WP 3 – Interactive Sonification and Active Music Experience of Dance

D3.1 – First version of the sonification software libraries

Version	Edited by	Changes
1.0	KTH	First draft version.
1.1	UNIGE	Added experiments demonstrated at SONAR+ and STARTS Workshop, and Festival della Scienza in Genoa.
1.2	KTH	Revised the structure of the deliverable. Added section "3. Planned work"
1.3	UNIGE	Revisions on the DANCE Sonification Framework and on Section 3.

TABLE OF CONTENTS

Introduction

The main aim of WP3 is to identify effective mappings between physical gestures and sound parameters to support feedback and understanding of quality features in human movements. In this context, we will focus on physical quantities derived by human body movements, from low level features (e.g., accelerations in running) to higher-level expressive qualities (e.g. fluidity of movement), and by human-generated movements (e.g., spatial movement of an object). This WP will therefore develop a number of different sound processing and synthesis models that will become the basis for the interactive sonification and active music experience. We will implement sound synthesis models for reacting to body movements in a natural way with the aim to map movement qualities into the auditory domain.

1. Preliminary Experiments and Feasibility Studies

1.1 Identification of first sound models for the communication of body motion qualitites

In order to identify what should be the main characteristics of sound models suitable for communication of body motion qualities, we run a pilot experiment with pre-school children (early description of the experiment can be found in DANCE Deliverable D5.1).

We chose children for this first experiment since we wanted to have spontaneous reactions from users to our sound models, since children usually show fewer inhibitions than adults, and it has been shown that they spontaneously move when their hear sound. The main idea with the experiment was to test if the quality of children's motion would vary when the sound generated by their own movements had different acoustical characteristics corresponding to smooth or jerky sounds. In particular, we created three filtered noise models ranging from very fluid (wind-like) sounds to very jerky (choppy, clicking) sounds.

1.1.1 Procedure

We carried out a repeated-measures experiment in which longitudinal data of subjects' movements was collected in a motion capture room. Groups of three to four children moved freely in the room, which was equipped with a 8 speakers audio system. Subjects were wearing hats with rigid body markers attached to them, allowing for tracking of their movements. The movement of the subjects triggered three different sonification models (S1-S3). Moreover, subjects got the chance to move freely to classical music ("Piano Trio No. 1 in D Minor, Op. 49: II. Andante con moto tranquillo" (M1) by Felix Mendelssohn and "Carneval des Animaux" by Camille Saint-Saëns (M2)). Two pre-school classes from Förskola Sture, Stockholm, participated in the experiment, giving a total of n=21 subjects (M=6, F=15, age 4-5 years). Subjects were divided into groups of 3-4 participants, with a total of 6 groups. Each group participated in two iterations of the experiment: one recording session in the morning and one in the afternoon.

The longitudinal data collected for this three level repeated-measures experiment resulted in a hierarchical data-set in which repeated measurements (level 1) were nested within in our unit of analysis, i.e., subjects (level 2), who were in turn nested within experiment groups (level 3). Each group was presented with five different auditory conditions: excerpt from the two pieces music M1 and M2 and the three different sonification models S1-S3. Each experiment began with a brief introduction by the test leader, who explained to the children that they were allowed to move freely in the room, and that their movements would produce sounds. Instructions were read from a pre-written script. The instruction was followed by condition M1. The purpose of introducing music model M1 into the experiments was to allow children to get acquainted with the task and to start moving freely to sound. Furthermore, the purpose was to introduce a control condition. After M1, a counterbalanced order of the sonification models were presented to the children. Each sonification model was presented 6 times. The entire experiment ended with condition M2. The length of all sonification conditions was 36 seconds. The music conditions were 1 minute long. The experimental sessions lasted approximately 13.5 minutes.

In this study, we opted for a repeated measures design. Even though it might be more difficult to make inference for dependent data than for independent data, repeated measure designs based dependent data can be very efficient. A longitudinal data setting in which multiple conditions are applied to the same subject over time can be beneficial since the subject will act as her/his own control.

1.1.2 Technical Setup

The technical experimental setup consisted of several different software systems that formed a chain, starting with the Motion Capture and ending with the generation and spatialization of the sound. The Motion Capture system we used was an Optitrack Prime setup, including 16 cameras, controlled by the Optitrack Arena software. While tracking and recording, the Arena software also streamed data to a second application, using the NatNet protocol. The second application, running on a second computer, was a custom piece of software, written in C++, that received the incoming NatNet data stream, visualized it, performed some additional calculations on it, packaged the original data with the derived secondary data, and finally sent it forward using the Open Sound Control (OSC) format. The final part of the chain was a third computer that took care of logging and sound generation and spatialization. The logging application took every incoming OSC-message, added a local time stamp, and wrote it to disk. For the audio, a Max/MSP patch was used to both generate and spatialize the audio, as well as automatically run through the set of sound models for each session in the experiment.

