3D audio source simulation on iOS devices

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Overview

The project goal is to realize a 3D audio simulator for the iPad.

- The interface allows to move the audio source around
- The interface also allows to change the orientation of the user (manipulating yaw and pitch of the head)

Overview

The app is written in multiple languages:

- **Ruby**, **Matlab** A *Ruby* and a *Matlab* scripts are used to pre-process the Database
- **Pure Data** The audio I/O is managed using a *Pure Data* patch
- **C++** The functional core of the patch is a PD external written entirely by us
- **Swift** The new Apple's language for iOS devices is used to develop the graphical interface of the app, which communicates with the PD patch

Outline

Database Preprocessing

- The KEMAR database is a list of HRTF recorded using a manikin with two microphones in place of the ears
- Each HRTF is a couple of 128-samples FIR filters (one per ear), associated to the position of the source at the moment of recording

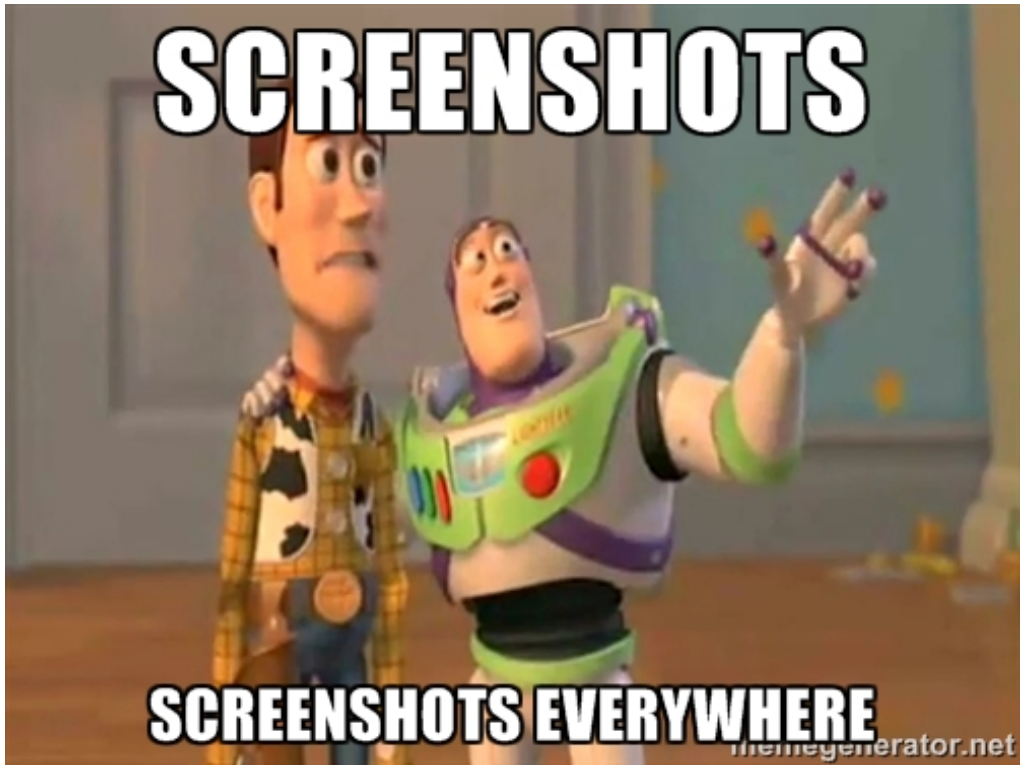
Database Preprocessing

- The database is a textual file containing the data
- The database is processed offline and translated in three vectors containing the points' position, their HRTF and the result of the *Delaunay Triangulation*

Database Preprocessing - Delaunay Triangulation

- Determines a subdivision of the points' space in triangles
- Each triangle has the points as vertices, such that no point is left inside a triangle
- This subdivision allows us to search for the three points that determine the triangle enclosing the source with little effort
- The subdivision is performed thanks to a Matlab script called by the Ruby one

