Internet and mobile technologies for a public role in noise surveying

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The traditional method of noise surveying is to use trained professionals to go to a specific site to measure and assess noise levels using dedicated and expensive equipment. This project aims to enfranchise the public by providing them with the opportunity to play an active role in noise measurement and assessment, and hopefully influence how their soundscapes are shaped. With the implementation of mobile phone, PDA and PC applications, alongside web based collation techniques; we aim to empower the public in the gathering of context specific data on soundscapes. The methodology will provide a case study for the wider research community in developing public participation-based research activities of this kind. This will provide a better understanding of the public's relationship with their soundscape and how this relationship varies with location and demographic data. Inferences will be compared from the analysis of data sets generated with other soundscape research, with a view towards validating the techniques and gaining new insights into the field.

1 Introduction

The IMPRINtS project (Internet and Mobile technologies for a Public Role In Noise Surveying) aims to enable and encourage public participation in a large-scale environmental noise survey. The research undertaken will build on a wide body of work pertaining to soundscapes by utilising data collected as part of the project. The term soundscape is derived from the visual notion of a landscape and can be defined as the auditory environment within which a listener is immersed [1]. Soundscapes also provide the contextual references that contribute to its inhabitant's feelings of belonging and place [2]. Creating the most appropriate soundscape is a challenge for the planning, development and construction of spaces and impacts on how we, as individuals, choose to spend each day.

Advances in mobile computing offer the opportunity to allow many people to participate in sound surveys. Recent developments in mobile technology will be utilised, including: mobile phones, PDA's, mobile/PC connectivity and distributed application technologies from the project website. The combined use of these technologies will contribute to the project in two respects:

1) It enables environmental noise data from a large participant base to be automatically collated and analysed.

2) It enables participants to include subjective responses to the soundscapes they inhabit, providing a more nuanced understanding of the context and reasons for human responses to environmental sounds.

With the widespread adoption of broadband internet, wireless network technology, managed application development and XML web services[3]; the retrieval, collation and analysis of objective and subjective soundscape data from numerous locations is possible using popular consumer hardware.

2 Background

2.1 Current noise methodologies

The current heightened interest in ambient noise is reflected by Defra's *Neighbour Noise Strategy and Ambient Noise Strategy[4],* supplemented by national noise mapping schemes such as *'The UK National Noise Incidence Study (NIS) 2000/2001'[5]* and the implementation of the Sound Immission Contour Mapping (SICM) system for Greater London.

"… the development of the [Ambient Noise] strategy is, therefore, very much a data and information gathering exercise. To move towards further action for noise control we must gather: - information on the ambient noise climate in the country. In simple terms, the number of people affected by different levels of noise, the source of that noise (road, rail, airports and industry) and the location of the people affected. This will be undertaken by producing noise maps of the main sources of noise - a major new exercise for which we have put aside £13m"[4]

The typical method of noise data retrieval is based on spot measurements performed by consultants with the use of specialist equipment, the process of which is inevitably limited by scope, scale and expense. The resultant noise maps are therefore built loosely from predictions based on measurements at static positions, usually close to identified noise sources, from which some basic idea of a persons expected noise exposure levels can be predicted by considering a persons movement patterns. These typical noise data retrieval methods cannot satisfactorily determine the levels of noise people are exposed to in their daily lives without the measurement equipment following the individual.

2.2 Public participation

The massive potential for public participation in noise surveying using mobile and internet technologies has yet to be utilised. Similar experiments in large-scale public-resource computing have already taken place in other fields, notably astronomy where the SETI project (Search for Extraterrestrial Intelligence) increased public awareness of their work and goals through members of the public providing background computing resources to process the projects vast data sets [6]. Today, a vast majority of the public carry mobile phones which contain microphones and comparatively sophisticated digital signal processing technology. The processing power these devices posses enables them to be used as audio recorders as well as digital signal processing tools. Recent advances in mobile technology and functionality mean that members of the public are now able to record and document the soundscapes they are experiencing. The amount and type of data this technique can gather, using the traditional methodologies of noise surveying are unheard of. Data on the preferences and opinions of individual members of the public can be used to make inferences on the subjective effects of acoustic environments, linking these individual responses to objective acoustic data to eventually ascertain the perceived "Quality" of the soundscape.

The outcomes will address the role that sound plays in the design process and appreciation of public spaces. With strong guidelines in place to determine what is acceptable and unacceptable in terms of aesthetics, the sound environment is lacking in these considerations and not as widely incorporated into urban planning and assessment. A possible reason for this is the ease at which the visual environment can be captured, designed and replicated compared to the difficulty of achieving this process in the acoustic environment. By empowering the public with the means to control what is being monitored, and allowing the individual to record specific impressions of this data, a more representative and complete analysis of the acoustic environment can be achieved.