An AZ8922 Digital Sound Level Meter was used to measure dBA for all soundmodels during one of the experiment sessions. The following values were obtained when setting the sound level meter to "fast max hold" for group 1, recording session 1: S1 77.4 dB, S2 70.3 dB and S3 80.1 dB.

1.1.3 Sonification models

In a previous study, sounds with rich spectral content have been shown to be more appealing than other sounds to children with hearing aids or cochlear implants, with an early stage of cognitive development and with physical disabilities (Hansen et al. 2012). Sound of speed and acceleration can be ecologically represented using simplified sound models reminding of the sound of wind, for example those used in the sonification of rowing actions (Dubus 2012; Dubus & Bresin 2015). Three simple sound models based on filtered white noise were defined for this experiment. One with very fluid, wind-like, sounds (S1); one middle model with somewhat jerky sounds (S2); and one with very jerky, choppy and clicking sounds (S3). For each sound model, low-level movement parameters (velocity and x- and y-position of the subject) were mapped to acoustic parameters.

Sound model 1 (S1) was achieved by filtering white noise using a resonance filter `MAX/MSP` `biquad` object with mode "resonant". Magnitude of the velocity of the subject's movement in the 2D-plane was mapped center frequency of the filter, in range 50 to 1100 Hz, and to Q-factor in range 1.8 to 4.0. Amplitude modulation of the filtered signal was carried out using the `rand` object, with input parameter 3 Hz. Finally velocity magnitude was logarithmically scaled to amplitude of the signal, so that no sound was heard when the subject did not move.

Sound model 2 (S2) was designed using the same technique as the one described above, but the resonance filter center frequency was set to 100-900 Hz and Q-factor range was set to 0.1-0.3. Amplitude modulation was also increased to 18 Hz.

The final sound model, S3, was also based on filtering white noise but with a band-pass filter, using the `biquad` object. As for the other sound models, velocity magnitude was mapped to the center frequency range, scaling it to 100-3000 Hz and mapping Q-factor to 0.01-0.6. Amplitude modulation was achieved by triggering peaks using the `curve` object (connected to a message box containing the following string "0.85, 0.0 50 0.5 0.0 200 -0.5") which produced a non-linear ramp of length 250 ms which was triggered every 50 to 800 millisecond depending on velocity.

In the experiment, each rigid body, attached to the head of the child, represented a sound source. Spatialization was done in such a manner that each child could hear the sound source follow her/his movement in the room. This was achieved through use of `VBap` 1.0.3 object (Pulkki 1997) by mapping distance from center point in the room to the spread of the virtual sound source and by mapping the subjects angle from the center point to the azimuth angle.

1.1.4 Results

Preliminary results show that the sounds models had an influence on the movement of the children (see Figure 1 and Figure 2). A repeated measure ANOVA indicated that the average velocity resulted to be different for the movements elicited by the five different sonic stimuli (M1, M2, S1, S2, S3). An observed trend was that the average velocity of most of the groups of children was higher when they moved with sound model S3 ("jerky" sounds) than with sound models S1 ("fluid" sounds). This confirms our hypothesis that sound models with different characteristics can be used for eliciting different qualities in body movements.

