AN INTERACTIVE APPROACH FOR TEACHING INFORMATION SONIFICATION

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ABSTRACT

Teaching sonification is interdisciplinary and multifaceted. It includes areas such as information graphing, auditory parameters for representation, psychoacoustics affected by the context and combination of parameters, auditory cognition, programming and foundational synthesis or sound production. The interactive pedagogical method presented here fuses these elements in a real-time interactive environment for learning and experimentation in order to familiarise students with basic concepts and develop an understanding of the interdependencies. It allows the student to listen and interact with instructive examples, quickly evaluate the efficacy of different display possibilities, move through the material at their own pace, investigate further online reading lists, and eventually helps them build their own sonifications. This paper describes pedagogical software that integrates these disciplines.

1. INTRODUCTION

The 'Sound Design and Sonification' unit of study was taught for the first time in 2005 within an undergraduate Degree program in Design Computing run at the University of Sydney. This paper originates in a gap in resources evidenced by this experience. In 2006 we will implement the software tutorial based approach to teaching this course that is described in this paper. Parameters for information sonification, issues of perception and orthogonality are well addressed in acoustic, psychoacoustic and neuroscience research, the field of teaching sonification is relatively young. Our software aims to integrate the teaching of these disciplines. In 2005 it became apparent that in order to develop effective sonification, students needed to embrace various areas of knowledge simultaneously, quickly and in an integrated fashion. Further, in applied sound design, learning-by-doing seems more pertinent than a purely theoretical approach to education.

In response, this paper proposes an interactive method for understanding information sonification in a real-time visual programming environment that enables students to learn and experiment with sonification parameters, synthesis procedures and different combinations of data representation. The interactive environment approaches the *interdisciplinarity* of sonification by allowing the student to hear and evaluate representations with immediacy intended to promote testing and listening, and with a non-linear approach to tutorial material designed to integrate the disparate fields that are useful in conceptualising auditory display. Figure 1 describes two ways of approaching the teaching of a complex interdisciplinary subject like auditory display. The

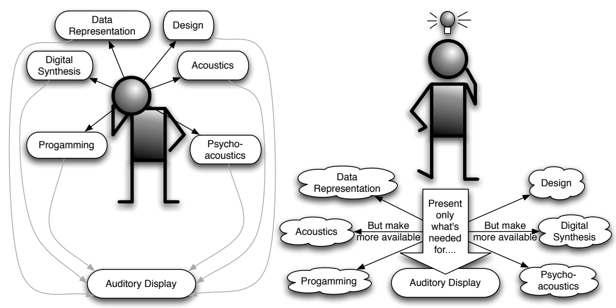

Figure 1: *Two approaches towards teaching auditory display.*

first approach requires the student to consider many very different fields in a considerable level of detail before being introduced to the focus of the course. This can lead to confusion and frustration with the lack of course focus. Another approach only teaches the minimum amount of the material in each of the disparate fields that is essential to understand the purpose of the course. However, it also offers the ability to 'drill down' at several levels into each of the disparate subjects it has touched upon. In the second method, there is a more direct path to implementation.

2. CURRICULUM AND BROADER APPLICATIONS

Teaching auditory display is the obvious and direct application of this approach but in the context of contemporary digital media curricula, understanding representation of data, gesture and human interaction in the auditory domain is also important in designing interactive multimedia, art installations, spatial sound environments and in information-driven music composition. The ability to choose appropriate auditory representation and to have a method for synthesizing sound and evaluating reactions is complementary to visually-centric teaching of animation, film, and interactive multimedia.

