Using Sound to Represent Uncertainty in Address Locations

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1. Introduction

All spatial data have positional uncertainty, which sometimes users ignore. There are a number of different ways of representing these data visually, but they have limitations which can be addressed by utilising non-visual methods. This study uses piano notes to represent spatial uncertainty in Ordnance Survey Address Layer 2 (AL2) data, and was evaluated by 49 spatial data users using computer based evaluations and discussion sessions.

2. Literature Review

The AL2 data set has different status flags within it indicating various factors including positional quality accuracy. This is important because greater uncertainty may mean addresses are shown up to several km away from their true location and ignoring this could have serious consequences (e.g. for routing applications in emergency services usage). Despite this, a number of interviews with Ordnance Survey Account Managers and Pre and Post Sales staff suggested that often status flags are not properly considered when the data is used by external organisations.

The representation of uncertainty has significant coverage within the literature and visual methods such as colour, blurring or multiple maps are generally effective (Appleton et al., 2004; Ehlschlaeger et al., 1997). However these methods can obscure underlying data or limit the amount of information shown. The use of other senses has been explored to address these limitations. Haptic (touch) maps are being developed, but they require specialised hardware and training to use (Golledge et al., 2005). Sound is also being researched and the hardware required (sound card and headphones/speakers) is readily available, but user training is required (Pauletto & Hunt, 2009).

One way of showing uncertainty information more effectively is to use sound in combination with vision, and this has been addressed from a theoretical and practical point of view (Krygier, 1994; Fisher, 1994). MacVeigh & Jacobson (2007) developed a prototype which sonified three different land uses (sea, land and harbour). They found participants understood the map quickly and that the sound enhanced their experience of the map. They suggested that an extension to an industry standard GIS (e.g. ESRI's ArcGIS) could be created which would use sound to represent spatial data. This integration into a commercial application would enable greater use and easier evaluation. Few of these ideas have gone beyond the proof of concept stage or had significant user testing. This field of research is still in an early stage of development and comparison is often difficult due to different terminologies and research frameworks (Frauenberger & Stockman, 2009).

3. Methods

An ArcScript (custom extension to ArcGIS) was created to allow evaluation of both visual and sonic techniques to represent positional uncertainty with Ordnance Survey MasterMap Topography and AL2 data from Norwich. The AL2 Positional Quality Accuracy status flag (PQA) was linked with the

Topography data using the associated TOIDs (topographic identifiers).

The AL2 PQA status flag values are: Surveyed (most accurate), Approximate, Postcode Unit Mean, Estimate and Postcode Sector Mean (least accurate). In a pilot study, participants said that five sounds were too many to understand effectively, as they were unable to discriminate between the different piano notes and found it difficult to relate the notes to the status flag values. The five categories were reduced to three by recoding Postcode Sector Mean to Estimate and Approximate to Postcode Unit Mean. The data presented to participants was altered to allow different proportions of Surveyed values (see below). One section of the evaluation required a second dataset to be presented; this was fabricated "Council Tax bands" information.

The three categories were represented using piano notes because the scale on a piano is very easy to visualise (i.e. participants can easily understand the difference between a 'high' and 'low' note) and the majority of people are familiar with this instrument. The notes chosen were E_5, G_4 & C_4, which were based on the CEG triad split over two octaves. A triad was chosen because triads are sets of notes which sound harmonious together (Burrus, 2009) and CEG was the favoured option in the pilot study. The highest note (E_5) represented the highest level of accuracy and the lowest note (C_4) represented the lowest. These were played as the participant moved the mouse over the buildings, allowing them to either query a specific building or scan an area of data to get an overall view. A legend was provided, to allow the participant to link specific notes to specific values. The data set was shown to the participant using four different presentation methods (see Table 1).

Table 1. The four different presentation methods (in the order they were shown to the participants) and which data were shown visually or sonically. The topography layer was always shown visually.