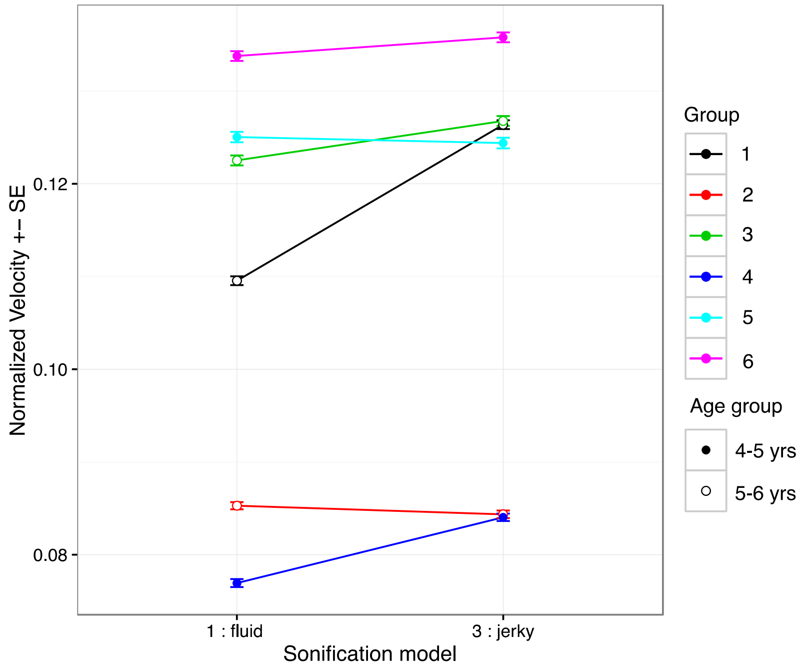
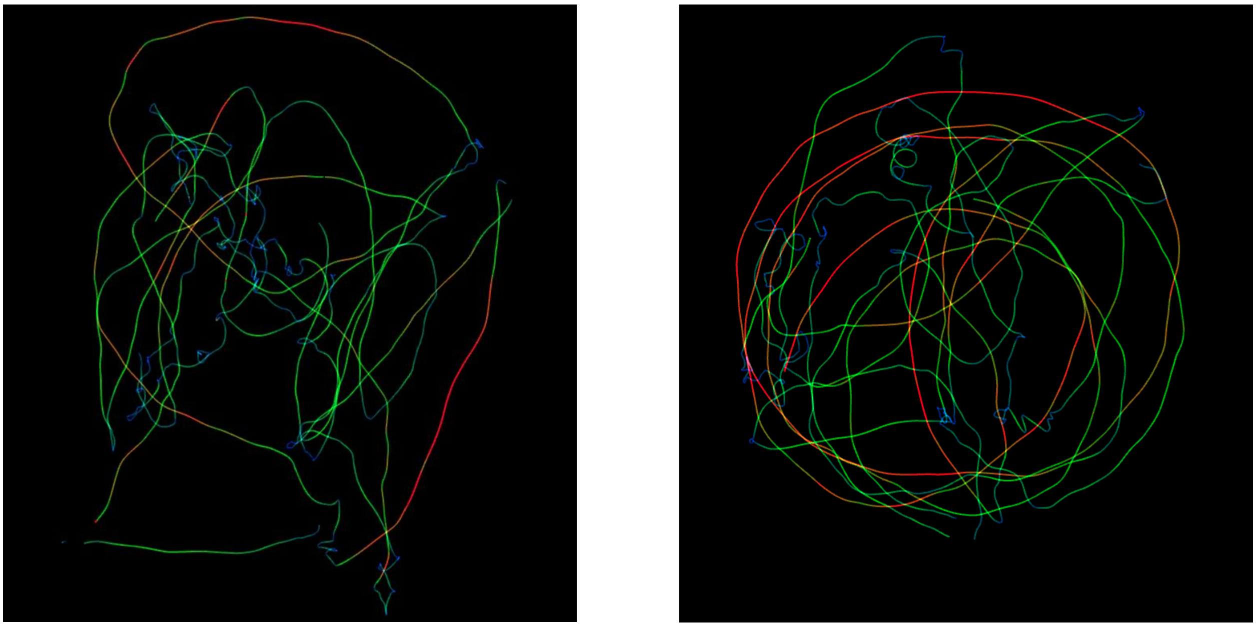


Figure 1 Normalized average velocity for each group of children moving with sound models S1 (fluid) and S3 (jerky).



Heat map S1, Group 1 Heat map S3, Group 1

Figure 2 Heat map for the movements of the same group of children (Group 1) with two sound models (S1, left panel; S3, right panel). Green colour show slow speed, red colour corresponds to high speed.

1.1.5 Perceptual experiment

In order to verify whether the sound models could communicate the hypothesised movement qualities or not, we run a perceptual test in which sounds generated by children in the previous experiment were rated by listeners along six different perceptual scales. The test was run during the Festival della Scienza in Genova (October, 27th 2015). Participants were asked to rate quality of the movements represented by a set of multimedia stimuli, along scales Fluidity, Energetic, Impulsive, Fast, Expressive, Rigid. Seven people (5 F, average age 28) took part to the experiment that was run on portable devices (tablets and mobile phones)