3 Methodology Stages

There are three principle stages in the acquisition and analysis of the data gathered by the project.

3.1 Stage One – Data Acquisition

Stage one sees the project participant accessing the IMPRINtS website. To join the project they must register by entering a range of details about themselves, where they will also select an individual username and password for use when accessing and uploading research data. Once registered, they will download a small application for use on their mobile device. A selection of versions of the mobile software will be available to cater for the differing capabilities of current and future devices and to ensure compatibility and maximum participation potential. These versions will be briefly described later on. The participant will be prompted to enter the make and model of their mobile device and the suitable software version will be made available for them to download. The full download will be a collection of applications comprising PC based applications alongside the mobile application. These PC based applications will be discussed in Section 3.2.

There are currently three major versions of the mobile software in development. Two of these are Java 2.0 Mobile Edition based (J2ME) with the other based on Windows Mobile 5.0+.

The Java mobile software exploits the audio capture functionality of the mobile phones through the Java JSR135 (Multi Media API)[7]. This API (Application Programming interface) allows the capture of audio through the device's microphone.

As well as the capturing of audio, all device configurations allow for the logging of subjective response data from the participant. The software will prompt the user to enter short worded responses, select from multiple choice options & select values from differential scales. The data gathered from the participant while immersed in the soundscape will provide a more accurate impression of the impact of the individual's soundscape as they are responding in-situ and not relying on memories of a sound space which may be inaccurately recalled. The amount of data requested from the participant must be kept to a minimum to ensure the user does not get bored or frustrated.

IMPRINtS Java version 1.0 is designed for lower end mobile phones that have the capability of capturing the compressed AMR-WB (Adaptive Multi-Rate – Wideband compression) format of audio only. This records using a maximum bitrate of around 16 kbit/s at 13 bit. The resultant signal has a filtered range of 50 – 7000Hz due to its optimisation for speech encoding [8]. Whilst this compressed format is not ideal for this purpose, the bandwidth provided is adequate for the capture of soundscape events. The major limitation of this format is the inability to directly access the raw audio data as is possible with the wav format. Version 1.0 can therefore only capture audio and not perform any signal analysis and visualisation of the audio data on the handset. The AMR data can be decoded and converted to the wav format at the users PC, described in Section 3.2.

Fig. 1 Nokia handset emulator running Java software version 1.0

Java version 2.0 of the software will be installed on higher end handsets that offer the capability of high bandwidth audio capture in the PCM wav format. This format allows the manipulation of the raw audio signal for graphical visualisation on the mobile device. As the assumption is that the participant will have no prior knowledge of signal analysis, the visualisations produced will be basic spectral plots and time domain waveform displays that will serve to introduce the person to some of the objective acoustic characteristics of the captured soundscape in a form that is easily interpretable.

The Windows Mobile software being developed in Microsoft C# for PDA's will provide further possibilities in terms of visualisation and feedback due to its increased processing power and memory capabilities, coupled with a larger screen and predominantly touch screen interface.

The recent advances in GPS (Global Positioning System) integration into mobile devices and Cell Identifier techniques for device location via triangulation of mobile base station signals [9], also allow for the 'stamping' of location and time information on each captured soundscape. Utilising these technologies also has the potential to provide spatial and temporal information with respect to noise and soundscape distribution.

In order to ensure the reliability of the captured audio data and reduce systematic error, a process of calibration must be devised that participants of the project can carry out. Calibration serves two purposes: the first being the actual acoustic calibration of the mobile device which is crucial to the usability of the audio analysis data and secondly to highlight the importance of calibration to the participant. For this process to be truly rewarding/appealing to the user, a fun and interactive method will need to be devised. To ensure participants follow best practice procedures when taking measurements, detailed instructions will be provided both online and on the handset at the time the measurement is taken.

3.2 Stage Two – Collation, Acquisition & Preliminary Analysis

Once the participant has collected a number of soundscape recordings along with a collection of responses to each one they will be prompted to upload this data to their home computer. This can be achieved via USB cabled connection, wireless Bluetooth connection or infrared wireless connection. The previously downloaded software package will streamline this process allowing the easy retrieval of any relevant data from the handset. With the data successfully uploaded the IMPRINtS PC software will assess the type of audio data and convert from the AMR format to wav if necessary. The increased processing power of the home PC will be utilised to provide more advanced methods of audio visualisation for the participant, e.g: waterfall plots, spectrograms etc. With each of these more technical representations will be simple explanations and activities for the user, in an attempt to describe and explain what they are seeing. As well as the more traditional acoustic analysis display methods, there is the possibility of including more abstract representations of the recorded soundscapes that may prove to be more easily interpreted and understood by the average participant.

The PC software will also prompt the participant to enter further reflective opinions on the soundscapes they have inhabited. This will allow for the input of more open responses facilitated by the computer keyboard and mouse. Soundscapes could be placed on a multidimensional grid in terms of user preference to discover preferences based on a variety of parameters.