2.1. Sonic Tai Chi

An example of a spatial interaction environment that sonifies data is the *Sonic Tai Chi* audio-visual installation by Jakovich and Beilharz at BetaSpace in the Sydney Powerhouse (Design, Science and Technology) Museum. A simple web-cam captures location and luminosity data locating the user's movement in space. Both

Figure 2: Sonic Tai Chi *installation sonifies motion direction and level of activity.*

the game theory rules creating a generative colony of Cellular Automata and the filtered body outlines of users are displayed on the rear-projection screen (Figure 2). Two sonifier engines display an auditory representation of the interaction. The first, adjustable in frequency range, roughness and timbre, produces a granular spatialised "noise" corresponding to the distribution of cellular automata, i.e. its spatialisation is governed by user movement that promotes the birth and death of Cellular Automata particles in patterns determined by the rules of Conway's 'Game of Life', stimulated or subdued by the direction of horizontal body motion. The second sonifier engine maps body movement very simply in vertical and horizontal directions, the former affecting pitch altitude and the latter affects panning and timbral spectrum. Due to the cumulative effective of rapid gestures, velocity also increases dynamic intensity. This is an example of gesture sonification applied in a public context, similar in content to interaction design subjects for which the proposed methodology would be a helpful test bed. Public installations afforded brief encounters require extremely simple mapping correlations, like in this example.

2.2. Course Background and Case Studies

The majority of students enrolled in the 2005 semester of the Sound Design and Sonification unit had some programming experience using *Max/MSP* with *Jitter* (its visual object library) for the purpose of controlling real time interaction, integrating physical sensors and video. Most had not previously focused on its primary purpose of sound design, nor were most students familiar with sound production or auditory terminology. For their final course assignment, students were asked to produce a total of four sonifications, 2 each for 2 different data sets. These differed substantially in complexity, but students were asked principally to communicate the information within the tables, without necessarily having to graph all information within the dataset. The first of the two datasets was a small categorical dataset with three columns entitled 'Width', 'Height' and 'Depth', with the final column entitled 'Intensity'. The second was a larger time-series dataset of sound level measurements taken every 15 minutes over six days. The level measurements used statistical measures, such as the maximum, minimum and average level in the 15-minute period, and also incorporated several percentile measures.

The parametric choices and approach were left up to the student's initiative and they were asked to experiment based on their knowledge. Students were required to write a report on their methods and were referred to the papers of the 2005 Auditory Graphs Symposium for some information on possible graphing methods. A couple of submissions are summarised here. Student One approached the time-series dataset with a uniquely musical sonification entitled 'Chronological March of the Six Synths'. Six of the columns were presented mapped to the intensity of six notes C3-E3-G3-C4-E4-C5. These notes were panned in their order from left to right. This approach was most successful as a genuinely listenable piece of information representation. Student Two approached the categorical dataset with an original scheme. She used a heartbeat sound effect and altered parameters of speed and separation between beats, as well as loudness and pan. The sonification had an immediately recognisable quality that seemed to stem directly from the sound effect she had chosen. The variations in heartbeat rate were particularly effective, possibly because human perception is somehow attuned to perceiving attributes of heartbeat sounds.

Overall, student application was enthusiastic and competent. However, the teaching of such an interdisciplinary subject was constantly hampered by inappropriate pedagogical resources, and it was difficult for students to gain independency in the subject. This response was planned both in order to improve the next year's course experience and to discuss this pedagogical experience.

3. TUTORIAL DESIGN

The key to the educational approach in this paper is interaction with the sonification algorithms and synthesis controls - i.e. the production of sound and allocation of sound categories to data properties (mapping). *Max/MSP* is a real-time visual programming environment and has graphic icons and a tree-like flow visibly connecting and showing interrelations of these parts of the sonification process in its editor mode. The student can alter parameters while hearing the outcome. Even with a visual programming environment, addressing diverse experience levels with programming is a significant challenge faced while teaching sonification. The aesthetic/intuitive use of sliders/dials and virtual console interface with comments makes the environment more accessible for students in order to maintain focus on the sonification objective. Many elements of a Max program that perform programmatic tasks also incorporate graphical user interface controls; when the program is running the student see the process and control parameters. The progressive journey through the console lets students read, learn and try interdisciplinary attributes of the sonification process, such as psycho-acoustic attributes of pitch and loudness with synthesis controllers of

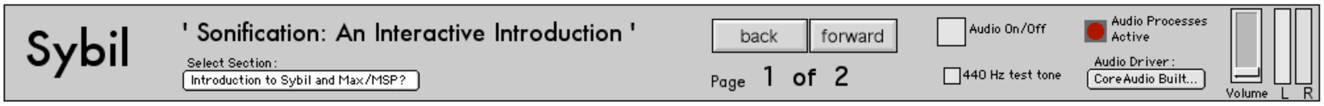

Figure 3: *A screenshot of the interface for controlling progression through the tutorial. Note the popup menu for choosing which section to approach – within each section there are a number of pages which can be stepped through.*