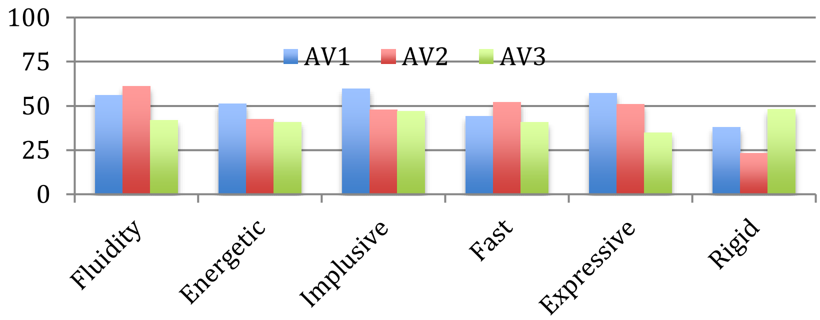
Stimuli

Stimuli presented in random order to the participants were of three types: videos with audio, silent videos, and sound only. For each stimuli category there were 9 stimuli corresponding to: 3 sound models x 3 repetitions. Participants were presented with a total of 27 stimuli. The videos showed the movements in the horizontal plane generated by children when moving to a sound model.

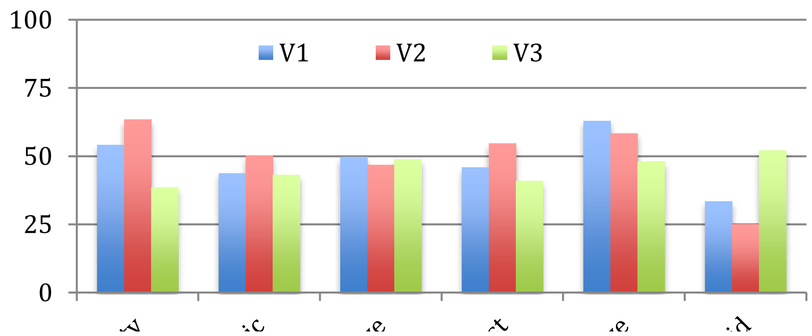
Results

The analysis of the collected data clearly shows that when only sound stimuli were presented to the participants, sound model S1 was rated as the one communicating fluidity of movements while sound models S3 was associated to the communication of jerky movements.

Participant ratings of Audio with Video stimuli. Videos AV1, AV2, AV3 correspond to sound models S1, S2, S3 respectively.



Participant ratings of Video only stimuli. Videos V1, V2, V3 correspond to sound models S1, S2, S3 respectively.



Participant ratings of Audio only stimuli. Audio stimuli A1, A2, A3 correspond to sound models S1, S2, S3 respectively.

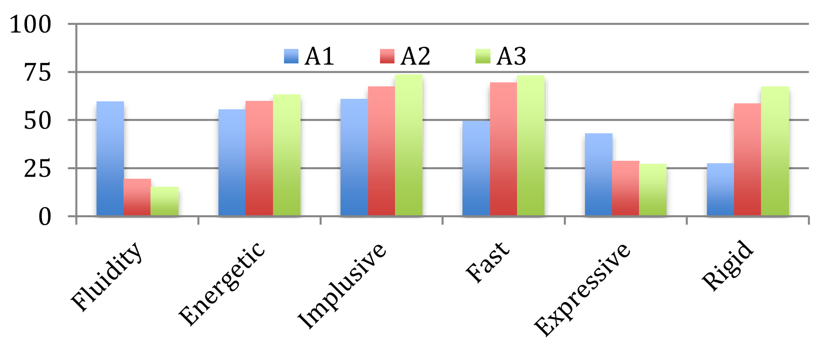


Figure 3 Average rating of all stimuli by the participants on the six scales Fluidity, Energetic, Impulsive, Fast, Expressive, Rigid.

Conclusions
The result from the experiments presented in this section confirm our hypothesis about what kind of sound parameter to manipulate for the communication of two body motion qualities such are fluidity and jerkiness, and provide us important information for the design of the sonification library described below.

1.2 Sonification of four movement qualities: energy, fluidity, weight, and impulsiveness

In parallel with the children experiment described in the previous section, experiments and trials in public events on interactive sonification of a first set of movement qualities (developed by UNIGE in collaboration with the composer P. Palacio) were conducted and evaluated at SONAR+ in Barcelona (June 2015), at the STARTS Workshop at Bozar in Brussels (June 2015), and at the *Festival della Scienza* in Genoa (October 2015). We designed a variety of synthetic acoustical models for the sonification of four movement qualities: energy, fluidity, weight, and impulsiveness. These movement qualities are the first implementation developed during the first phase of the project, and are computed from accelerometers data and from mocap. The public experiments were implemented with xOSC wireless accelerometers. Each of these sound synthesis approaches models the response of sounding objects, materials or natural phenomena using mathematical abstractions. The sonification approaches range from what is known as Parameter Mapping Sonification (PNSon) to Model Based Sonification (MBS).

