ScanIR

USER'S GUIDE

Introduction

ScanIR is an application for high-fidelity impulse response measurement, storage, and analysis via Matlab. ScanIR is currently available on Mac OSX platforms only. To use ScanIR, you will need the Psychtoolbox-3 toolkit for Matlab, which allows simultaneous multichannel audio I/0, which is necessary for recording impulse responses.

Getting Started

To use the application, just navigate to the ScanIR folder in your Matlab directory, type 'ScanIR' into the prompt window, and hit enter. You will see a welcome screen (Fig. 1) offering two options: create a new session, or load a previous session. For now, just click "Create New Session."

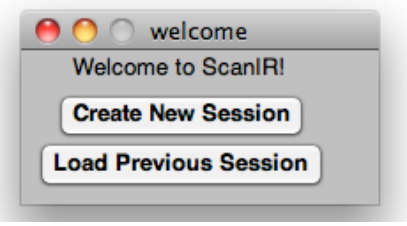

Fig. 1. ScanIR welcome screen

You are now at the initialization screen for a new measurement session (Fig. 2). This window contains options for initializing the static parameters of your measurement session (those that will not change over the course of a session).

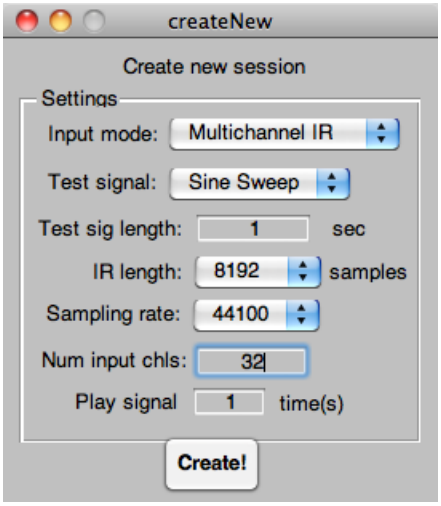

Fig. 2. Initialization screen for new ScanIR measurement session

The first menu on the initialization screen asks you to select an **Input Mode**. ScanIR has three primary uses, which are each implemented in separate input modes:

1) *Mono IR* – records a single-channel room impulse response.
2) *HRIR* – records a series of two-channel head-related impulse responses for given azimuth angle, elevation angle, and distance. This mode additionally may record a single position at once, or it may be configured for recording an array of positions in sequence. Because HRIR measurement sessions often involve a large number of regularly defined positions, HRIR mode is designed to allow a quick definition of an array of measurements to expedite the process. While the other input modes only allow output from a single channel at a time, HRIR mode also allows the possibility of measuring impulse responses from consecutive loudspeakers in quick succession, allowing even faster HRIR measurements. If you select 'HRIR' as your input mode, another menu will appear at the bottom of the initialization screen that reads **Output Mode**. This menu allows you to select whether you want to measure one HRIR position at a time (*1 channel output*) or multiple channels consecutively, up to the limit of your audio interface (*multichannel output*).
3) *Multichannel IR* – records a series of impulse responses on a dense microphone array to measure sound propagation in space across different frequencies. If you select 'Multichannel IR' as your input mode, a text box will appear at the bottom of the initialization screen that reads **Num input chls**. This allows you to set the number of channels that you will be simultaneously recording impulse responses with, up to the limit of your audio interface.

The next menu asks you to select the **Test Signal**. This refers to the type of excitation signal that will be played and recorded to measure impulse responses. The options are *Sine Sweep*, which plays a logarithmic swept sinusoid from 20 Hz to 20 kHz; *MLS (Maximum Length Sequence)*, which plays a noise-like burst of sound calculated to have equal energy at all frequencies; and *Golay Codes*, a pair of noise-like sounds whose autocorrelation functions sum to an idealized impulse response. *Sine Sweep* is generally better for quiet environments, as it bypasses natural nonlinearities in the audio output system being used. *MLS* and *Golay Codes* are more robust to background noise.

The third option on the initialization screen asks you to set the value of the **Length of the Test Signal** being used. This must be greater than zero, with a maximum value of 10 seconds.

The next popup menu asks you to set the **Length of the Impulse Responses** you will be recording. If you are in mono input mode, this will give values from 1-9 seconds, as acoustic room impulse responses can be very long in reverberant environments. If you are in HRIR mode, this will give values in increasing powers of 2 samples, from 128 to 8192. This is because the lengths of impulse responses

corresponding to the filtering effects of your head are very short. In fact, any content from room reflections should be windowed out of the signal to preserve only the HRIR itself. If you are in multichannel mode, you will have an additional option of choosing *samples* or *seconds* as your time unit, depending on the context of your impulse response measurement session.