Database Preprocessing - Delaunay Triangulation



Outline

Pure Data patch

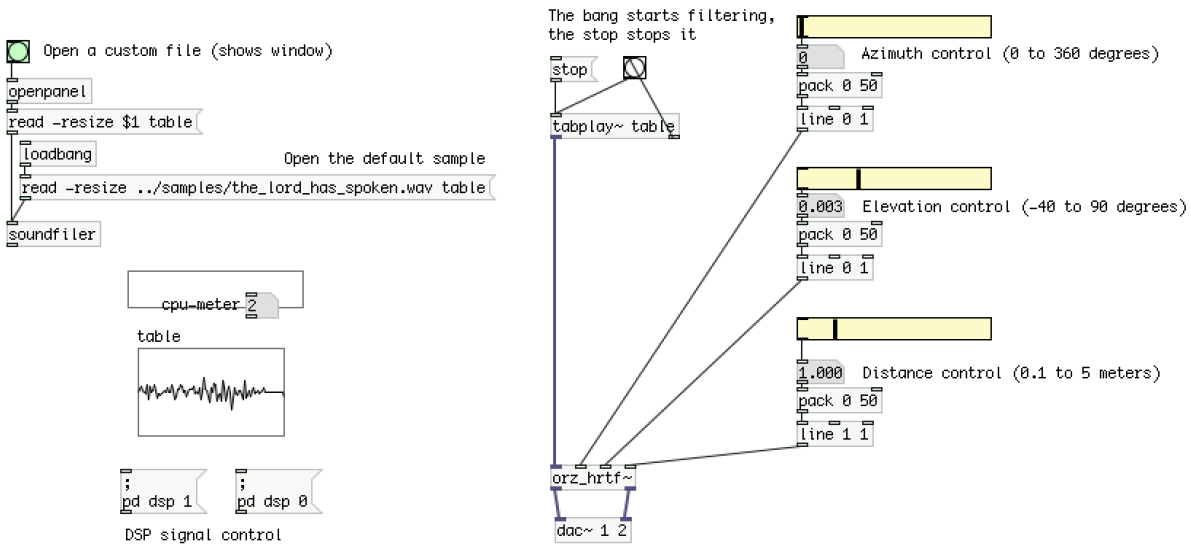


Figure 1: The patch used to test our external

Pure Data patch

- The block orz_hrtf~ filters the signal in the given source's position
- The position is given in azimuth, elevation and distance from the user
- The resulting outlets are the left and right channel of the filtered signal

Pure Data patch

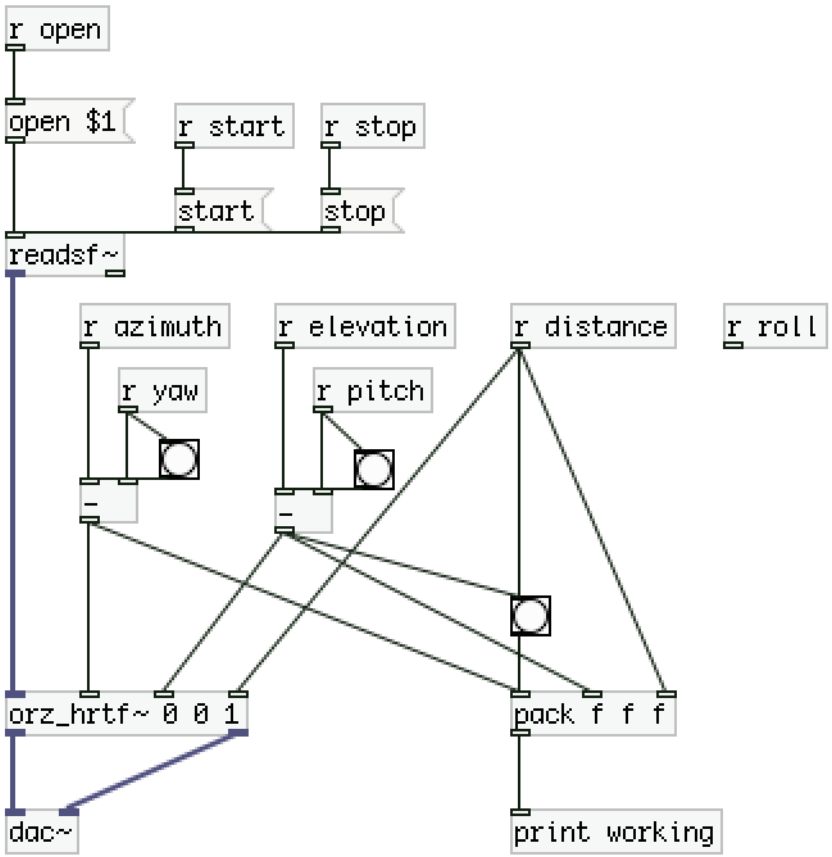


Figure 2: The patch used by the app

Pure Data patch

- Now the parameters are received from outside (r blocks)
- Also, the azimuth and elevation are modified accordingly to the given yaw and pitch of the head

Outline

Processing external - Structure

- A Pure Data external must be written in C (or wrapped in C++)
- A *setup* method is called when the block is loaded in the patch to initialize inlets, outlets and callback methods
- A *new* method instantiates the internal data of the class
- A callback method to handle the DSP signal must be present, in our case it is called *perform*

Processing external - Structure

The *perform* method works this way

- Find the points that form the triangle which encloses the source
- Determine the coefficients for the HRTF interpolation interpolate it
- Filter the signal separately with the left and right HRTFs

Processing external - HRTF interpolation

- The distance between the triangles and the source is used as a first estimate of the probability of enclosing the source
- The correct one will be the one that produces positive coefficients for the source's HRTF interpolation

Processing external - HRTF interpolation

$$HRTF_{s,l,r} = \sum_{i=0}^{2} \frac{g_i}{\left(\sum_{j=0}^{2} g_j\right)} \cdot HRTF_{i,l,r}$$

$$g = H^{-1} \cdot s$$

$$H = [point_0|point_1|point_2]$$

Processing external - Filtering

- The filtering is a convolution of the signal with the two computed HRTFs
- Past filters are used to smoothen the transition from one filter to another