The design of each of the following synthesis models and non-linear mapping strategies aims at a conveying intuitively the characteristics and qualities of movement. The sound synthesis models and mapping strategies were designed to transmit the richness, complexity and realism of real world sounds, as a means to fulfil DANCE objectives to translate a movement quality into sound. The synthesis models are built and mapped taking into account the underlying common ground between dance and sound, and how movement qualities may also be considered in relation to the nature and articulation of sound objects. As it may happen with everyday sounds, what we listen depends on the sensorimotor coupling with an instrument or a resonating object in a way that we can possibly infer the movement from the resultant sounding morphology (Spence 2011).

Finally, although there is always a systematic model for the way movement and sound are coupled, in order to add more realism and richness to the interaction, small variations of sonic details were overlapped to the basic synthesis models.

These preliminary sonifications were written in Supercollider language. Next steps of DANCE will include the development of further sound synthesis and mapping environments using also other languages and tools, including Max/MSP. The following subsections describe the preliminary synthesis models employed for each of the four movement qualities evaluated and disseminated in the first year public events mentioned above.

1.2.1 Energy (quantity of movement)

An original implementation of first order dynamic stochastic sound synthesis. In this model the extracted quantity of movement of each virtual sensor (pre-processed data from xOSC accelerometers) is connected to the Brownian movement simulation that perturbs the breakpoints of a polygonized audio waveform. The energy index of the dance movement is connected to the position of the elastic barriers and step size of the amplitude and duration of random walks on such poligonized audio waveforms. The sonic gamut ranges from an equilibrium state with calm low and damped mechanical sounds, passing through bright clusters of bounded glissandi to more noisy entities covering the mid high registers.

A sound synthesis model of scrubbed rubber conveys the energy of movement injected in the system. In a nutshell, the model is comprised of an array of comb filtered sawtooth waves whose frequencies and delay times are controlled by a low frequency oscillator that generates polynomially interpolated random values. The energy index extracted from the dancer's activity controls this random number generator. Finally, although sound spatialization may be regarded as a tangential aspect of the signification at this stage of the project, the two clusters of synthesizers are spatialized on the stereo field and assigned to each sensor.

1.2.2 Weight

A granular synthesis model that may produce percussive sounds ranging from wood-like dabbed or light quick strokes to heavy metal drum-like percussive hits. The heaviness of the dancer's movement is mapped across this acoustic axis. In this model a noise generator whose values are only either 1 or -1 is filtered with 18 frequencies that are exponentially distributed. This type of combination is very effective in order to produce sharp metallic sounds. A Gaussian distribution is used to organize the percussion clouds. The more weight is put in the movement the more metallic, longer the decay and denser is the stochastic cloud of percussive sounds.

The model of scrubbed rubber is used again to sonify the weight quality of movement. The nature and abrupt time dynamics of the weight index produce a result way different from the one obtained in the energy index. Also In this case only one synth (instead of a cluster as in the energy model) is employed. Accordingly instead of assigning different synths to each sensor, the most relevant weight value is chosen among all sensors and thus connected to the parameters. This way all pertinent movements are sonically displayed. The acoustic result is that of clear twisted rubber friction sound which works very well with friction movements that match Laban's wringing effort.

1.2.3 Fluidity

A resonating string model achieved based on a synthetic model of a resonating string system combining subtractive and additive synthesis. Each synthesizer is composed of a variable number of integer multiples of a fundamental. These partials are perturbed by a Brownian movement generator that adds a natural and organic quality to the sound. However, the perturbation of each partial does not deviate from its centre frequency by more than 2%, which leads to a spectral fusion of the tone complex into a single pitched sound, following Diana Deutsch model of grouping mechanisms in music. Finally a random number generator controls the frequency range and rate of glissandi. The fluidity index connects with the parameters of the random number generator as well as with the amplitude and damping of the partials. The acoustic result moves between flowing, soft and waving glissandi when fluidity is high, and mechanical frequency changes and more metallic sound entities for low fluidity. In addition, the energy index is used to inform spectral brightness controlling the actual number of partials to be perceived and it's relative amplitude.

A sounding liquid synthesizer that models both the vibration of surface water and underwater bubbles was originally implemented in the programming language. Fast movements, thus more keen to have less fluidity, are connected to surface water sounds while slow movements emphasize the underwater part of the model. Accordingly when the dancers move fast the acoustic response is that of splashing the liquid, while slow fluid movements produce underwater sounds since when being underwater our movements are slow and fluid. Accordingly the fluidity index control parameters such as bubble radius, density of bubbles and reverberation index.