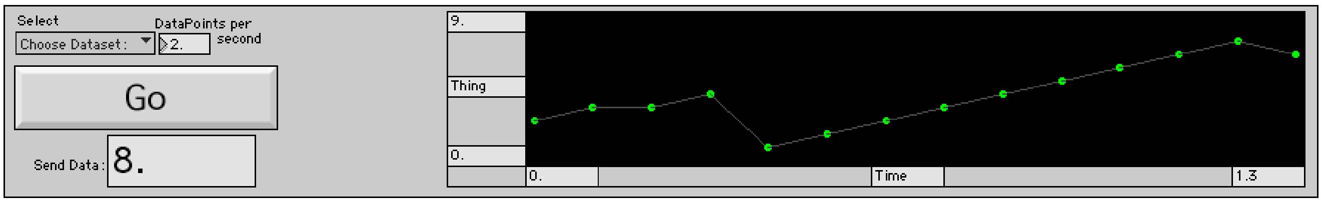

Figure 4: *A screenshot of the data control interface.*

timbre/sound production.

Furthermore, with students of different aptitudes and levels it is essential to be able provide the material at different speeds. The interaction basis allows students to progress through the material at a speed that they prefer, and they can revisit material at any time.

3.1. Interface

Sybil is a modifiable tutorial interface, which was developed by Clarke et al. for teaching the basics of digital synthesis in an interactive way [1]. It was based on a previous piece of software *Synthia*, which used the computer music technology available in the 1990's [2]. *Sybil*'s main contribution is to provide a topic and slide based presentation scheme, providing a seamless and continual tutorial system (Figure 3). For teaching auditory display the requirements were slightly different to the original version, and we have developed and built upon this code base. One of the main introductions is a simple interface for importing and controlling small datasets for sonification (Figure 4).

Sybil is based in the *Max/MSP* environment, which is a visual programming language popular for synthesis and music applications [3]. *Max/MSP* gives a lot of flexibility by providing pre-programmed objects useful for graphical display and user interaction as well as an extensive array of digital signal processing modules for programming synthesis and sonification algorithms. By basing our tutorial in a programming language we provide an introduction to a method for students to realise their own application or variation on the algorithms and processes discussed. They can even alter and reuse portions of the tutorial in their own programs. Max/MSP provides a mix of standard graphical user interface elements and other elements specific to *Max/MSP*, so an early portion of the tutorial is devoted to familiarizing the student with this environment.

Generally, the material is presented in a narrative fashion. Comments in text explain both the tutorial material and processes occurring, and how to interact with the interface in order to modify particular aspects of sound. User interface elements like pop-up menus also form part of the textual explanation, incorporating interaction as closely as possible with the explanation. An important element of the interface is the ability to hide more detailed information in *Max* 'sub-patches' - screens with further information that are initially hidden from view. This provides the possibility of a non-linear flow of concepts, allowing details unimportant to the primary content to be included in a type of 'sidebar'. In this way, it is possible to provide an enormous amount of supporting material without disturbing the focus of the tutorial.

Another important reason for situating this tutorial in the *Max/MSP* environment is that it forms an extensible platform that can be used in other parts of the Degree program, including subjects that deal with visualisation and interaction.

3.2. Interacting with Datasets

An element of this tutorial system that is specific to information sonification purposes is the incorporation of a method for reading data into the sonification algorithms. The dataset control interface is designed for simplicity and to aid familiarity for the student. The presentation of a simple visualisation simultaneously with the sonification allows the student to relate the two. This is necessary because often students find the sheer concept of auditory graphing so unfamiliar that they need to partner it with a more familiar representation to understand the idea behind it.

