Wave Arts Panorama HRTF File Format

Last update: Dec 7, 2022

Overview

This document describes the file format for Wave Arts Panorama HRTFs. HRTFs (head-related transfer functions) describe the transformation of sound from the fee field to the ears of a listener. In practice the data is stored as time domain impulse responses, known as HRIRs (head-related impulse responses), but the terms HRTFs and HRIRs are interchangeable. For a given listener or dummy head subject, an HRTF set will typically contain hundreds of individual HRTF measurements made at locations distributed evenly around the head.

The Panorama file format stores a set of HRTFs for a single subject at a single sampling rate. A text header file stores the parameters, and the filter coefficients are stored in a binary data file. For subject "dummy" the header file would be named "dummy.txt" and the corresponding binary data file would be named "dummy".

Organization

HRTFs are organized according to measurement direction specified in polar coordinates: elevation and azimuth angle. Elevation angle is measured from the horizontal plane; 0 degrees elevation is on the horizontal plane, 90 degrees elevation is overhead, and –90 degrees elevation is directly below. Azimuth angle is measured from the medial plane; for sources on the horizontal plane 0 degrees azimuth is directly in front, 90 degrees azimuth is directly to the right, -90 or +270 degrees azimuth is directly to the left, and +180 or -180 degrees is directly behind.

HRTFs are stored at a set of elevations angles specified in the header. At each elevation the HRTFs are stored at evenly spaced azimuths. The data stored for each HRTF is a set of "b" coefficients, an optional set of "a" coefficients, and an optional interaural time delay (ITD) value. Thus, the format allows for FIR or IIR filter specifications. The "b" coefficients are used to store time domain impulse response data (FIR filter coefficients). The "a" coefficients would be used to store filter feedback coefficients; however, Panorama does not use "a" coefficients. Each HRTF within the file stores a stereo pair of left and right ear responses, with the same number of coefficients, as determined by the number of "b" coefficients plus the number of "a" coefficients.

HRTF header file

HRTF parameter information is stored in the text header, with filename "XXX.txt". The header has the following format:

```
% comment
sampRate numElev numHrtf hrtfFlags numBCoeff numACoeff
elevs(1,:)
elevs(2,:)
itds(1)
itds(2)
...etc
```

```
itds(numHrtf)
```

Lines beginning with "%" are comments. "sampRate" is the integer sampling rate, "numElev" is the number of elevation angles, "numHrtf" is the actual total number of HRTFs stored, "hrtfFlags" are defined as:

```
#define HRTF_SYM        0x01
#define HRTF_ITD        0x02
#define HRTF_FREQ       0x04
#define HRTF_CRYPT      0x08
```

HRTF_SYM means the data is symmetric about the median plane, and thus HRTFs at azimuth angles greater than 180 degrees are not stored. When accessing a left hemisphere HRTF, the software uses the mirror image right hemisphere HRTF and automatically swaps the channels. HRTF_ITD means the HRTFs have their ITD extracted and stored in the header. The software will use a fractional delay line to restore the proper ITD. HRTF_FREQ means the HRTFs are stored as frequency domain magnitudes (using the b coefficients), without phase information. HRTF_CRYPT means that the HRTF data is encrypted. "numBCoeff" is the number of "b" coeffs per HRTF, "numACoeff" is the number of "a" coefficients per HRTF. When storing in frequency domain, the entire magnitude spectrum is stored, i.e., numBCoeff is the FFT size.

elevs(1,:) is a list of the elevation angles given on a single line of text, elevs(2,:) is the corresponding number of azimuths at each elevation (without considering symmetry, thus this determines the azimuth increment between measurements). The ITDs are stored one ITD per line, in units of sample periods, in the same order as the HRTFs are stored in the datafile. ITDs are only written to the header file if the HRTF_ITD flag is set. A positive ITD corresponds to a positive azimuth, i.e., a right hemisphere source. Panorama HRTFs must be in time domain format and must have number of "a" coefficients set to 0. However, the ITDs do not have to be extracted. This means that the HRTFs can be populated with impulse response data of measured HRTFs. In this case, the ITD is encoded by leading silence in each ear's impulse response.

HRTF data file

The coefficients are stored in the data file, starting from the lowest elevation, azimuth 0, and ordered by increasing azimuth (up to 360 degrees), followed by the next elevation. Each HRTF is stored as a stereo pair of ear responses of equal length. Within each HRTF, coefficients are ordered as follows:

```
b coefficients, left ear
a coefficients, left ear
b coefficients, right ear
a coefficients, right ear
```

If the number of "a" coefficients is 0, as is typically the case, then each HRTF stores the FIR coefficients for left ear followed by the FIR coefficients for the right ear. HRTF data is stored in 32-bit IEEE floating point format, with 1.0 being full scale amplitude. The byte ordering is **big-endian** format. This is because Panorama file format was developed on a Macintosh Plus computer which used a Motorola 68000 processor.

