Chapter 5

5. Sonification Details

Sound has many attributes that can be used for representing various data dimensions, including pitch, loudness, rhythm, damping or attack/decay rate, direction, duration and repetition, timbre and harmonics, phase, and rest periods. The preferred attributes provide independence, resolution, continuity, and ease of perception by untrained users.

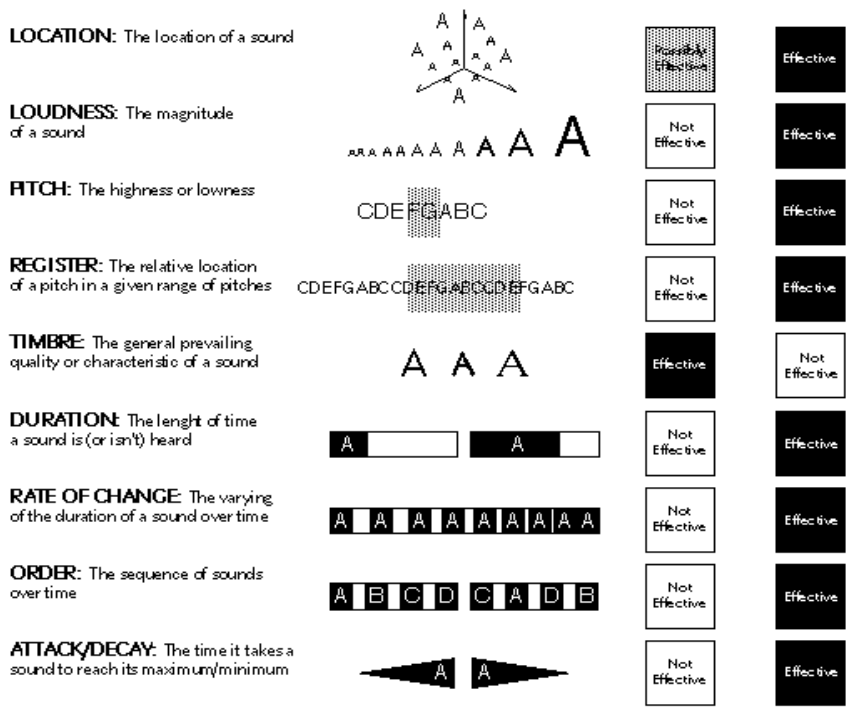

Figure 5.1: Sound Attributes

- **Location:** The location of a sound in a two or three dimensional sound space.

Location is analogous to location in the two dimensional plane of the map. As a sound variable location requires stereo or three-dimensional sound displays. Two- and three-dimensional sound allows for the mapping of left/right, up/down, (and in 3-D) forward/backward locations. Location can represent nominal and ordinal data. For example, a two-dimensional stereo sound map could use location to direct attention to a specific area of the graphic map display where the fastest change is occurring in a spatial data set over time.

- **Register:** The relative location of a pitch in a given range of pitches. Register describes the location of a pitch or set of pitches within the range of available pitches. Register is a more general case of pitch, where one can specify a high, medium and low register, each retaining a full set of chromatic pitches. (note 4) It can add to pitch as a broader ordinal distinction. An application which uses register and pitch is discussed later in this paper.

- **Timbre:** The general prevailing quality or characteristic of a sound. Timbre describes the character of a sound and is best described by the sound of different instruments: the brassy sound of the trumpet, the warm sound of the cello, the bright sound of the flute, etc. Timbre, then, implies nominal differences (Risset and Wessel 1982, Kramer and Ellison 1992). For example, a brassy sound could be used to represent an urban phenomena while a warm or mellow sound could be used to represent a rural phenomena. Such an example draws attention to the evocative nature of sound.