Next, the initialization screen will ask you to set your **Sampling Rate**. This defaults to 44100 Hz, but can be changed to values from 22050 Hz to 96000 Hz. Make sure that the sampling rate you choose is compatible to your audio interface.

The final setting (other than mode-specific options) allows you to change the **Number of Times the Test Signal is Played**. This defaults to 1, but may be increased to as many as 5 times. If this is set to a number greater than 1, ScanIR will play and record multiple test signals and average their response, allowing irregular background noise to be eliminated from the final impulse response.

After you've finished initializing your session, hit **Create!** and ScanIR will create your session, with the specifications you've chosen. ScanIR will now open up its main window for recording and analyzing impulse responses.

Using ScanIR

The following instructions will help you get familiar with the specific uses of the different input modes in ScanIR.

Mono Input Mode

Mono input is the simplest of the three input modes. ScanIR uses this mode to record single impulse responses, one at a time (fig. 3). This is most appropriate for recording room impulse responses, which characterize the early- and late-field reverberation in an acoustic space. A future version of ScanIR will include additional analysis tools for calculating room acoustic parameters from these impulse responses.

If you look in the upper-left of the main window you will see the **Settings** panel. This includes most of the static data you set in the initialization screen. In addition, the *Output chl* box allows you to edit the current output channel that ScanIR will use for its test signal. The number of the output channel corresponds to the signal routing used by your audio interface.

Beneath this, you will see the **Description** panel. This contains the specific position data and other information about a single impulse response measurement. Though *azimuth* and *elevation* are used less when describing room impulse responses, they can be set here if the source's position relative to the receiver is important to the measurements. The third parameter, *distance*, may be more useful but is optional as well. The *comments* field allows unrestricted string input for any information that you wish to record about a particular position. For instance, this would allow you to instead record x-y-z coordinates for source positions rather than defining the source relative to the receiver.

*** PLEASE NOTE *** The data about a position is stored when that position is measured! Therefore you must enter all this data before hitting the *Measure* button.

In the lower-left corner, you will see the **Control Panel**. This allows you to measure new impulse responses and to index through previously measured responses. The *Measure* button sends the selected test signal through your audio system on the channel selected in the *Settings* panel. Your system will simultaneously record this signal and deconvolve to generate an impulse response for that source-receiver combination. If you click the checkbox labeled *Save backup WAV*, your system will save a wave file of the raw recorded data into the ScanIR directory.