Presentation Method	**Visual Data**	**Sonic Data**
Sonic only *(see Figure 1)*	Topography outlines only	AL2 Positional Accuracy
Visual only *(see Figure 2)*	AL2 Positional Accuracy	None
Visual and Sonic representing the same variable (VS Same)	AL2 Positional Accuracy	AL2 Positional Accuracy
Visual and Sonic representing different variables (VS Different)	Council Tax bands	AL2 Positional Accuracy

For each presentation method, the participant was asked to identify the proportion of Surveyed values, from options of 25%, 50% or 75%. The data were randomly assigned one of these values using a stratified random method for each presentation method. Other background questions were also asked, which allowed analysis depending on musical experience, learning preference and a number of other variables. This task was chosen because it combined a simple principle (i.e. what proportion of the values are Surveyed) with the need to utilise sound in a way that visual representations are often employed.

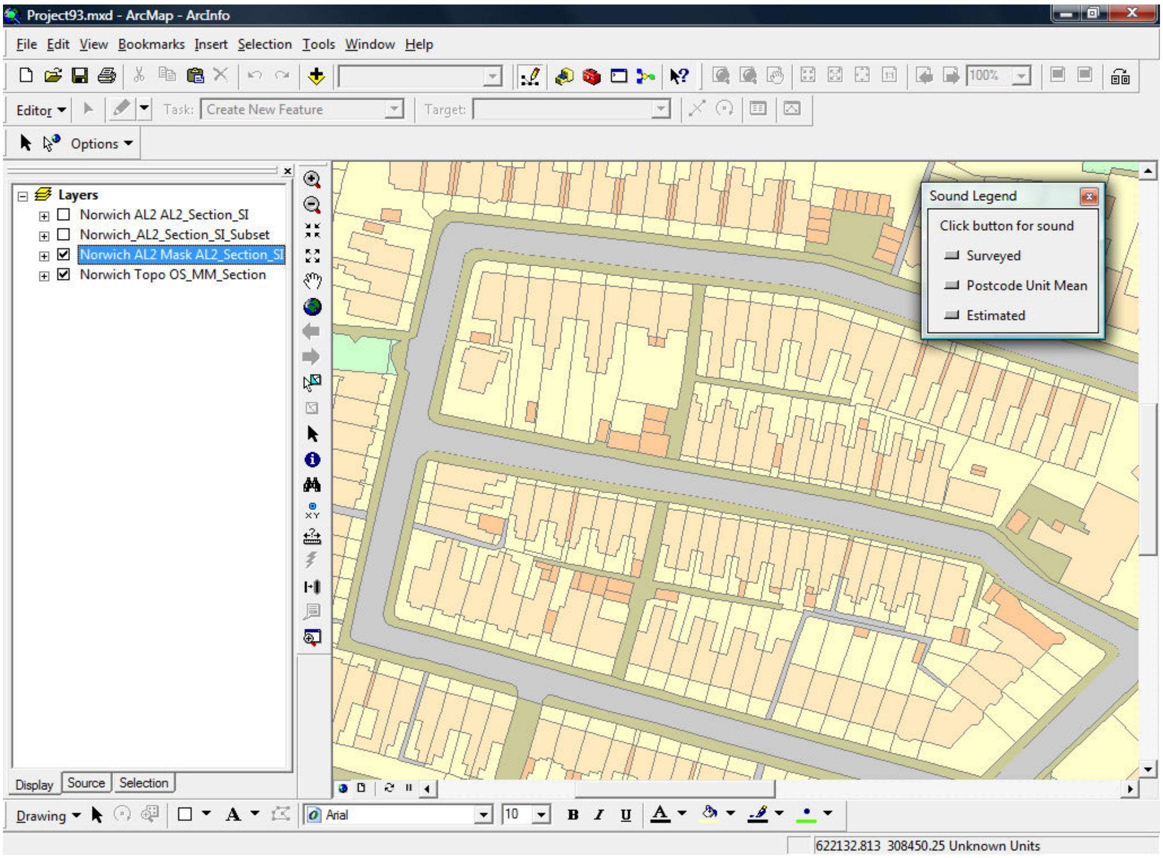


Figure 1. Screen shot of ArcGIS showing the data represented sonically. Note the topography layer shown visually, and the sound legend in the top right-hand corner.