The main elements of the dataset control interface (Figure 4) include:

- A choice of a number of pre-assigned datasets demonstrating different trends that may be present in a dataset.
- A control that sets the data presentation speed (rate) in points per second.
- An automatically rescaling graph that bases its axes' scales on the dataset statistics.
- A graph that visually presents each data point as it sends it to the sonification algorithm.

The datasets presented are currently limited to simple two-dimensional data with time as the x-axis. It also includes a facility for importing datasets of this nature.

3.3. Incorporating Synthesis and Programming Material

Clearly our approach sets out to cover a large amount of material, and the sheer scale of material can cause confusion about the purpose of the tutorial. It is important to provide the practical knowledge for students to achieve their auditory display goals, without the tools becoming too complex, which might confuse the progress a course primarily concerned with auditory display. For implementation of auditory display synthesis knowledge is clearly of practical use, and is a valuable addition to an integrated course. However, the most common texts on the subject (for instance [4], [5] or [6]) have enormous scope, and even a fraction of this amount of material would act to confuse the student. A clear approach for selecting the small amount of synthesis material that is useful for the auditory display student is necessary.

This is addressed in two ways: basic synthesis concepts that form essential vocabulary are presented early in the tutorials, and more complex concepts are abstracted (hidden) in 'sub-patches' that are treated like 'black boxes' within the main narrative of the tutorial, and in the sonification algorithm being presented. These boxes are explained as being concerned with synthesis by a slide in the opening of the tutorial, and upon 'opening the box' the student is presented with a explanation of what is going on inside, effectively hiding a second tutorial within the main narrative.

This has the effect of directly associating the synthesis information with the algorithm for which it would be most useful. Thus, this approach is helpful for reuse and alteration, and is crystallised further by the extraction of these functions into a library of 'abstractions' (the Max equivalent of a dynamically linked library), which can then be reused in *Max* programs independently from the tutorial.

Max/MSP is a relatively simple high-level language, and its visual nature makes it easy to understand for simple programs, but only if the user understands what each of the 'objects' do within the flow of the program. Very short explanatory notes guide the user through the program, giving them a general idea of the process. A link to the object's Help launcher allows the user to access the generic Max Help page that explains the object in detail.

As the students become more adept at programming in this language, more advanced strategies are necessary to deal with the further complexities it presents. Short explanations of basic practices in debugging, encapsulation and program design and style are incorporated within the tutorial at appropriate stages.

3.4. Situating Learning Within Literature

In many learning situations of decades previous, the knowledge to be presented was commonly vested in the lecturer of the course and perhaps a textbook. This ensured that the student relied on these two sources of information. This is no surprise in traditional subjects, with the course progress following a linear track through a typical course text. However, in today's learning environment it is common to find students turning first to electronic resources before considering books and printed material. This is pointed out not necessarily as a criticism of students, but rather as a realisation of a fact in modern education. With this in mind, our framework guides the decisions students make about further reading, as it is well understood that a high proportion of electronically available information is questionable. Showing great foresight, the International Community of Auditory Display has made their papers available as online proceedings. Many other conference publications and journals are incorporated in major electronic indexes, and are therefore available instantly to students of subscribing universities, often offering at least the abstract publicly. This allows direct linking from a demonstration of a particular auditory display technique to various papers providing much more information on the topic.

Using further reading lists comprising predominantly of hyperlinked articles has the advantage of encouraging further reading without delay or expense. It also allows comparable resources for those students without access to large or specialised libraries. Encouraging students to engage directly with reputable research literature is an aim of this tutorial.

3.5. Designing Meaningful Auditory Display

Students can be concerned by the large numbers of theoretical possibilities auditory display provides, despite relatively few of them having been encountered in everyday life. Comparatively, visualisation systems are widespread; we are often systematically taught to understand numerical information in a visual manner within the primary and secondary school system. Walker and Kramer's summary of some of the more common classifications of auditory display methods is useful in developing a basic vocabulary for design tasks [7]. These classifications include: **Alerts and notifications**, simple sounds designed to alert a user to refocus on an object or event; **Auditory Icons**, are icons in the auditory domain, and represent their target with sounds that the target produces; **Earcons**, sounds that represent their target with a melody or symbolic sound not directly related to the target; **Audification**, which is the process of turning a non-sound data stream into sound, often by using a frequency shifting process; **Process Monitoring**, which exploits the ear's ability to notice very small changes in repetitive patterns; and **Sonification**, which is the use of non-speech audio for information display.