1.2.4 Impulsivity

A very simple additive synthesis model was developed, in which the more impulsive the movements are, the more harmonics the corresponding sound has. The algorithm distinguishes between new impulsive movements (positive values) and stopping a repeated movement pattern (negative values). This distinction is sonically displayed using sharp attacks for positive values and slower attacks for negative values.

These early interactive sonification models were exploited and preliminarily validated in the public events SONAR+, STARTS and Festival della Scienza with dancers and non-dancers.

Short video demos of these public events are available in the project website: dance.dibris.unige.it.

These sonification models constitute a starting point for a second iteration of the DANCE project interaction design, described in papers in preparation (paper submissions to MOCO Conference, July 2016).

2. The DANCE Sonification Framework

The development of the sonification framework has so far resulted in a library of software modules supporting the design of interactive sonifications. An interactive sonification application will consist of analysis modules, based on the EyesWeb platform, a *Mapper* module and a *Synth* module for sound synthesis. The Mapper acts as a transfer function and mixes and combines different data streams, from the analysis that precedes it in the chain, into specialized control data that is sent to the Synth. The Synth is a high performance real-time audio synthesis application that is capable of creating a wide range of sonic outputs.

The Mapper can be implemented either as a module in EyesWeb or as a separate application in the *SuperCollider* programming language, an open source development environment that provides support for Windows, MacOS, and Linux.

At the time of this writing, a Mapper software implementation at KTH is at an early prototyping stage of development, with some of the mechanics of the input, processing, and output working. The full user interface is not finished and the more complex forms of data processing are not yet available. Mapper implementations at UNIGE have been developed in EyesWeb, for the experiments on the interactive sonifications including the previously mentioned public events.

All implementations of analysis and interactive sonification modules communicate by means of shared standard protocols, including OSC (Open Sound Control), as explained in the following sections, thus enabling the ex hange and integration of modules developed by KTH and UNIGE, and possibly by external users exploiting the results of the DANCE project.

Implementations of the Synth include the modules adopted in the public presentations as well as the modules adopted in the feasibility study and experiments with children described in the previous sections. .

The DANCE Sonification Framework was adopted at the Enterface 2015 International Summer Workshop.

2.1 The Mapper

The input and output of the Mapper application is sent using the Open Sound Control format (OSC), an open standard for communication that is very common in software for media production and analysis, making it compatible with many, if not most, systems that would be usable for motion tracking and other data generation methods (e.g. *openFrameworks*[1], *Cinder*[2], *Max/MSP*[3], *SuperCollider*,[4] *Pure Data*[5], or *EyesWeb*[6]). OSC allows for a large variety of message types, and the Mapper software will allow the user to define a very large variety of logic structures to interpret the incoming data and generate new data streams, specially designed to control the Synth application.

The interface of the Mapper implementation developed at KTH will consist of a matrix-like structure, or lattice, where the inputs to the Mapper are sent into each row, and the outputs from the Mapper are represented by the bottom of the columns, see Figure 4 (Roads, 2004) for an illustration that shows the flow of data through the Mapper. In each "cell" of the matrix a transfer function can be added that manipulates the incoming data and sends the result to the corresponding output. This allows the user to both combine several inputs to one output as well as distributing one input to many outputs. In technical terms this allows for one-to-one, one-to-many, many-to-one, and many-to-many mappings. In other words, using the case of the sonified dancer as an example, several different qualities of movement (e.g., speed, quantity of motion) can be combined to control one synthesis parameter (e.g., amplitude, frequency), but in another case, one important movement feature could be used to control many parameters in the audio synthesis, but perhaps in different ways.

1 http://openframeworks.cc/

2 https://libcinder.org/

3 https://cycling74.com/products/max/

4 http://supercollider.github.io/

5 https://puredata.info/

6 http://www.infomus.org/eyesweb_ita.php

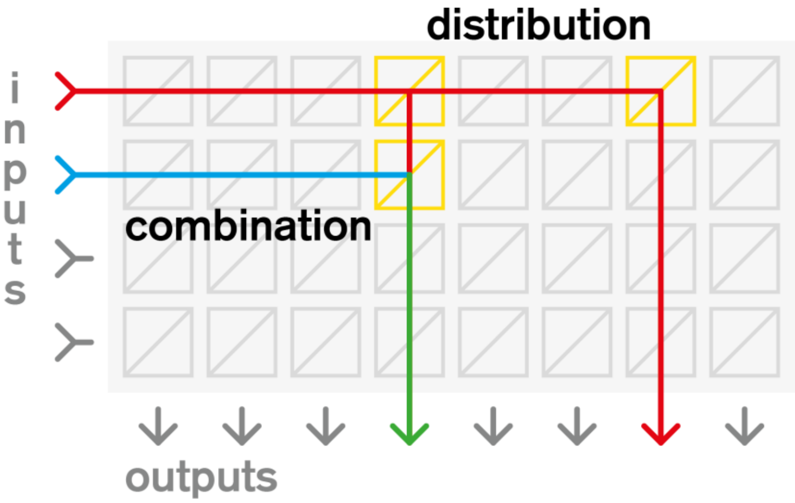


Figure 4 An illustration of the flow of data through the Mapper.

