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Application of novel techniques for the investigation of human relationships with soundscapes

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ABSTRACT

This paper outlines the methodology and preliminary results obtained from the Sound Around You projects dataset. This large scale public participation soundscape research project has gathered soundscape recordings from 200 respondents along with subjective responses and opinions for each. The objective metrics extracted from each recording describe the soundscape using a musical analysis model, with metrics such as tonality, rhythm and structure. The subjective responses predominantly use nine point semantic differential scales with three questions asking for a combination of single word and open ended textual responses. Textual source responses were divided into: human, natural and artificial categories for analysis. These two respective datasets were run through a process of statistical analysis in an attempt to discover any significant correlations between the objective characteristics and subjective responses to these soundscapes. A further stage of principal component analysis aims to uncover a set of uncorrelated components for variability and manipulation in the simulation of soundscapes for subjective testing in an immersive environment. This process should serve to validate the projects existing dataset as well as afford new insight into the effects that these influential metrics have on a person's subjective response to the sounds around them. Preliminary results from the first stage of testing will be discussed along with projections for future uses for this technique and system, including the use of modern smartphones in soundscape analysis.

1. INTRODUCTION

1.1 Project premise

The Sound Around You Project aims to enable and encourage public participation in a large-scale mass participation soundscape survey. The research yield of the project will build on existing work pertaining to soundscapes by utilising data collected as part of the project. The influential characteristics within these subjectively perceived sound environments are also yet to be fully defined and to determine this, input from a large number of individuals would be required to ensure any explorative analysis techniques are considered statistically robust. Subjective experiences such as soundscapes can never be truly quantified and explained using a traditional positivist approach. This warrants a more flexible approach that places aspects of the experimental method at the discretion of the participant or subject. Crowdsourcing [1] or Citizen Science [2] style soundscape experiments provide this flexibility, allowing participants to choose what type of soundscape is investigated, as opposed to presenting them with an environment to comment on. Placing this element of choice on the participant may provide a more nuanced perspective of soundscapes in general, but may introduce a bias that stems from the types of soundscapes people will be inclined to choose.

Advances in mobile computing offer the opportunity to allow many people to participate in soundscape surveys. Recent developments in mobile technology will be utilised, including: mobile phones, PDAs (personal digital assistants), mobile/PC connectivity and distributed application technologies from the project website. The combined use of these technologies will contribute to the

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project in two respects:

- It enables environmental soundscape data from a large participant base to be automatically collated and analysed.
- 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.

The proliferation of mobile devices has given rise to a number of projects [3-6], all with similar intentions of tapping into a potentially huge, geographically and culturally diverse subject set. With many people taking their phones with them wherever they go, this places these mobile sensing units in a variety of environments, situations and soundscapes. An example of the pervasive nature of mobile devices is seen in India, where more people access the internet from their phones than from a computer [7]; a trend that is expected to be mirrored globally in the future.

The enormous potential for public participation in soundscape surveying using mobile and internet technologies has yet to be utilised. With the extensive adoption of mobile technologies, the retrieval, collation and analysis of objective and subjective soundscape data from widespread locations is now possible. This engagement aims to equip members of the public with mobile phone applications and tools that allow them to acquire quantitative and qualitative environment information directly from their surroundings. It places the public in more control of the data collection in terms of what sounds are recorded. This project brings together three main aspects in its methodology: the environment, mass participation and an example of pervasive computing. The geographical coverage attainable using this technique is therefore far superior to previous research techniques. The extended reach of these technologies allow for the identification of cultural trends in soundscape response data, affording an insight into how appreciation varies with location.

The project aimed to enfranchise the public by letting them contribute to the science that might eventually inform legislation with an impact on the quality of their lives. This is an example of ‘research in the wild’ [8] where participants are given freedom to influence current and future research.

A key issue was ensuring that the mediating technologies were fully stable for members of the public who naturally have a wide range of technical abilities. The pilot studies with 14-16 year olds were invaluable in ironing out problems as the students were perfect beta testers of the mobile apps, freely vocalised any issues they had. The main online portal for the project was http://www.soundaroundyou.com. The site provided software and other materials for members of the public to take part directly in measuring and assessing soundscapes and a global online map for users to view contributions. Throughout the 6 month ‘live’ duration of the project, the website accumulated over 800,000 unique hits with 14,000 page views per month. There were a significant number of contributions from around the world. The project promoted soundscape research awareness and its relevance and importance to the public as well as engaging the public in conversation about soundscapes.