Whilst it is obviously important to understand the basics of acoustics, synthesis, psychoacoustics and sonification algorithms, it is unwise to assume teaching this material will lead directly to convincing auditory display. A framework within which to think through the design problem posed by a particular auditory display situation is essential for students to use the information they have learned in the previous sections. We approach this problem by employing the Sonification Design Patterns described by Barrass and developed further by Adcock and Barass [8], [9]. These patterns were designed by surveying approaches taken by designers that documented their work, and therefore there are many examples to draw on for illustrating the ideas behind each of these patterns. Another advantage of these design patterns is that they are documented centrally (along with other design patterns mostly for software engineering) on the WikiWeb (http://c2.com/cgi/wiki), which can be consulted for updates dynamically through the use of a hyperlink to the site. This integration of online material reinforces the contemporaneity of the tutorial and introduces the student to reference material they may not have previously found.

It is also useful to understand basic classifications of data and basic statistical concepts. This is achieved through simple explanations and demonstrations. The most basic information in statistical thinking is probably the most important in design of auditory displays.

3.6. Redundant Encoding

Once the auditory dimensions are chosen, further decisions are required regarding the use of redundant encoding. Some argue for avoiding redundancy as it may diminish comprehension – the multiple dimensions result in divided attentions and increase the cognitive load. Others insist that redundancy can lead to better comprehension. Peres and Lane use auditory graphing to

