the site falls in NEC C.

  Birdsong, for example, can exceed the latter 82 dB criterion, which would imply NEC C. Yet few people would argue that birdsong should necessarily have such a large impact on a planning application.

  In practical terms, PPG 24 type assessments are carried out over a 24-hour period by means of an unmanned noise monitoring survey due to economic reasons. An instrument that could enable practitioners to 'log' sounds exceeding this criterion and could automatically assess its content, by means of identifying and evaluating the sound, will be beneficial.

3.2 The Potential Use of ISRIE in BS 4142

British Standard 4142 is used to assess whether noise is likely to give rise to complaints from people residing in nearby dwellings. Typical noise sources are industrial premises or fixed installations and sources of an industrial nature in commercial premises.

The noise level of the assessed noise source, such as mechanical plant noise, is referred to as the 'specific' noise level and should normally be measured or calculated at the assessment location, such as the potentially affected nearby dwelling. The noise at that position consists of the specific noise level and the 'residual' noise level, which is effectively the noise level in the absence of the specific source. The 'background' noise level at the assessment location should also be measured, in terms of the L_{A90}, when the specific noise source is not operating at the time of the measurement.

A +5 dB correction factor should be added to the specific noise level in order to obtain the 'rating' level provided there are 'distinct' acoustic features in the assessed noise. Other correction factors should include an on-time correction that needs to be applied to the specific noise level if the source is not operating during the whole reference time interval of 1 hour during the day or of 5 minutes during the night.

Differences between the rating and the background noise level dictate whether there is a likelihood of complaint. The greater the difference, the greater the likelihood of complaints.

The potential use of ISRIE in this planning application tool include:

- According to BS 4142, L_{Aeq} measurements should be carried out with the specific noise on and off. The reason for this is to subtract the residual noise level from the overall noise level in order to deduce the specific noise level alone.

  An instrument that could enable practitioners to quantify the noise environment in terms of the relative contribution of the residual noise and the specific noise would be useful since it could

reduce the time in carrying out the measurement and assessment and avoid any typical practical limitations and time constraints.

- In practice, the measurement of the specific noise level can be difficult. For example, suppose that the impact of an air conditioning unit is to be assessed on a residential property in close proximity to a busy road. The passing of road traffic vehicles would clearly affect the measured L_{Aeq} level and would not give a representative level associated with the true noise of the air conditioning unit. According to BS 4142, one method of minimising the influence of noise from other sources is to measure the L_{Aeq} specific noise level *"…as separate component parts when the influence of other noise sources can be avoided only by measuring samples of the specific noise…".* This can be achieved by pausing the measurement during the passage of individual vehicles or a number of vehicles.

  An advanced sound instrument that could distinguish mechanical plant noise from transport related noise would be beneficial since practitioners might not need to resort to this 'start-and-pause' technique when other sources of sound interfere with a measurement.

- An instrument that could analyse the time history of a measurement over a given time period and automatically apply on-time corrections for daytime and night-time intervals would be beneficial. Non-continuous operation of mechanical plant noise could therefore be assessed through the unmanned noise monitoring use of such an instrument.

- As mentioned before, in the case where there are certain acoustic features present in the specific noise level, then a +5 dB correction factor should be added to the specific noise level in order to obtain its rating level.

  An instrument that could provide an objective assessment of whether the specific noise level has certain acoustic features would be useful for these types of assessment, although this is something that a modern sound level meter is also capable of undertaking through standard frequency analysis techniques.

3.3 The Potential Use of ISRIE in Noise Nuisance

The topic of a noise nuisance is broad in its nature, however there are a number of legislative Acts in the UK that are currently used by Environmental Health Officers (EHOs) in order to deal with the assessment of statutory noise nuisance.

The most common one is Section 80 of the Environmental Protection Act 1990 in which local authorities have the powers to tackle noise problems emanating from premises. Fines up to £5,000 are available or up to £20,000 where the nuisance arises on domestic or industrial premises respectively, provided the noise abatement notice is not adhered to. A statutory noise nuisance determination is based on the subjective opinion and professionalism of a qualified EHO. Therefore, while quantitative data may not always be necessary, it is sometimes helpful to be able to refer to such data to support these decisions.

The uses of ISRIE in this category may not be as clear as in the previously two legislative applications since the assessment of this type of noise application is, in most of the cases, subjective and context based. However, there may be some potential uses of ISRIE in these cases:

- Currently, EHOs tend to leave a 'noise nuisance recorder' in the complainant's house in order for the resident to 'self-record' the intruding sound when it takes place. The intruding sound would then be assessed either by judgement or by further analysis techniques by the qualified EHO.

An instrument that could 'isolate' and characterise the *level* and the *nature* of the offending sound from the remaining background noise would be beneficial.

On the one hand, such an instrument could obtain the true magnitude of the offending sound when discriminated from background noise, and could provide EHOs the framework for further quantitative analysis, if necessary, in order to assess a noise complaint. Any increase or decrease in the relevant sound level or other features of the background sound being assessed, can be considered to be an indication of either a negative or a positive impact of a noise management action plan [4].

On the other hand, EHOs who only base their assessment on their professional judgement, could still benefit from such an instrument since it could enable them to categorise the nature of the offending source through an objective class taxonomy system. In other words, there could be 'classes' of 'offending' and 'non-offending' sounds.

- Source localisation with the current use of noise recorders and sound level meters is not widely possible.

  An instrument that could enable stakeholders to define the direction of the offending sound based on robust measurement techniques could be beneficial in litigation cases in order to support evidence about the source.

4 CONCLUDING REMARKS

ISVR Consulting, Newcastle University and the University of York are currently developing a new type of sound meter named ISRIE. The principal idea is to develop an advanced instrument that will not only measure the overall *effect* in a soundscape in terms of sound level and frequency, but will also automatically identify, recognise, characterise and localise the different types of sound contributing to the mixed sound environment.

The ultimate plan of this research work is to integrate a low-cost measurement microphone array into a wireless network module system combined with advanced signal processing techniques for sound source separation, signal analysis and classification. Such an instrument will ultimately enable stakeholders to identify and characterise different sound sources in terms of their individual sound level, frequency characteristics and location contribution in a given soundscape.

Particular emphasis has been placed on the potential use of ISRIE in UK planning applications, such as PPG 24, BS 4142 and noise nuisance.

5 ACKNOWLEDGEMENTS

The authors would like to thank the Engineering and Physical Sciences Research Council (EPSRC) for funding this particular research work.

6 REFERENCES

1. B. Berglund, T. Lindvall and D.H. Schwela, Guidelines for Community Noise, World Health Organisation, Geneva 1999.
2. P. D. Schomer, Criteria for Assessment of Noise Annoyance, Noise Control Engineering Journal 53(4) 132-144. (July-August 2005).
3. EU's Future Noise Policy, WG2 – Dose/Effect, Position Paper on Dose Response Relationships between Transportation Noise and Annoyance, European Commission. (20 February 2002).

4. BS 9142: 2006: Assessment Methods for Environmental Noise – Guide, BSI.
5. Planning Policy Guidance 24: Planning and Noise, Department of the Environment, 1994.
6. BS 4142: 1997: Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas, BSI.
7. Environmental Protection Act 1990 (EPA).