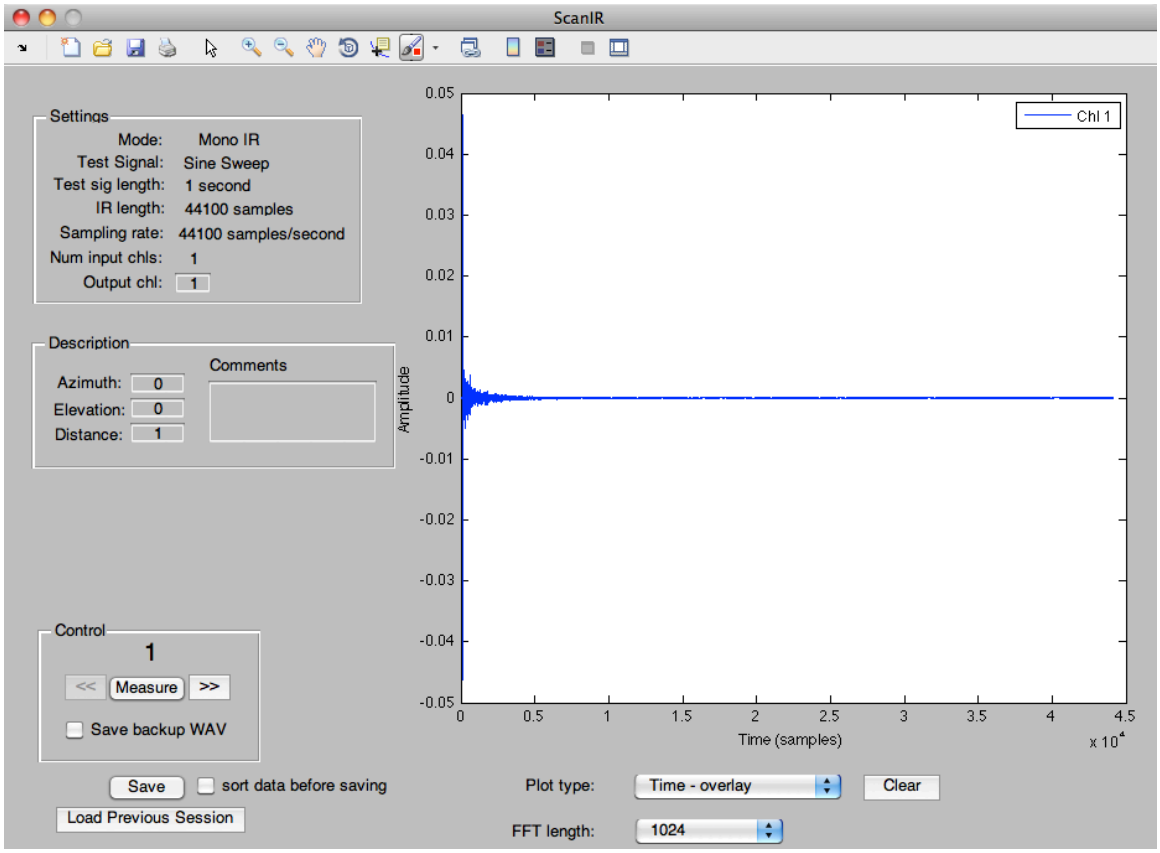

Fig. 3. Main application screen, Mono IR mode

On the right-hand side of the main screen, you will see the **Data Plot**. This is where the impulse responses will be viewed in either the time or frequency domains. The x-axis will either represent time (in samples) or frequency (in hertz), depending on the visualization domain. The type of visualization is selected in the **Plot Type** menu below. In Mono mode, only two visualization options are available: *Time – overlay* and *Frequency – overlay*. Below this menu is the **FFT Length** menu, which allows you to change the length of FFT used to visualize the frequency domain. A larger FFT size will give you higher frequency resolution. Finally, the Data Plot may be cleared at any time using the **Clear** button, although your recorded data will remain and may be plotted again by clicking on the appropriate domain in the Plot Type menu.

In addtion to the visualization menu, the normal Matlab plot visualization tools are available at the top of the screen for zooming/dragging the image, as well as rotating (for 3D plots, available in ScanIR's multichannel modes).