Mapper implementations in EyesWeb will enable dynamic, adaptive, and context-sensitive mappings between movement analysis and sonic features, at different levels of abstraction. This means that the same vector of movement qualities may be mapped onto different sound parameters, according to the state of the system and the context of the interaction. This approach will be described in scientific papers in preparation (submissions at MOCO Workshop) and in reports/papers on collaborations with composers and artists.

2.2 The Synth

Once the control data is received by the Synth, it might use it to drive, control, and blend a number of different sound models. Therefore, there is no processing of the incoming control data in the Synth, as that operation has already been carried out by the Mapper. The Synth, instead, allows the user to create a set of any number of sound models that can be layered in any combination. The individual sound models are described. Instead of assigning one sound model to each dancer (for instance), each type of movement in the performed choreography can be connected to completely different types of audio synthesis. The illustration in Figure 5 shows how the different sound models can be layered and arranged in a continuum, in which the position can be controlled by control data sent from the Mapper. In parallel, this is comparable to have access to a full orchestra instead of just a single instrument.

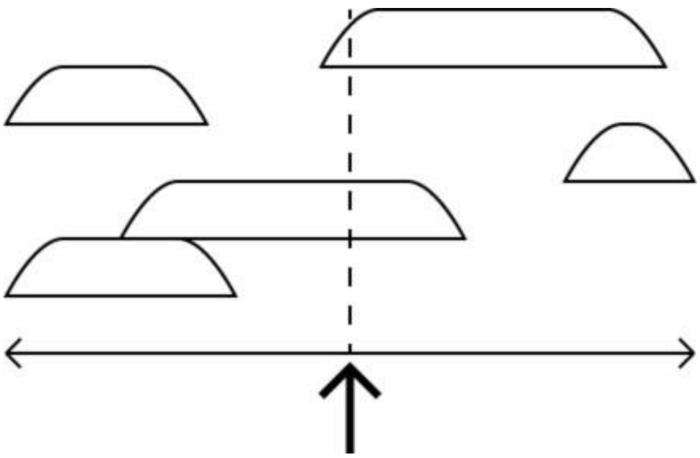


Figure 5. Illustration of the layering of sound models that allows a single parameter to move through a series complex combinations of sound models.

2.3 Sound Models

Short descriptions of further sound models currently implemented in the Synth are provided below

2.3.1 Subtractive – Periodic

This is a model derived from the classic early synthesizers concepts where a rich periodic waveform is filtered, using a combination of low and high pass filters, to sculpt the spectrum while still maintaining a clear sense of pitch. This model is useful if a tonal or harmonic characteristic is wanted.

2.3.2 Subtractive – Stochastic

Similar to the model above, this model filters a rich but a-periodic, stochastic, sound, i.e. noise. This has been widely used in the literature and it has been shown that it is useful to convey measures of speed, size, and other movement qualities.

2.3.3 Frequency Modulation

With the Frequency Modulation synthesis technique, introduced by Chowning (Chowning, 1973) and popularized by Yamaha, a wide range of sounds are possible, tonally different than those made possible by the sound models above, especially since it allows for in-harmonic, bell-like, metallic sounds.

2.3.4 Granular - Sample Based

Granular synthesis is a technique that produces a large number of very small *grains* of sound, often in the 10 - 100 millisecond range (Roads, 2004). The stream of grains are then controlled as a group rather than on an individual level. The model is capable of sounds ranging from the very smooth all the way to percussive and abrasive. In this mode, the grains are actually short pieces of a sound file that is loaded into the model, and because of this any sound source that can be recorded can be exploited by this sound model.

2.3.5 Granular - Phase Modulation

This model is similar to the sample based granular synthesis model, but instead of filling the grains with small snippets of a sound file, the grains all contain a simplified version of the phase modulation sound model described above (Roads, 2004). This allows for very interesting seamless morphing between noise, in-harmonic sound, and harmonic sound.

