THE UNIVERSITY *of* EDINBURGH
Edinburgh College of Art

REID SCHOOL OF MUSIC

Sound Design Media
ARCH1100

Week 07
Impulse Responses & Convolution

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What is convolution?

- Convolution is the process where each single sample of a sound is multiplied by *every* sample of another sound. It is different from the plain multiplication of two sounds where a single sample of the first sound is multiplied by the corresponding single sample of a second sound.

What is convolution?

- Curtis Roads (1996) describes convolution as:

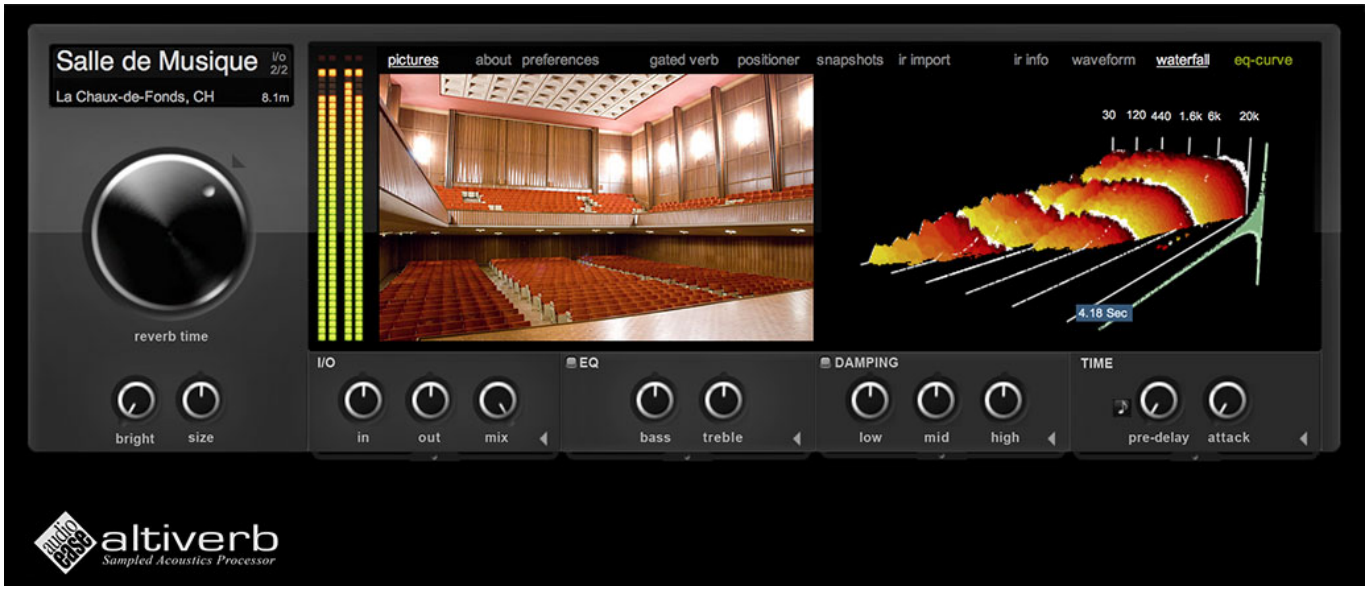
  “Convolution of two audio signals is equivalent to filtering the spectrum of one sound by the spectrum of another sound. Convolution of spectra means that each point in the discrete frequency spectrum of input ‘*a’* is convolved with every point in the spectrum ‘*b’*.”

What are Impulse Responses (IR)?

- An Impulse Responses is a way of capturing the acoustic characteristics of a space (or piece of sound altering equipment).
- It can be described as an acoustic ‘photograph’, where, instead of capturing a space visually, it is captured aurally.
- IRs are captured by recording how a space responds to a full range of frequencies (typically 20Hz to 20,000Hz)
- This is achieved by playing back a burst (impulse) of a full range of frequencies within the space and recording it.
- For more accurate results, it is common to use a sine-sweep across the audible frequency range.
- The IR is simply an audio file.

Applications

- What can we do with convolution and IRs?
- Most commonly used in audio to recreate real world spaces.
- Incoming audio is convolved with an IR to make it sound like it is from that environment. Particularly useful in post.



Applications

- IRs of audio processing equipment can be captured.

- Cheaper and more practical than the real thing!