To disseminate the retrieved research data to the participants, the project website hosts the soundscape map shown in Figure 1, created using the Google Maps Application Programming Interface (API) [9], which allows members to view all of the projects uploaded soundscape recordings and responses in an easy-to-use location-based format.

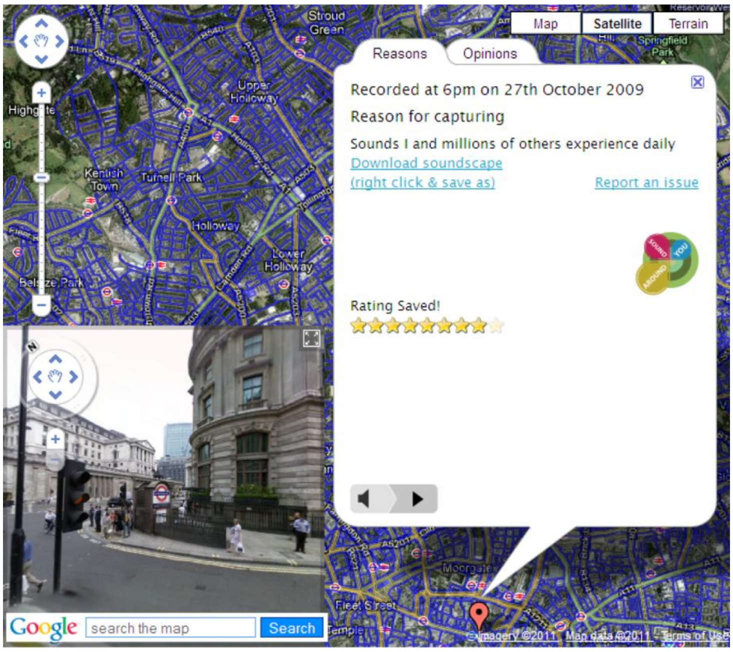

Figure 1 - Soundscape Map and Street View on soundaroundyou.com, using the Google Maps API

Each soundscape is automatically added to the map as it is uploaded by the participant, creating a continually evolving visualisation of public soundscape evaluation. Each soundscape is marked with a clickable marker which, when clicked displays a selection of the participants responses as well as the soundscape player. With the addition of the Google Street View [9] panel shown in Figure 1, the location at which the soundscape was recorded can be viewed in a revolving 3-D image if such an image exists at that particular location.

2. PROJECT METHODOLOGY

2.1 Application Development

Participants were encouraged to download a small application for use on their mobile device. A number of versions of the mobile software were available to cater for the differing capabilities of current and future devices and to ensure compatibility and maximum participation potential. There were two major versions of the mobile software during phase one of the study. These were a Java 2.0 Mobile Edition based (J2ME) version with the other based on the Windows Mobile 5.0+ platform.

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 and select values from semantic differential scales. The data gathered from the participant while immersed in the soundscape will provide a more accurate impression of the impact of the individuals' 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.

The differing audio recording capabilities of mobile phones were another factor. Newer models allow uncompressed wav file capture up to sampling rates of 44.1 kHz. Older models however could only record in a compressed AMR-WB format (Adaptive Multi Rate Wideband Compression) optimised for speech encoding. This format provided a maximum bit rate of around 16kHz at 13 bit producing a resultant signal with a filtered frequency range of 50-7000 Hz. Recordings made using this codec were quite rare (and will be removed from the data analysis stage).

The recent advances in Global Positioning System (GPS) integration into mobile devices and Cell Identifier techniques for device location via triangulation of mobile base station signals [10], 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.

2.2 Survey Question Set

Table 1 describes the subjective measures asked of the participant for each soundscape captured using the projects mobile software and web based interface. The semantic differential scales used in the project were chosen from previous research [11-14], who determined the most influential measures of soundscape quality in the use of four semantic differentials shown in Table 1. Previous studies [15,16] have also identified these measures to constitute the principle components in the assessment of soundscapes, producing the highest explained variance based on existing research.