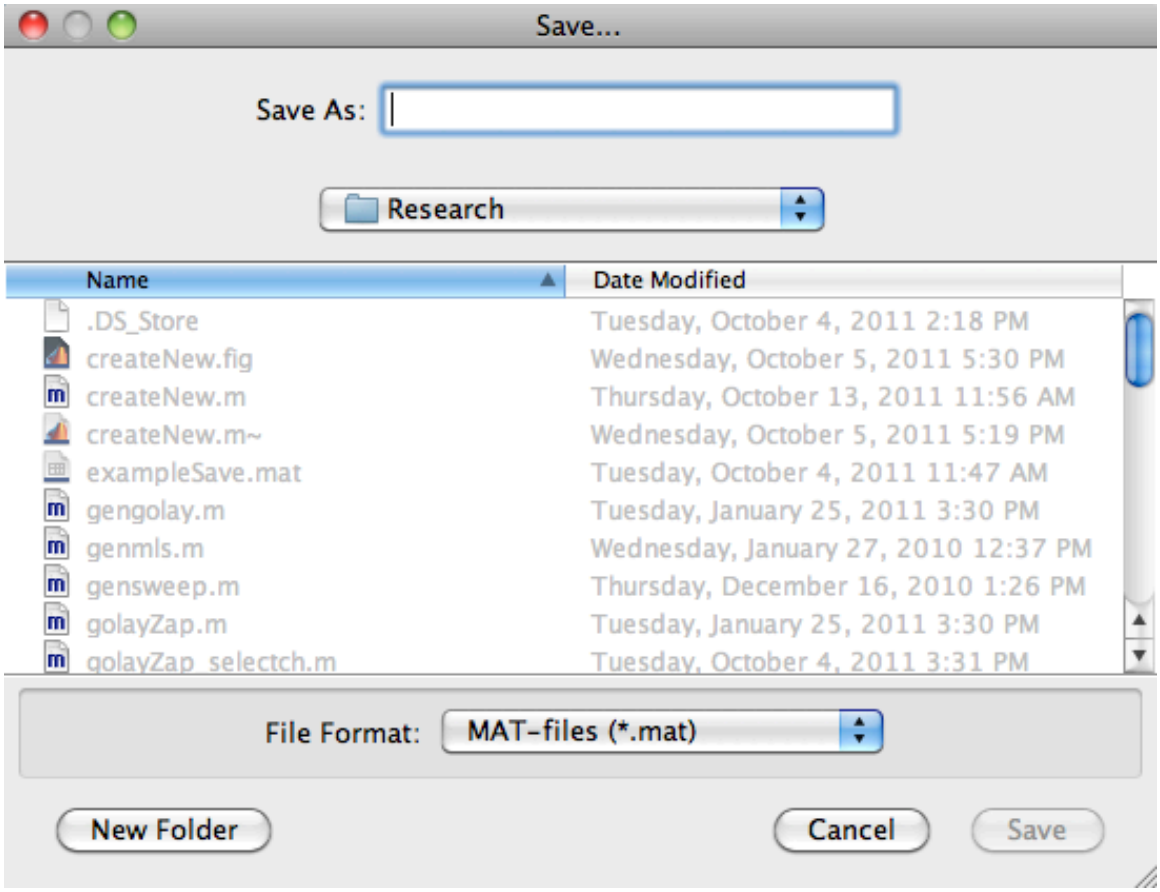

Fig. 4. Save file dialog

Below the **Control** panel, you will see the **Save** and **Load Previous Session** buttons. The save button allows you to save all recorded measurements in the session, along with all the position data associated with them, as a .mat file (fig. 4). If you select the checkbox labeled **sort data before saving**, the impulse responses will not be stored in the order they were measured – rather they will be indexed first by the 'azimuth' value stored to each one, and secondarily by the 'elevation' value. Thus, a sorted set of impulse responses will contain all measurements at the lowest given azimuth, from lowest to highest elevation, followed by all measurements at the second lowest azimuth, etc. This sorting is most useful in HRIR multichannel output mode, but it is still available in Mono mode in case data positions might need to be re-sorted. Finally, the **Load** button allows you to load a previously saved dataset of impulse response measurements. This is identical to the **Load** button available when you first run ScanIR. When you load new measurements, your current data (if any) will be lost, so be sure to save before loading. However, if you need to quickly sort the data you're using, you can save (with the sort option checked), and then load the .mat file you just saved to view your data in a new order.

HRIR Input Mode

Head-Related Impulse Responses (HRIRs) refer to the set of binaural filtering effects produced by the torso, head, and outer ears. Because these filters change based on position, recording them often requires a dense array of measurements that are regularly spaced. For this reason, ScanIR has a specific mode dealing with the measurement of HRIRs. In addition, HRIR input mode has the option of 1-channel output (the same as in Mono input mode) or multichannel output. We will examine 1-channel output first.

1-channel output

Most of the main window will look the same in HRIR mode as in Mono mode. However, you may notice that the *Azimuth* and *Elevation* fields in the **Description** panel are now grayed out. This is because *Azimuth* and *Elevation* are controlled through the **HRIR Locations** panel, located below (fig. 5). This allows the user to define arrays of regularly spaced source positions, which will automatically update when the application progresses to the next measurement. This panel works by defining a *start angle*, *interval angle*, and *end angle* for both azimuth and elevation. The interval may be defined in a positive or negative direction. In addition, once you are done with the currently defined array of measurements, you may update the panel to generate a new array of positions if you need different measurement densities for different areas. Once the current array is defined, the *Azimuth* and *Elevation* fields will update automatically, again cycling through the azimuths and elevations defined by the panel.

*** PLEASE NOTE*** that you will still need to update the **Output Chl** field for each new measurement, according to the channel you need for the defined position!

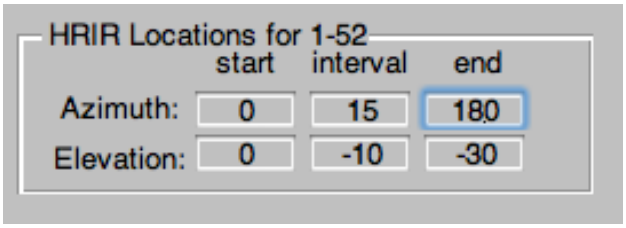

Fig. 5. HRIR Locations Panel

HRIR mode also contains extra visualization options: in addition to the default 'overlay' options for the time and frequency domain, HRIRs may also be viewed as *Time – cascade* or *Frequency – cascade*. These options put the separate channels on different axes, one on top of the other, rather than plotting them with different colors on the same axis. In addition, a fifth option is available, *Frequency – cascade chl*. This cascade-by-channel option is only available if you have recorded multiple positions. When this is the case, this option allows you to view the intensity by frequency for a single channel across multiple measurements. 3D plot rotations are useful for viewing this 3-dimensional data plot.