- **Order:** the sequence of sounds over time. The order in which sounds are presented over time can be "natural" - such as the progression from a low pitch to a high pitch - and this means that it should be easy to detect general trends (patterns) in data presented with sound variables such as pitch or loudness. The "natural order" of sounds can be manipulated to represent data "disorder" or different orders. For example, if a natural order of sounds (say pitch from low to high) is matched to chronological temporal order, any non-ordered sound will be recognizable as an indication that data are out of chronological order. An example will be discussed later in this paper.

- **Attack/Decay:** the time it takes a sound to reach its maximum/minimum. The attack of a sound is the time it takes for a sound to reach a specific level of loudness; the decay is the time it takes to reach quiet. Attack has been found to be much more successful in conveying information than decay (Lunney and Morrison 1990, 144). Attack/decay could be used to represent the spread of a specific data variable in a given unit: for example, pitch may represent an average value for the income in a county and attack/decay the spread of values; a long attack and decay would represent, then, a wide range of incomes in that county. Attack/decay may also be used to represent rates of diffusion or recession.

The sound attributes according to the sound attribute overview which haven't been explained yet are issued in the following sub chapters. They are emphasized in separate chapters because they are part of the application xSonify.

5.1 Sonification Modus: Pitch

The probably most famous way to display information in an acoustic way is to choose the pitch attribute of sound. The lowness and highness of a sound (the frequency) respectively contains in that case the information. Pitch is highly distinguishable and is one of the most effective ways of differentiating order with sound. On average, individuals can easily distinguish 48 to 60 pitches over at least four or five octaves, and this implies that pitch, divided up by octaves can be used to represent more than a single variable in a sonic display (Yeung 1980, 1121).

But beside all the positive aspects of this Sonification method there are also things which have to be considered.

- Judgments of pitch will vary somewhat from person to person.
- Western music has traditionally employed a scale of eight octaves comprised of twelve pitches each; extreme pitches, however, are hard to distinguish.
- Mapping with pitch is appropriate for ordinal data. In addition, pitch may imply direction, where, for example, an increasing pitch represents upward movement.
- Tonal sharps and flats can be used to some effect also, possibly to represent a second variable such as variations in data quality. Every twelfth pitch has the same pitch color (chroma) and this may serve to represent nominal or ordinal data (Weber 1993b). Pitch, then, can represent quantitative data, primarily ordinal. Time can be added to pitch to create a sound graph which tracks ordinal change in data over time.

5.2 Sonification Modus: Volume/Loudness

The second parameter of sound which is used to hear the data is the volume of a certain tone. According to the current values in the data sequence the volume/ loudness is measured in terms of the decibel and implies an ordinal difference. The average human can just detect a one decibel sound, can detect differences in loudness of about three decibels, and can tolerate up to approximately 100 decibels (e.g. the loudness of a jet taking off). Loudness is inherently ordered and thus seems appropriate for representing ordinal level data. Loudness may be used to imply direction and can be varied over time to represent ordinal change in data over time (e.g. to alert one to important but infrequently occurring phenomena).

It is known that humans usually become unconscious of constant sounds (Buxton 1990, 125). For example, although the hum of a computer's fan in becomes inaudible soon after switching it on, even a slight variation in the fan will be instantly noticed. This effect can be used to represent information where a quiet tone represents a steady state and any variation represents change.

5.3 Sonification Modus: Rhythm

The last modus in our software application is the idea to use a certain rhythm of a beat instrument to display the information. During this modus the whole range of data values are fragmented into a certain number of groups. Default amount of groups are 20 but can be changed in the average panel. The idea is that every group has the value of the average of all values inside a group and the value represents a certain rhythm.

According to the sound attribute overview in the introduction of this Chapter this modus covers the sound attributes “Duration” and “Rate Of Change”.

- **Duration:** The length of time a sound is (or isn't) heard. Duration refers to the length of a single sound (or silence) and can represent some quantity mapped to that duration. Silence must be used in tandem with duration if one is to distinguish the duration of multiple sounds (Yeung 1980, 1122). Duration is naturally ordinal.