Table 1 - Descriptions of subjective semantic differential scales

Subjective measure	Description (scale from 1 – 9)
Overall location quality	Rating of the location in general (bad ←→ good)
Soundscape quality	Rating of the soundscape in general (bad ←→ good)
Soundscape pleasantness	Rating of how pleasant (unpleasant ←→ pleasant)
How exciting	Rating of how exciting (boring ←→ exciting)
How eventful	Rating of how eventful (uneventful ←→ eventful)
How tranquil	Rating of how tranquil (chaotic ←→ tranquil)
Positive sound	Text entry of one of the sounds that contributes positively to the soundscape
Positive sound prominence	Rating of how much the above sound stands out within the soundscape (small ←→ large)
Negative sound	Text entry of one of the sounds that contributes negatively to the soundscape
Negative sound prominence	Rating of how much the above sound stands out within the soundscape (small ←→ large)

The predominant use of semantic differential scales is mainly due to the restrictions on data entry that the devices introduce. The semantic differential technique also provides the most transparent form of questioning, allowing the participant to answer the questions unsupervised.

3. ANALYSIS OF PROJECT DATASET

3.1 Statistical analysis

3.1.1 Semantic differential analysis

The purpose of this stage of analysis is to identify factors that characterise the soundscapes submitted to the study, based on their associated subjective responses to the semantic differential ordinal scales and positive/negative source identifications.

The frequency distribution of activity type that the participant was involved in when the soundscape was recorded and commented on revealed that the majority were captured whilst being passed through on the way to somewhere else.

To investigate the difference in mean scores between participant activity types for the subjective responses a Kruskal-Wallis one-way ANOVA was performed on the different activity groups. This identified strongly significant differences in the subjective ratings of: soundscape quality, location quality, pleasantness and tranquillity between activity groups. Based on this, it can be assumed that the activity a person is involved in will have an effect on their perceptions of the soundscape they are immersed in.

To investigate further into this, mean ratings for each subjective descriptor are plotted for each activity grouping showing on average how participants responded when involved in different activities.

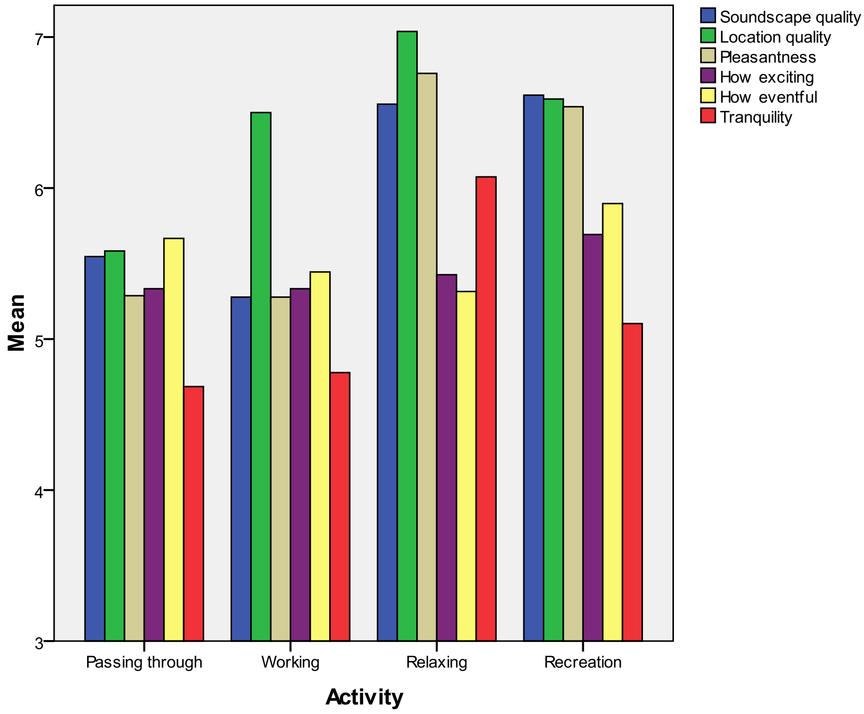

Figure 2 - Mean ratings for each subjective descriptor, grouped by activity

On average, participants perceived the soundscapes quality as being higher when their activity was logged as “relaxing” and “recreation”. This implies that a person chooses to relax in a place that they regard as being of good quality in terms of the location itself and its soundscape. The perceptions of pleasantness are also generally higher when participants are relaxing or taking part in recreation. The exciting and eventful means are more consistent across the activity groups suggesting that these factors are not considered so much when choosing a location to spend time in. As expected, the tranquillity average is at its highest when respondents were relaxing and taking part in recreation. It is worth mentioning however that the participant was actually “actively” listening to the soundscape when these responses were made. This means that their perception of the soundscape would have been generally heightened due to the process of taking part in this study.