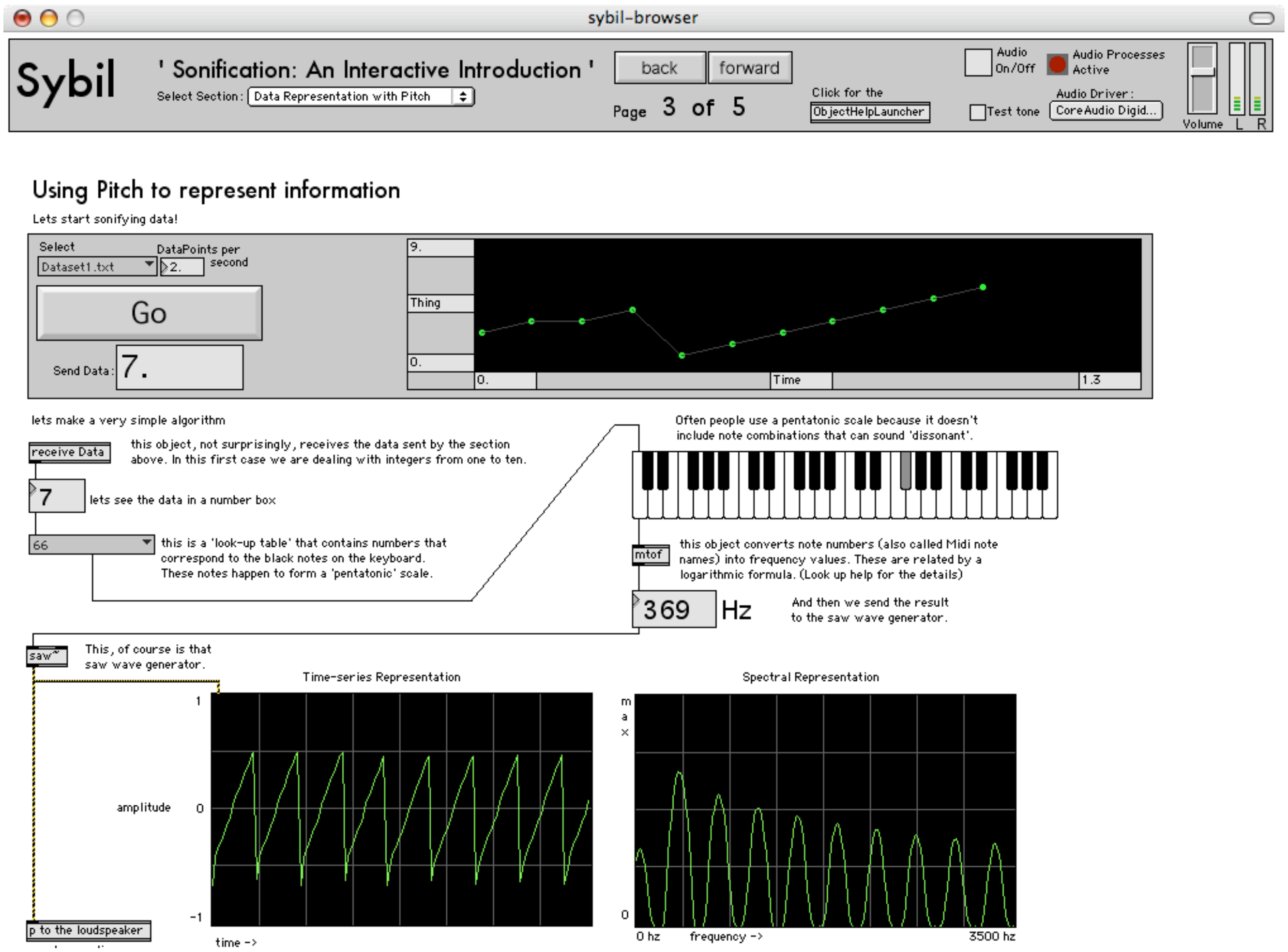

Figure 5: *Screenshot from the tutorial demonstrating the Sybil control mechanism (grey section at top) and an interactive slide discussing a mapping to pitch by way of the pentatonic scale.*

represent statistical data [10]. The auditory dimensions employed are pitch, loudness and time, both individually and redundantly in combination. They state that integral dimensions exhibit better performance when two parameters are used to reinforce the same data. Walker argues that more research needs to be undertaken [7]. In this context the designer bears the responsibility of determining whether redundancy can improve comprehension.

4. INFORMATION SONIFICATION PARAMETERS

In a tutorial regarding the design of information sonification it is necessary to describe the various methods of mapping data to sound. The usage of Pitch, Loudness, Spatiality, Time and Repetition, and Timbre are described in detail and demonstrated. The chosen parameters introduced in our tool show the student typical sonification applications and the variety of ways in which these parameters can display information. The nature of the data – its detail and distribution are also significant, as are considerations of scaling.

Pitch, spatiality, timbre and time are categories for mapping whose efficacy is supported in a sonification literature review, briefly summarised following. Loudness, while quite effective in certain contexts, is controversial as it is influenced by auditory environment, frequency content, and playback equipment [11]. For the purposes of a learning environment, however, we do not seek to provide a prescriptive set of parameters alone, but also to nurture a culture of investigation and experimentation. Including loudness as a parameter for testing in sonification combined with other contextual conditions and mapping choices, promotes this investigative opportunity for further evaluation.

Whilst this paper's purpose is to introduce an educational method, it also serves to inform potential users of the structure of the tutorial. Therefore, it can be observed that the tutorial design basically follows the outline and literature review below. Each subsection presents basic information about aspects of each sound parameter, followed by examples of mappings to this attribute.

4.1. Pitch

Pitch is a defining property of tones. Flowers found that representations of data familiar to the general public required less effort or training to be understood [12]. However, it possesses certain complexities for mapping purposes and to use it carefully requires finesse.

Authors have divided the sensation of pitch into three separate sensations; pitch strength [13, 14], pitch chroma, and pitch height [15]. Pitch height is the general sensation that is described by the terms 'low' and 'high'. Pitch chroma pertains to the harmonic character of tones, whereby certain proportional frequency relationships sound more similar than other relationships (for instance octaves and fifths). Pitch strength is less well known, and refers to the strength of the sensation of the sound being 'tonal', or 'pitched' sound. This sensation decreases in the very high and low frequency ranges. The phenomenon of virtual pitch perception demonstrates the perceptually defining features of tonal sounds. Terhardt is credited with developing an effective model of this process [13].