Outline

The iPad interface

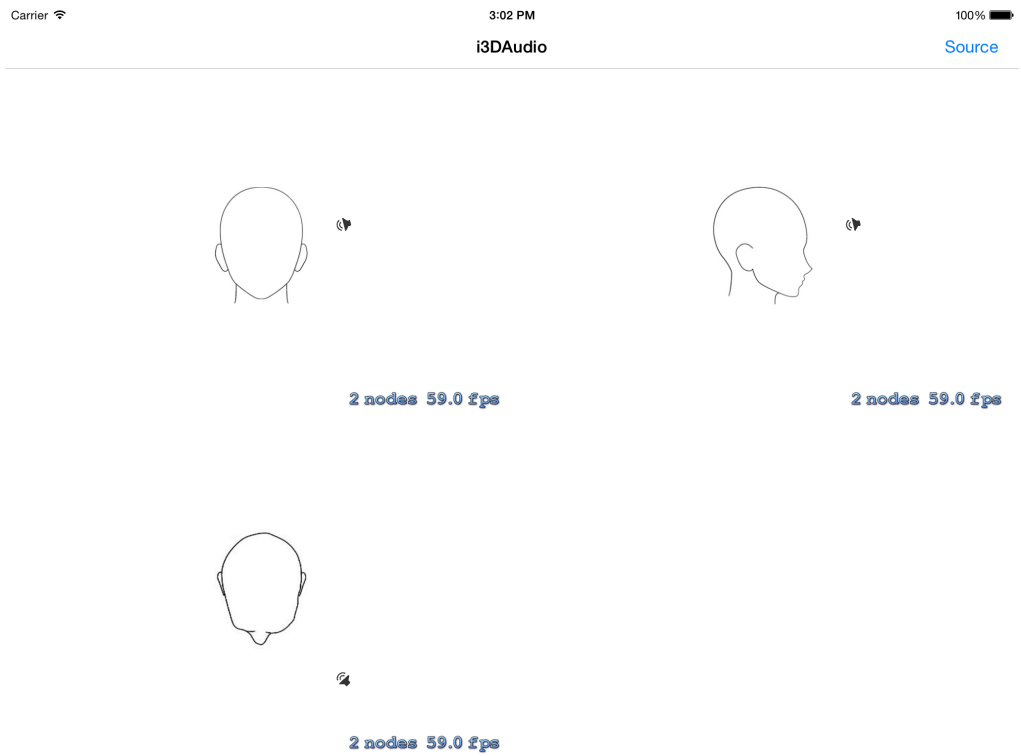
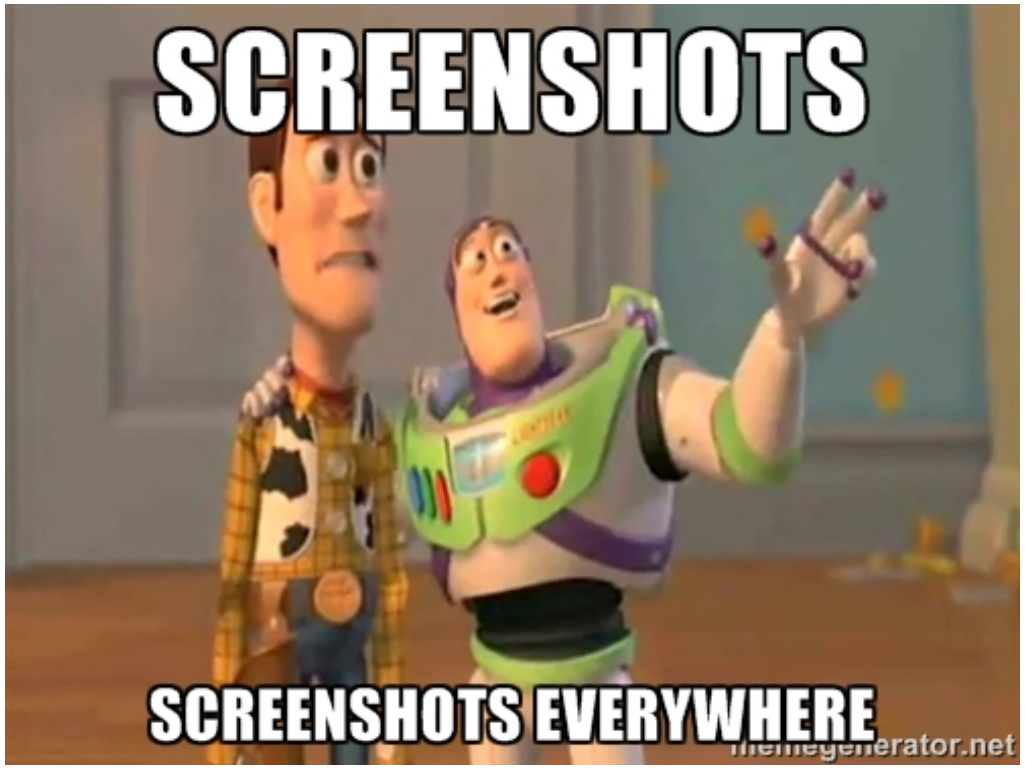


Figure 3: The app running on an iPad

The iPad interface



The iPad interface