To investigate the interrelation between the subjective responses a stage of correlation analysis was carried out. Due to the non-normality of the ordinal scales distribution, the non-parametric Spearman’s rank correlation was used. Significant correlations were found between the responses to the semantic differential scales. All mentioned significances are at the sub 0.01 level (2-tailed). As expected there is strong correlation between soundscape quality and location quality, suggesting that the soundscape appreciation does play an important part in an appraisal of a locations overall quality. Pleasantness and tranquillity is also strongly correlated with soundscape quality making them strong contenders for influential factors. The rating of excitement of the soundscape is significantly correlated with quality but it only explains around 5% of quality variance suggesting that it is related but is not one of the influential factors in quality perception. The prominence of the positive and negative sound sources are positively and negatively correlated to quality respectively, indicating the influence of these sources in quality appraisal.

A soundscapes rating of eventfulness and how exciting it is are highly correlated, indicating that they stand as factors together when describing a soundscape. Eventfulness is also negatively correlated to tranquillity, showing that a tranquil soundscape is generally regarded as being low in eventfulness.

3.1.2 Principal Component Analysis

To investigate the influential and distinct characteristics of these soundscape, a principal component analysis was performed on the responses to the semantic differential scales using a variance maximizing rotation of the original variable space (varimax). Table 2 shows the two components extracted with a criterion factor of eigenvalue > 1, which account for 68.8% of variance (Component 1 – 42.7%, Component 2 – 26.1%).

Table 2 - Varimax rotated component matrix for subjective descriptors

Rotated Component Matrix[a]

	Component	
	1	2
Pleasantness	.863	.154
How exciting		.897
How eventful		.885
Tranquility	.719	-.393
Positive sound prominence	.684	.404
Negative sound prominance	-.676	.300

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Component 1 mainly consists of descriptions of relaxation, containing the variables: soundscapes pleasantness, tranquillity and positive source prominence. Component 2 describes the dynamics of a soundscape, made up predominantly from the ratings of excitement and eventfulness.

Component 1 (relaxation) is shown to be highly correlated with people’s perceptions of soundscape quality. Component 2 however, shows only a weak correlation (5% of explained variance) with participant’s ratings of soundscape quality, suggesting that the dynamics of a soundscape do not play a direct role in a subjective rating of quality. This shows similarity with findings made by Kang [11] and Axelsson[17], where a principal component of relaxation was extracted from semantic differential perceptions of soundscapes. Axelsson described the main two components in his analysis: Pleasantness (component 1) and eventfulness (component 2).

4. THE NEXT STAGE

The second stage of the project will make use of the latest generation of smartphones to gather a higher volume of data. This will benefit the project mainly by targeting a small number of popular devices where the tolerances and acoustic response are known. For instance the Apple iPhone is extremely successful and widespread globally and also provides a high end hardware platform capable of providing advanced functionality as well as enhanced connectivity. Participant could simply install an app, which would handle the recording, subjective comment and also upload of data to the project server. The main reason for removing the option to upload directly from the Java mobile app was the cost of data transfer over mobile networks. But smartphone mobile contracts often include a significant data allowance removing this worry. Based on our experience, the streamlined methodology should help increased uptake and reduced dropout rates. Android OS mobile phones are also another viable option.

With the ubiquity and power of modern smartphones, the research potential on this platform is very appealing. With only three major operating systems (Windows Phone 7, Android and iOS) offering direct access to device functionality, the development and distribution of mass participation research applications is now possible. The ease of installation on these platforms is another reason for their potential overcoming issues involved in distributing older Midlet and Windows Mobile applications.

5. CONCLUSIONS

With a survey of this nature, the inevitability of high systematic error should be offset by the decrease in stochastic error due to its potential for a very large participant base. The geolocative data gathered and mapping technologies used can also serve to identify locative trends in soundscape appreciation and evaluation. The initial findings from the first stage of the project reveal a number of salient factors in soundscape appreciation, most notably the extracted principal components of “relaxation” and “dynamic”. To further investigate the methodology, stage two of the data gathering will be undertaken using current smartphones. This will serve to validate the original methodology and expand on the findings of stage one.

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