Levitin writes of memory for musical attributes, '...the contour is remembered better than the actual intervals...', and '...the identity of melody is independent of pitch...', [16]. However, Neuhoff demonstrates that large pitch changes must be used to avoid confusing the listener regarding polarity [17].

Walker and Kramer initially considered that either pitch or loudness might be the optimal auditory dimensions to use, regardless of the type of data, since listeners are likely to be most familiar with these auditory dimensions. They conducted several experiments for four display dimensions (pitch, loudness, onset and tempo) and four data dimensions (temperature, pressure, rate and size). Each data dimension was mapped to each display dimension and according to their results, pitch is an appropriate mapping for many types of data [18].

Another attribute of pitch that recommends its use is that the auditory environment does not often significantly influence it, making it more reliable and robust for sonification than other auditory dimensions. Our tutorial demonstrates simple strategies for mapping data to pitch, and discusses their relevance. Some of these include:

- Musical scales. We give the user a choice of mapping to various musical scales (for instance chromatic, pentatonic and diatonic). The scaling used is also addressed, particularly the process of converting data ranges to discrete intervals.
- Mapping directly to continuous ranges of fundamental frequency, or by employing a logarithmic transform.
- Using the harmonic series to represent integers.

4.2. Spatiality

Perception of the spatial location of sound sources is another parameter that can be manipulated for auditory display purposes. However it is used for a wide variety of purposes. Blauert offers the most widely referenced introduction to spatial localisation [19].

Another aspect of spatiality is the effect it has to improve perception of spatially disparate signals. This is, to some extent, based on the increased signal-to-noise ratio differences present in each ear when two sources are spatially separated on the horizontal plane [20].

For an example of direct mapping to spatial location, statistical graph sonification has been used by Franklin [21]. Perceived source location was used to represent aspects of a pie chart. Five different designs were compared to find the most effective way and the smallest angular separation of sound sources was evaluated in different frequencies.

For an alternative purpose, spatial location is widely used in circumstances with high visual workload (such as air traffic control systems [22]) or for the visually impaired. Although the perception of spatial location lacks accuracy compared with visual perception, it is advantageous due to its ear-point-eye function. For instance, localisation displays have been used to direct aircraft pilots to the location of an inbound target [23].

In the tutorial we introduce three basic spatial methods that are appropriate in the context of a stereo playback system. Three fundamental parameters to manipulate are:

- Horizontal source location, controlled by interaural level differences (ITDs), the most common method for controlling pan in a stereo playback system.
- Perceived Source distance, manipulated using both direct-to-reverberant sound ratio, and with gain controlled by the inverse square law. Shinn-Cunningham provides a review of 'auditory distance perception' [24].
- Horizontally perceived source width, manipulated using complementary comb filters applied to a harmonic tone.

4.3. Loudness

The perceptual sensation of loudness is an intrinsic attribute of sound. Whilst it is strongly related to the sound pressure level of a sound stimulus, many authors have described its various dependencies, such as frequency range, stimulus bandwidth and duration [25].

Although as a continuously variable attribute of sound it can be used for conveying information, Brewster recommends using loudness carefully , because of the potential problems of loudness adaptation, fatigue and risk of damage [26], [27]. Also, Flowers states that one of the most important factors precluding the successful widespread use of loudness for conveying quantitative information is the non-linearity of playback equipment of differing qualities [11]. Furthermore, explorations into the relationship between pitch and loudness have also been conducted by Neuhoff et al., revealing that people can perceive a greater change in the same loudness with a rising pitch than with a falling pitch [28].

However, despite these caveats, loudness is useful for certain purposes. Flowers advocates the use of loudness to signal contextual cues or events within a pitch mapped stream [11].

Our tutorial will demonstrate loudness mapping. We temper this however by also demonstrating the orthogonal effects of pitch and duration, especially at low frequencies. The need to take into account the wide variety of audio systems available to a user is demonstrated through simulation based on compression and filtering. Demonstrations of the provision of contextual cues while sonifying a data stream will also be provided.

4.4. Time, Repetition and Duration

Time is often an integral part of auditory displays, especially in sonification contexts. Sonification can not be scanned in the same way that visual graphs can, due to its dependence upon presentation over time. This is a strength of sonification, as the auditory system is generally considered to be more finely tuned to temporal characteristics than the visual system [29], and some patterns can emerge very quickly when this type of approach is taken.