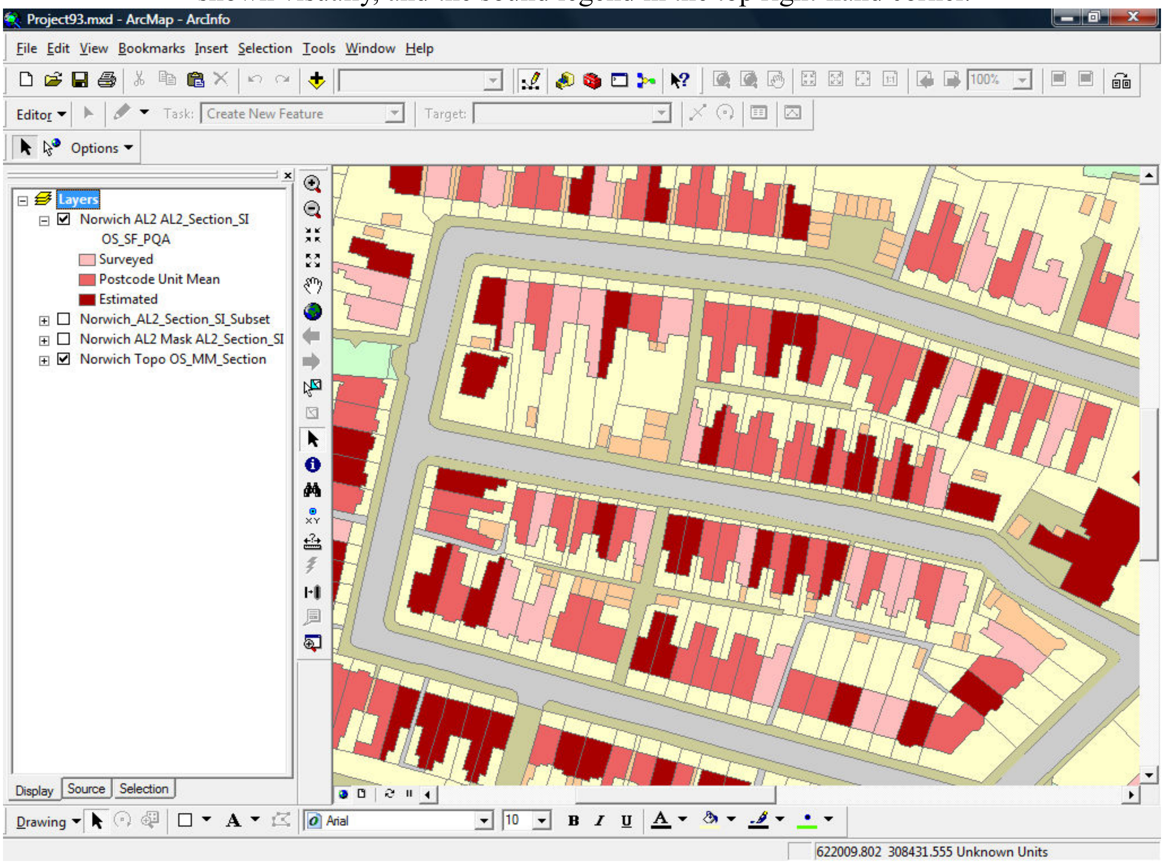


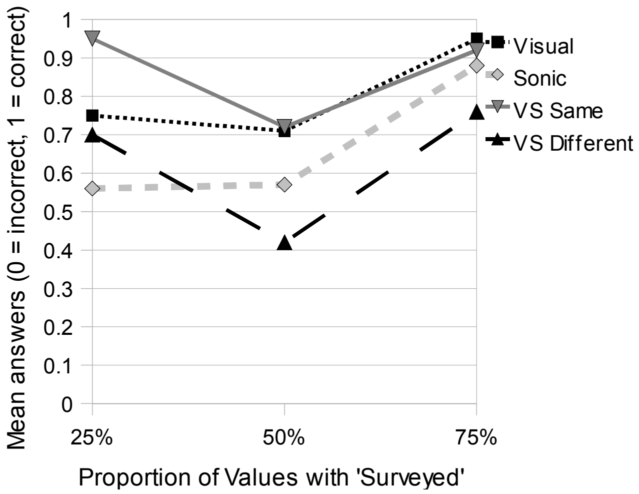
Figure 2. Screen shot of ArcGIS showing the data represented visually. Note the AL2 data shown visually, and the legend on the top left-hand side. The topography layer is also visible.