2.3.6 Waveguide

Waveguide synthesis is a way of creating a physical model of how sound waves propagate through different objects (Smith, 1992). With it, emulations of strings a drum membranes can be created that possess many of the complex "natural" qualities that their real-world equivalents do.

2.4 Future work

- After further testing, the graphical user interface of the Synth module will be reworked in response to the feedback of the users.
- More modules of the Synth as well as more sound models will be added to the Synth, such as:
  - Additive Synthesis
  - Scanned Synthesis
  - Banded / Dispersive Waveguide Synthesis
  - Spectral Modelling Synthesis
- An effect section will be added for post-processing of the layered sound models in the Synth, such as:
  - Reverberation, echo and other delay-based effects.
  - Dynamic compression.
  - Filtering and spectral equalization.

3. Planned work

The work described in this document constitutes a preliminary step of the interaction design process of DANCE. New parallel iterations are in progress and are here briefly summarized.

Next steps in the development of the Sonification Framework include its refinement and development by adding more sound models, based on both results from scientific experiments and from evaluation in public events and collaborations with artists. UNIGE will further collaborate with composers aiming at extending both the models of mapping and of sound synthesis, and to create a platform useful, for example, for the evaluation and comparison of different sonifications of the same movement quality. In this direction, UNIGE collaborated with the composer Pablo Palacio for the interactive sonification of movement qualities in the SONAR+ EU booth (Barcelona, June 2015), at Bozar STARTS event in Brussels (June 2015), and at Festival della Scienza in Genoa (October 2015). In future events and collaborations with artists we will investigate different scientific challenges, including the following: development of dynamic mappings enabling a continuous interpolations and moulding between different mappings, in order to change the sonification in real-time between different mappings, and to create a sort of "storyboards" of mappings depending on high-level movement parameters. KTH will test his Sonification Library on the motion capture data of specific movement qualities collected by UNIGE.

KTH has recently received a new R-IoT IMU sensor developed by IRCAM[7] in the framework of the "CoSiMa project (funded by ANR) and the MusicBricks project funded by the European Union's Horizon 2020 research and innovation programme". KTH is planning to test the Sonification Library also on movements collected using R-IoT.

KTH will run perceptual experiments for the evaluation of different sonifications using the online Survey Gizmo platform[8]. In a first discussion within the project consortium we were planning to take advantage of the Mechanical Turk system available at Amazon[9] but, for ethical issues that has emerged on the use of that system[10][11], we have decided not to use it and to organized our test with Survey Gizmo.

UNIGE will develop a serious game platform for the evaluation and comparison of sonification strategies, that will be presented in upcoming papers and public events, also in collaboration with artists.

Evaluations of sonification will be subject of validation by means of neuroimaging experiments in collaboration with MU.

KTH and UNIGE will collaborate on a joint study and publication on leadership in group-dynamics. We will analyze the motion capture data collected with the experiment with children presented above in Section 1.1. For doing this we will apply the methods developed by UNIGE for the analysis of leadership in musical ensemble (e.g. quartets and orchestra).

---

[7] http://ismm.ircam.fr/riot/

[8] http://www.surveygizmo.com

[9] https://www.mturk.com/

[10] The Unknown, Poorly Paid Labor Force Powering Academic Research

http://motherboard.vice.com/read/the-unknown-poorly-paid-labor-force-powering-academic-research

[11] Can crowdsourcing be ethical?

http://www.brookings.edu/blogs/techtank/posts/2016/02/03-can-crowdsourcing-be-ethical-williamson

References

Chowning, J. M. 1973, The synthesis of complex audio spectra by means of frequency modulation, Journal of the Audio Engineering Society, 21(7):526-534

Dubus, G. 2012. Evaluation of four models for the sonification of elite rowing, Journal on Multimodal User Interfaces, 5(3-4):143-156

Dubus, G., R. Bresin, R. 2015. Exploration and evaluation of a system for interactive sonification of elite rowing," Sports Engineering, 18(1):29-41

Hansen, K. F., Dravins, C., & Bresin, R. 2012. Active listening and expressive communication for children with hearing loss using getatable environments for creativity. Journal of New Music Research, 41(4):365-375.

Pulkki V. 1997. Virtual Source Positioning Using Vector Base Amplitude Panning, J. Audio Eng. Soc., 45(6):456–466

Roads, C. 2004. Microsound, MIT Press

Smith, J.O. 1992. Physical modeling using digital waveguides, Computer Music Journal, 16(4):74-91

Spence, C. 2011. Crossmodal correspondences: A tutorial review. Atten Percept Psychophys (2011) 73:971–995. DOI 10.3758/s13414-010-0073-7