Pulsation of sound can reduce the chance of masking because our auditory system is attuned to locating rhythmic signals [30]. Hellier presents a method for calculating the pulse rate necessary to affect a specific amount of change in urgency [31]. Our tutorial demonstrates this mapping simple datasets to transforms of pulse repetition rate based on Hellier's research. We also demonstrate auditory location of rhythmic elements in complex sound mixtures, as well as the use of pulsing to avoid masking.

One of the more apparent misunderstandings of sonification design was the use of data presentation rate. Novice designers can produce sonifications that are often much slower than necessary, especially with large datasets. Our data control interface already incorporates control over this attribute, but it will be extensively demonstrated. The use of duration as a parameter for conveying information is not often advised in research literature. Comparison between this and other methods will demonstrate this aspect of memory.

4.5. Timbre

Timbre is a multivariate attribute of sound. At a very basic level, it can be described by its temporal and spectral characteristics.

Timbre can be investigated to a degree through the use of Fourier analysis, and we are supported by *Max/MSP's* scrolling spectrogram display and extensive visualisation facilities. Gain can also be extracted and displayed interactively, and by this method we can discuss overall temporal characteristics. In this context we then introduce filtering and alteration of the quality of temporal envelopes.

Brown et al. state that using sounds with a complex spectrum improves their perception, and makes them easier to use than sine waves [32]. Sine waves also exhibit many unique characteristics such as the covert peak area effect (see [19]) that are generally not appropriate in most auditory display applications. These effects can be allieviated by using any tone with a complex spectrum. Timbre is effective for conveying categorical information and less often used for continuous or time-based data. A useful characteristic of timbre is that it enables listeners to distinguish sounds which have similar pitch and loudness, and Brown et al. also observe preference in users and increased performance for timbral differences between streams [32].

Neuhoff has discussed a more developed use of recognisable environmental sounds as a method for display, as opposed to typical auditory displays that employ abstract sound parameters to convey data [33]. Natural sound contains some characteristics that can be associated with objects by aural metaphors and assists user to recall the role sharing in real world.

Our tutorial approach defines timbre very broadly, and as such we discuss simple uses of timbre. Streaming based on timbral differences is demonstrated – the student is given control over two data streams mapped to pitch and a variety of similar and different timbres. They can experiment with using same, similar and different timbres, and the effect this has on streaming and grouping. Finally, we develop a display based on altering characteristics of natural sounds in the manner discussed by Neuhoff. For this we use the heartbeat sample that Student Two presented (as in Section 2.2), and exploit the extensive sample playback control provided by *Max/MSP*.

5. FUTURE WORK AND CONCLUSIONS

Future plans for the tutorial include the incorporation of much more supporting material and more primary material regarding sonification algorithms as it becomes available. A special focus should be on auditory icons, earcons and the design of auditory alert schemes, areas not yet covered thoroughly. Due to *Sybil's* modular design, new topics and demonstrations can be very easily and arbitrarily added.

Students are bi-annually required to complete a subject evaluation in which feedback will be obtained on the subject in general, and also the contribution made by this particular tutorial design.

A disappointing limitation is the lack of accessibility features for the visually impaired. Being a visual programming language, *Max/MSP* significantly preferences vision and is probably difficult if not impossible to use through typical screen-reading software. Unfortunately, there seems no comparable environment that provides the necessary flexibility in this integrated digital media curriculum. It would be very helpful if this limitation could somehow be addressed.

In conclusion, this paper has presented the foundations of an information sonification education platform in development. The parameters chosen for mapping and graphing are based on current auditory graph literature. The purpose of the tutorial software environment is to give students a practical auditory-aware introduction to the breadth of knowledge required for information sonification, to attempt to rapidly engage students across the gamut of bases implicit in the interdisciplinarity of data sonification and to introduce fundamental literature and online resources supporting this emerging area. Its educational context is for teaching sonification and also to support the wider need for an understanding of the relation between data representation and auditory parameters, utilised in sound design, interaction and installation design courses.

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