A total of 49 participants completed the assessment, consisting of 19 from Ordnance Survey, 23 from UEA and 7 from Local Authorities. All the participants had at least a basic knowledge of GIS, spatial data and ArcGIS and used these on a regular basis, although experience with AL2 varied. Headphones were used to provide auditory stimuli, with adjustable volume. The evaluation took place in groups of three to six, and was followed by a facilitated discussion for around 20 to 30 minutes which covered the participants' views and feelings and the potential uses of this technique.

4. Results & Discussion

Nearly all participants (46 out of 49) identified the correct proportion of Surveyed values for 3 or more of the presentation methods. Figure 3 shows how the mean answer for participants (correct = 1, not correct = 0) varies between proportion and presentation method, which are the two main influencing factors. The general trend was for more correct answers with 25% and 75% data proportions and less with 50% proportion. The exception to this was the Sonic presentation method, which performed as badly with 25% as it did with 50%. Visual and VS Same (see Table 1 for definitions) performed reasonably well, while Sonic and VS Different had lower correct frequencies. This could occur because the nature of the program makes it very easy to find the sounds when they are common, but difficult when they are sparse. This would impact Sonic and VS Different and potentially result in participants over estimating the proportion. Both proportion ($p < 0.005$) and presentation method ($p < 0.05$) had a significant influence on whether a participant identified the correct proportion.

Figure 3. Answers for all participants, split by presentation method and proportion



A higher knowledge of the data set being sonified increased the likelihood of the participants choosing the correct proportion. However, this trend was not especially strong and although including it in a logistic regression model with proportion and presentation method improved the model (see Table 2) the addition was not statistically significant.

Table 2. Factors added to the Logistic Regression Model and their impact

Factors added to Model	-2 Log Likelihood	Cox & Snell R^2
Proportion	182.01	0.043
Presentation Method	169.579	0.11
Address Knowledge	167.319	0.116

The free text answers showed that some participants found the sonification very useful and that it added a large amount to the interpretation of the data, while others said the sound was very difficult to understand and when combined with vision, distracted them from the visual interpretation. Sonic and VS Different were considered harder to use than Visual and VS Same. Sonic only had a very low success rate and seems unlikely to ever be successful with this type of interface.

The discussion sessions after each evaluation session provided further qualitative information and gave participants a chance to suggest changes and improvements to the technique. Preferences for the types of sounds used were subjective, and are likely to vary depending on the data set and the analysis taking place. A wider range of audio clips coupled with user choice could allow easier differentiation of sounds and potential for representation of a larger number of variables. Possibilities include different piano notes, different instruments, or completely different sounds, such as environmental or animal sounds. Colour-blind users were highlighted as a group who might find this sonification useful, however a larger sample size is required to effectively evaluate this.

The task chosen may limit the wider applicability of the results but there are few existing evaluations in this area so there is very little comparative data. The task needed to be easy enough to ensure that some of the participants managed to answer most/all of the questions correctly but not too difficult so that it would result in exclusively incorrect answers. Possible future options include more complex tasks (such as clustering exercises) and more comparisons of different presentation methods, utilising both sound and vision.

This research has highlighted specific characteristics that influence the ability of users to interpret sound to make proportion judgements. The proportion of the data the the user is interested in and the presentation method are the two factors that have the most impact on whether a person will be able to understand the proportion correctly. Knowledge of the data set being sonified also appears to have some impact, but this is not so clearly apparent with these results. These issues will be explored in future research when the author's PhD research evaluates the use of sound to represent uncertainty in UK climate scenario data.

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Biography

Nick Bearman completed his MSc GIS at University of Leicester in 2008 and is currently studying for a PhD at UEA in Environmental Science, researching different methods of representing uncertainty in a variety of spatial data environments.