Multichannel output
Since HRIR measurement sessions often require a large amount of measurements, it can often expedite the process to automate measurements by using a multichannel system and measuring consecutive channels in immediate succession. ScanIR's multichannel output mode is designed for this, and only works when in HRIR input mode.

When you select *HRIR* as the input mode in the ScanIR Initialization screen, you will see that another menu appears allowing you to choose *1-channel output* or *multichannel output*. If you select multichannel, another field will appear asking you to input the number of channels you wish to output to, up to the limit of your audio interface. Once this is instantiated, ScanIR will take consecutive measurements from channel 1 up to the maximum channel number you selected.

In the main screen's **Settings** panel, you will see that the *Output chl* field is now grayed out and contains a series of numbers (1-8, for instance). In addition, the *end angle* fields are grayed out for both Azimuth and Elevation in the **HRIR Locations** panel. This is because each time you hit measure, you will cycle through a complete array of positions, and the size of the array will equal the number of output channels you selected for this measurement session. If you are arranging your loudspeakers on a diagonal, as is common during HRIR measurements, you should define the *interval angle* field to be nonzero for both Azimuth and Elevation. Whereas in single-channel output mode this array defined a rectangular array of size (number of azimuth positions by number of elevation positions), the multichannel version will now only define those positions on the diagonal.

For instance, if you chose 4-channel output, and defined your azimuths as starting at 0 degrees with an interval of 10 degrees, while your elevations began at -10 degrees with an interval of 5 degrees, you would then record positions at

(0,-10), (10,-5), (20, 0), and (30, 5)

After measuring this diagonal, you could then increment the azimuth position (often accomplished by turning the subject's chair) by 10 degrees. Then the next array of positions would be defined with azimuth starting at 10 degrees, with all other parameters remaining the same. The **sort data before saving** checkbox is particularly useful when recording diagonal position arrays, as the data can then be organized easily by azimuth and elevation.

If you are not measuring along a diagonal, simply enter the *interval angle* of the dimension you are measuring along (azimuth or elevation), and enter 0 for the interval of the other dimension. This will record a line of vertical or horizontal postions.

Multichannel Input Mode

Because the PortAudio API used to power ScanIR is only limited by the number of channels available to your personal audio interface, ScanIR also contains a Multichannel Input Mode to allow measurement simultaneously on a large number of input channels. While the uses and common practices for a measurement system of this type are not yet well defined, it is hoped that this mode will allow the user to push the boundaries of smaller-scale impulse response measurements in innovative ways. For that reason, this mode is defined rather flexibly, allowing the user greater freedom in defining his or her own uses for the system.

Multichannel input mode allows the user to measure impulse responses on the time scale of either samples or seconds. Thus, if a user wanted to generate a room impulse response of only 512 samples, he could use this mode rather than the longer impulse responses available in Mono input mode. Conversely, if a user were to measure HRIRs in a reverberant environment and wanted to keep the room reflections in the final impulse responses, she could define a 2-channel session in this mode using seconds rather than samples.

This mode has been used here at NYU's Music and Audio Research Laboratory for recording dense sound radiation measurements. Using a prototype array of microphones spaced closely together, this mode can then track change over the time or frequency domain between measurements, or over a single channel as the microphone array is rotated around a sound source (using the *Frequency – cascade chl* visualization option).

When using this mode to measure absolute rather than relative onsets for all channels, it will be advisable to also save wavefiles of the raw recorded data as well. This is because ScanIR automatically finds the first peak of the measured impulse responses (for all measured channels at once) and offsets the first peak by 100 samples from the beginning of the response vector. Thus, relative time differences between channels are preserved in a single set of responses, but to track this over a longer period of time the raw recorded data will have to be saved and analyzed.

As the uses and potential of this mode becomes clearer, future versions of ScanIR may incorporate new organizational features or optional functionality for multichannel impulse response recording sessions.

Final Things

Troubleshooting
If you have troubleshooting issues, first make sure that your audio interface is connected and that you're getting a good clean signal in and out. If ScanIR can't get a clean signal, your impulse response will be all noise and its peak detection may cause an indexing error. Watch out for the "Low SNR" warning. So far this has only happened when the application was getting no sound whatsoever, but do be mindful of it.

If you have other issues, feel free to let me know at bbb259@nyu.edu.

Obligatory Thanks
Thanks for using ScanIR. I hope this application can be useful to you and your research.

All best wishes,
Braxton Boren

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