Applications

- In fact anything that changes sound and can be stimulated by an impulse can be used to make an IR.
- Everyday objects like pipes, cans and bottles can be used to create IRs to process other sounds.

Limitations

- Convolution can only describe Linear processes.
- Non linear processes such as compression or distortion cannot be fully reproduced.
- Convolution can also only describe Time Invariant processes.
- A time invariant process is one where is doesn’t matter when you apply the impulse, you will always get the same output.
- Plugin parameters not as editable as algorithmic versions – emphasis instead on IR libraries.

Recording IRs - Source

- Sine Sweep
  - Preferred and most accurate method for creating IRs.
  - Sine wave that sweeps through a range of frequencies played into the space / equipment / object.
  - Longer sweeps provide better signal to noise ratios.
  - Longer sweeps also necessary for spaces with long reverb times.
  - 30s sweep typical.
  - Recorded sweep then deconvolved to create the IR.
- Transient Method
  - Short impulse or burst of noise such as starting pistol or clapper board.
  - No deconvolving required.

Recording IRs - Equipment

- Speaker(s)
  - Should be able to reproduce a wide frequency range.
  - Mono most common but stereo often used in larger spaces.
- Microphone(s)
  - Good mic's with flat frequency response.
  - Omni condensers often used.
  - Mono, stereo, multichannel and ambisonic techniques used (dependant on software support).
- Playback / Recording equipment
  - Can be separate devices or one.
  - Should be good quality and low noise.
- Document your setup!

Recording Tips

- Always record in 24 bit
- Use high sample rates to aid post production.
- Try and maintain the cleanest signal chain.
- The position of the speaker and microphones are obviously important! Do test recordings if possible.
- Allow headroom.
- If you're not using an all-in-one process like REW ensure that you (a) keep a copy of your sweep file for deconvolving later (perhaps record dry on to another channel to make lining up with the response as easy as possible) and (b) take a clap response as a fall back.

Tools

- There are a variety of tools available for sine-sweep generation and the de-convolution process:
  - Logic's Space Designer: The Space Designer plugin in Logic is a convolution plugin. Hidden within its menus is a de-convolution utility, where it can create an IR when fed the dry sine-sweep and the recorded sine-sweep.
  - Apple/Logic's Impulse Response Utility: Impulse Response Utility is included with Logic (Applications > Utilities) and is a complete solution for recording IRs. It is capable of generating and recording the sweeps, editing, de-convolution and creating Space Designer presets across a range of multichannel formats. Another advantage with Impulse Response Utility is that the IR it generates can be used in any other convolution software.

Tools

- AudioEase Altiverb: Altiverb is a boutique convolution plugin and ships with a library of fantastic IRs. It is also capable of de-convolving recorded sweeeps, but encodes the IRs into a proprietary format.
- Voxengo Deconvolver: Voxengo's Deconvolver is a windows application that generates sine-sweeps and de-convolves them into IRs, although unlike Impulse Response Utility it has no recording facilities.
- Room EQ Wizard: Actually a tool for doing acoustic testing, but free and very easy to use.
- Reaper's *Reaverb* has a facility for generating sweeps and deconvolving the response.
- The HISSTools MaxMSP objects allow for a wide range of impulse response gathering techniques, including using MLS noise instead of sweeps.

Editing

- A de-convolved IR will need some trimming and a fade out to get rid of noise (room tone/hiss).
  - Trim any audio before the impulse starts.
  - Apply a fade to the end as the impulse recedes into the noise floor.
- Avoid digital processing such as noise reduction.
  - If required some filtering can be applied.
- Reshaping the envelope of the IR can produce interesting effects.
  - For example reverse reverbs.

Exporting

- Room EQ Wizard will export the impulse as a .wav file. It seems to always put a 1000ms pause at the start.
- Apple's Impulse Response Utility creates a .sdir file. This is nothing but a regular audio file that be imported into any DAW or convolution software by renaming the file to .wav.
- Other de-convolving utilities, like Voxengo's Deconvolver, output a regular .wav file.
- AudioEase Altiverb, Waves IR-1 and McDSP Revolver use proprietary formats when de-convolving IRs, although they are capable of importing wav files.

Getting Creative

- As well as accurate representations of spaces convolution can be a very creative tool:
  - Try using contact mic's on objects when creating IRs.
  - Use different microphone choices to colour the sound.
  - After deconvolution the IR can be processed.
  - Use pitch shift, time stretch or other effects to manipulate the IR.