Example

Below is an example header file.

```
% fs n_elevs n_hrtfs flags num_b_coeff num_a_coeff
% flags: symmetric ITD_extracted
44100 14 368 3 128 0
% elevs(1,:)
-40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
% elevs(2,:)
56 60 72 72 72 72 72 60 56 45 36 24 12 1
% ITDs(1...n_hrtf)
0.000000
2.501299
3.979090
5.690882
...etc.
```

This header file has the following values: 44100 Hz sampling rate. HRTFs stored at 14 different elevations. A total of 368 HRTFs stored. Flags of 3 indicates symmetric data with ITD extracted. Number of "b" coefficients per HRTF is 128, number of "a" coefficients is 0. HRTFs are stored from -40 degrees elevation to +90 degrees, every 10 degrees elevation. At -40 degrees elevation, there are 56 azimuths, which corresponds to an azimuth angle increment of 6.428571 degrees. Because the data is symmetric, at -40 degrees elevation HRTFs will be stored for azimuths 0 degrees, 6.428571 degrees, 12.857143 degrees, etc., up to and including azimuth 180 degrees, but no data is stored beyond 180 degrees. Hence 29 HRTFs are stored at this elevation. At +50 degrees azimuth, there are 45 azimuths, so HRTFs are stored for 0 degrees, 8 degrees, etc., up to 176 degrees, for a total of 23 HRTFs stored at this elevation. The ITD at elevation -40, azimuth 0, is 0.000000 samples; the ITD at elevation -40, azimuth 6.428571, is 2.501299 samples, etc. The data file will begin with the left ear impulse response for elevation -40, azimuth 0, which will be stored using 128 32-bit floats in big-endian format. This data is followed by the 128-pt right ear response, then the left ear impulse response at elevation -40 and azimuth 6.428571, etc.

Panorama HRTF file directories

Panorama factory HRTF files are stored in a directory on the hard disk. On Windows, this directory is:

```
C:\ProgramData\Wave Arts\PLUG\PanoramaHRTFs
```

On MacOS, this directory is

```
/Library/Application Support/Wave Arts/PLUG/PanoramaHRTFs
```

Where PLUG is the name of the plug-in, e.g., “Panorama 7”.

Panorama 7 scans a separate directory for user supplied HRTFs, such as those converted from SOFA format via the Sofa2Pan application. On Windows, the user directory is:

```
C:\Users\USER\AppData\Roaming\Wave Arts\PanoramaHRTFs
```

Where USER is your login name. On MacOS, the user directory is:

```
~/Library/Application Support/Wave Arts/PanoramaHRTFs
```

where “~/Library” is your user library directory.

Legacy Panorama v5 and v6 file conventions

This section describes the file conventions employed by Panorama v5 and v6 (“Legacy Panorama”). Legacy Panorama needs an integer ID to refer to an HRTF set. Legacy Panorama also lacks the ability to apply sample rate conversion to HRTF files, hence files created for Legacy Panorama are typically supplied at multiple common sampling rates. HRTF files at different sampling rates are grouped by naming the files appropriately. Here is an example of the files used to store related HRTFs for 44.1 kHz and 48 kHz sampling rate:

```
Dummy_44.txt
Dummy_44
Dummy_48.txt
Dummy_48
Dummy_hrtf.txt
```

The 44.1 kHz data is stored in the header file "Dummy_44.txt" and the corresponding data file "Dummy_44". Similarly, the 48 kHz data is stored in the header file "Dummy_48.txt" and the corresponding data file "Dummy_48". The file “Dummy_hrtf.txt” supplies a name and an integer ID for the HRTF set.

Legacy Panorama recognizes the following sampling rates and corresponding filename abbreviations:

```
11025       11
22050       22
32000       32
44100       44
48000       48
88200       88
96000       96
```

The file "Dummy_hrtf.txt" defines the HRTF set and must be present for Legacy Panorama to recognize the HRTF data. An example of its contents is given below:

```
My dummy head
2001
```

The "XXX_hrtf.txt" file is a text file containing two lines. The first line has the name of the HRTF set, as will be displayed in Legacy Panorama's HRTF menu. The second line has the integer ID of the HRTF set. This number must be between 0 and 65535 and must be unique for each HRTF set loaded into Legacy Panorama. The ID becomes the value of the HRTF parameter, and hence is used in saved presets to remember which HRTF set was used. IDs from 0 to 1999 and above 10000 are reserved for use by Wave Arts. If you are loading your own HRTFs, use IDs between 2000 and 9999.

When Legacy Panorama is created, it scans the HRTF directory looking for files with name "XXX_hrtf.txt". When such a file is found, the contents are read, and if successful, then Panorama looks for HRTF header files with name "XXX_FS.txt" and data files with name "XXX_FS", where FS is one of the sampling rate

abbreviations listed above. If errors occur loading an HRTF file, they are not reported to the user, instead the HRTF at that sampling rate is simply not loaded.

MATLAB functions

Wave Arts has published a set of MATLAB functions to read and write HRTFs in Panorama format. The functions are distributed as a zip file of MATLAB .m files, and are available at the Wave Arts website.