Another major role of this PC stage is the completion of further more advanced signal analysis on the audio data, as well as the collation and analysis of the subjective responses of the participant. Temporal and spectral analysis can be performed in the background with results stored for use in the final stage of the methodology detailed in Section 3.3. This technique of shared resource computing will serve to spread the computational load over a large number of participant computers thus alleviating the need for a large amount of processing to be carried out on the raw data of each participant. The data retrieved from this stage will therefore be pre-processed and 'packaged' in a format that requires little to no further acoustical analysis.

3.3 Stage Three – Primary Analysis

The final stage in the projects methodology begins back at the participant's home computer, where the pre-processed 'packet' of data is sent back to the project server via the IMPRINtS PC software. XML web services will be utilised to provide a standard and secure means of automating the transferral of data between the different technologies in use by the project. The server application can thus automatically collate, analyse and present data received from any of the enabled technologies (mobile, PC, PDA etc) providing visual feedback to the participants on their contribution to the project.

Relatively new, XML web services and their compliant middleware are key enabling technologies for the IMPRINtS project. Via .NET or the java virtual machine remote objects can be instantiated client side using proxy class definitions. Hence the client can assess these remote objects as if local to the client machine. The middleware takes care of interaction using XML data. Multiple clients connected to the server effectively become components of a larger distributed application for the collection and collation of data and the broadcast of information. The web services written for IMPRINtS provide secure managed access to the main server database and file system thus enabling members of the public to register, upload data, score and comment on each other's uploads and follow the science interactively.

Response data will be analysed using the statistical analysis software SPSS, where quantitative data can be extracted from the subjective open responses of participants, alongside a process of qualitative analysis. This can then be used with the objective analysis data already obtained to make inferences on the effect and importance of the holistic and atomistic soundscape features in terms of their acoustic characteristics and their subjective influences.

3.4 Pilot Study

A pilot study involving 300 Key Stage 4 students (ages 14-16) will be undertaken before the national survey has begun to enhance the public engagement benefits of the project and to develop optimum sampling methodologies. This will involve 10 collaborating schools in Manchester, where two hour interactive lessons will be carried out in each. These lessons will be designed to promote interest in the fields of Environmental Science and Acoustics through the practical use of the project's mobile and computing technology alongside acoustic measurement equipment. The objectives of these lessons are suited to the KS4 science programme of study as they supplement the majority of the knowledge, skills and understanding sections of “How Science Works”.

“... in order to understand how science works, learners need skills such as practical collection of data, working safely, presenting scientific information; they need to understand the power of science to explain phenomena, the way understanding of science changes over time and the applications of contemporary scientific developments”[10]

The calibration techniques, mobile applications, PC applications and web-based resources will be prototyped to asses the significance of both systematic and stochastic errors, as well as ensuring that optimum techniques are utilised. This stage will be critical to the success of the national survey which will be shaped around the findings and decisions made in the pilot study.

Preliminary studies will compare results with more traditional methods of noise surveying. The public method of noise surveying will naturally generate a higher percentage of erroneous data, but the advantages of being able to sample a larger number of environments and gain a better understanding of public perception; will hopefully outweigh many of the disadvantages.

The current project delivers a mobile ICT based learning tool, accessible to a wide range of learners due to its use of popular consumer hardware.

3.5 National Survey

Participants will register on a database and mailing list and be invited to download the client applications that will need to be executed on mobile and desktop computing devices. Instructions will be provided for the setup, calibration and operation of each element of the applications. The applications will be designed to be simple to use and self-explanatory to cater for a wider range of users with varying levels of computing proficiency. Participation will be as large and widespread as achievable, promoting heightened awareness of environmental noise issues and reducing stochastic errors as well as increasing the scope of potential inferences that can be made.

The initial target for participants is 3000, although there is potential to cater for a much larger number. Funds are available for promotion of the project including advertising, flyers and travel costs to science fairs and similar promotional outlets. National events related to the project, such as Noise Action Day can be utilised to publicise and promote the enlisting of participants as well as gaining the attention of journalists, companies, communities and organisations that have an interest in related fields.

Throughout the duration of the project, participants will have access to a well publicised multimedia web site detailing issues related to Environmental Science, Acoustics and the KS4 resources. This site will also provide research findings of the project and allow participants to identify their contribution to the work being done, thus personalising the experience.

4 Conclusion

The potential to gather vast amounts of data from a huge number of participants should provide new insights into how sounds vary spatially and peoples’ relationships to their acoustic environments. The data gathered, combined with the inferences made, can be used to better inform strategies for environmental noise abatement and the enhancement of public spaces through increased soundscape consideration. However, there are a number of technological challenges to be overcome, not least the issue of calibration.

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