- **Rate of Change:** The relation between the durations of sound and silence over time. Rate of change is primarily a function of the varying (or unvarying) durations of sounds/silences in a series of ordered sounds over time and can represent consistent or inconsistent change in the phenomena being represented.

5.4 Sonification Process

Ed Chi [16], worked on a way how to display a visualization process and named it the "Data Pipeline". Analogously to this process Sylvain Daude[17] and Laurence Nigay presented a Sonification process which transforms and prepares the raw data to be finally sonified.

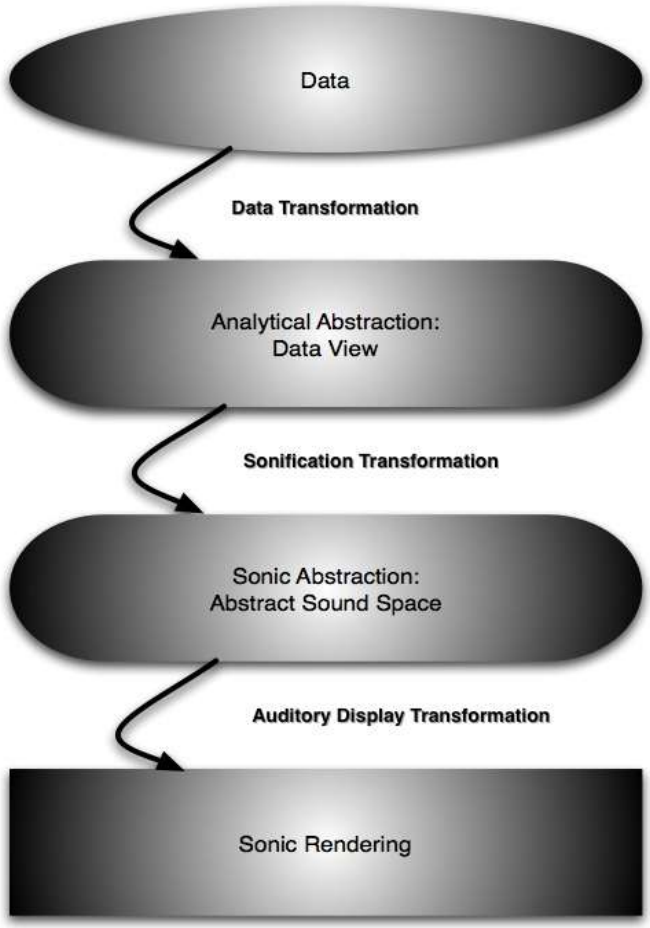

Figure 5.2: Sonification Process

The single points of this process will be explained in the following steps:

From Data To Data View: **Data Transformation**
In this step the raw data will be mapped value by value into a range of values between $0 < x < 1$. This process can be considered as a kind of standardization of values which is necessary to make the data available independent from their unit and scale.

From Data To Abstract Sound Space: **Sonification Transformation**
During this step the data are prepared according to the chosen Sonification modus. Every value will be assigned to a certain position at a "time line". This "time line" is represents the time line of the Sonification sequence which will be played in xSonify

in the MIDI player.

From Abstract Sound Space To Sonic: **Auditory Display Transformation**
This is the part where the signal is finally displayed on a physical device. In xSonify this is the part where the MIDI sequence will be transmitted to the MIDI player and played.

5.5 Delivering Of Information Through Sound And The Difficulties

Beside all the tempting opportunities and chances of the usage of the different sound attributes for Sonification I would also like to point to difficulties and challenges which can appear during the design phase of an application for Sonification.

Some complications are the direct result of how our nervous system processes sound, while other problems can be associated with the task presented or the environment in which the Sonification is used.

The following aspects which are representing some difficulties of Sonification should only give an idea of the problems which have to be faced during the design of an application:

- low resolution of some auditory variables
- limited spatial precision
- lack of absolute values
- absence of persistence
- no printout

Naturally the kind of application automatically determines if the usage of Sonification is appropriate at all and if so what kind of sound attributes or rather Sonification modus should be applied in the program.