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Convolution reverb & impulse responses

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Convolution reverb is an innovative piece of technology that allows for great authenticity. It allows the user to replicate the acoustics of any space using an impulse response. Taking an impulse response, or IR, is the act of capturing the acoustic properties of a space using some kind of sonic impulse. The information derived from the IR can later be interpreted by a convolution reverb plugin and turned into a brand new plugin preset. Plugins like Audio Ease's Altiverb and Emagic's Space Designer possess convolution capabilities that make importing one's own impulse responses a simple task. The process of taking an impulse response may not be so easy, but can be a great way to give a unique quality to a mix. When making personal impulse responses, there is abundant room for experimentation to make some very creative reverb presets.

The leading force in convolution reverb is a company called Audio Ease. Their plugin, Altiverb, is a veritable cornucopia of impulse responses of reputable spaces all over the world. Their list of spaces is interesting in comparison to other libraries. Most other IR libraries use indefinite names such as Hall 1 or Small Tile Room. Altiverb gives the user the benefit of knowing exactly what room he or she is using. The engineers of Audio Ease have acquired impulse responses from some of the most highly reputable acoustic spaces in the world. They have IR's of Disney Hall in Los Angeles, the Berlin Philharmonie, and the Sydney Opera House. Instead of getting an impulse response of some mystery hall in an unknown land, one has the ability to use impulse responses from spaces that were specifically designed and constructed for acoustic excellence. They even have IRs of older and more exotic spaces like the Gol Gumbaz of India, which is the largest dome in Asia with a twenty-five second reverb time. It took two years of negotiation for the Audio Ease team to get permission from the Indian authorities to take an impulse response of the dome. The oldest room in Altiverb's library is the Hypogeum Temple in Malta that was built over four and a half thousand years ago (*Altiverb 7 Guided Tour*).

Altiverb's convolution reverb allows anyone to use the acoustic properties of hundreds of spaces where they never would have been allowed to record. Aside from not being allowed to record in these places, some of the spaces in the Altiverb library no longer exist. The Oscar-winning Todd-AO film scoring stage in Hollywood is no longer in business, but the space is still available through Altiverb. Though some spaces have been closed or torn down, they are in a sense, immortalized forever (*Altiverb 7 Guided Tour*).

The Altiverb plugin gives specifics of the spaces they provide which can be very helpful in determining what type of room you want and what type of room you need. For each impulse response in Altiverb, six different parameters can be viewed. First, there is a map of the space showing its exact shape, including all the contours of the walls. Second, it shows the dimensions of the room in meters. Third, it shows a small picture of the actual building itself. This can help get a sense of the height of the building, given that no height measurement is provided. Fourth, it shows the number of speakers and microphones used. Some spaces are recorded with a mono speaker to a stereo pair of microphones, and others are recorded with stereo monitors to stereo mics. Fifth, the exact placement of the microphones and speakers in the space is shown. It shows how far, in meters, they are from the nearest wall as well as how far they are from each other. And sixth, it shows the polar pattern of the mic or mics and what direction they were facing. All the parameters shown in Altiverb make it very clear exactly what you are getting from the plugin. All the mystery is removed, you are even free to go and visit some of the spaces in the Altiverb library to see and hear for yourself how accurate their convolution process is.

Though Altiverb is recognized as one of the most advanced convolution reverb plugins on the market, that fact also makes it fairly expensive. Other plugins such as Space Designer by Emagic are priced much lower. In fact, Space Designer comes stock with Apple's Logic. Despite it's only being usable in Logic, it is actually quite an impressive plugin. Space Designer comes fully loaded with over a thousand impulse responses. They are not specifically labeled like in Altiverb, so one can never be sure exactly what space you are hearing. But that fact hardly renders the plugin useless. Many of the IRs in the Space Designer library seem more abstract in nature. The library is not simply a list of beautiful sounding concert halls. From a musical standpoint this may seem a drawback, and perhaps it is, but from a sound designer's view it may be an advantage. IRs of spaces like the inside of a car or an average bedroom can give incredible realism to cinematic projects. These IRs of average spaces are hardly unique to Space Designer, but they do make a convolution reverb plugin much more useful to a wide variety of people (White). There are a number of high quality IR libraries available to consumers, but most convolution plugins also allow users to create their own impulse responses.

Taking an impulse response requires three foundational factors. First, there needs to be a space with desirable acoustics. Second, some kind of sound source is required to send sound out into the space. Third, one or more microphones are needed to record whatever is used as an impulse. The act of taking an impulse response can be simple yet complex. There are a variety of different techniques to consider for taking an IR. Some techniques yield higher quality results than others (*How to Make an IR with Altiverb 7*). Originally impulse responses were taken by firing a starter pistol, or bursting a balloon. What was desired is called a Dirac pulse. A Dirac pulse is a signal that is only one sample long that contains all frequencies from zero to the Nyquist limit with equal power. Like a sine wave, this pulse does not exist in the natural world (Adriaensen). Starter pistols and burst balloons are meant to emulate this effect, but they always take some amount of time to achieve their full amplitude, and there is always some amount of decay time. Because these impulses are so short, they often struggle to give a pure representation of the room. A problem often met when taking impulse responses in this manner is the presence of noise. With so short an impulse, it is difficult to play the impulse loud enough to prevent noise from being a major factor. The solution to this problem is to make the impulse longer and draw out the process. In doing so the signal to noise ratio is greatly reduced. Thus arose the use of a swept sine wave (Walker).

A sine sweep is usually defined as a sine wave that starts at 20Hz and slowly rises to 20,000Hz. Most convolution reverb plugins have their own sine sweep files that work specifically for their system (Walker). Altiverb has eighteen different sine sweep files that are designed for various sized spaces with different reverb time lengths. Longer sine sweeps allow for a more accurate IR, but in some cases it is difficult to achieve a long enough silence. In city areas, often times shorter sine sweeps must be used to avoid the noise of traffic and passersby. It is best to attempt to eliminate as much noise as possible, but Audio Ease has made some highly adequate IRs with the presence of audible traffic noise (*Making Impulse Responses*).

The process of taking an impulse response is much the same with a sine sweep as with a Dirac pulse. One or more high fidelity speakers are placed somewhere in a space with one or more microphones set up to record. The idea is to place the speaker where a musician would be imagined to perform and the microphones would be positioned as an imaginary audience. This is often a more abstract concept when recording in a place like a factory room, but is much more practical in a space like a church that has a stage and seating for an audience. There are no rules however. The makers of Altiverb encourage a few different practices to help achieve the best IR result. They recommend using separate devices for playback and recording to allow for increased mobility (How To Make An IR In Altiverb 7). When they take an impulse response of a room, they first play a track of dry audio in the room as they walk around the room trying to find the best mic placement. In order to get a well rounded sound they play back a specific dry audio track that they created. It cycles between trumpet, drums, and vocals so the mic placement can be chosen to benefit a range of different sound sources (*Making Impulse Responses*). At each potential mic placement, they listen with headphones to how the room colors the dry signal. After listening, they proceed to the next step. It is wise to record some of the dry audio played in the space to be able to compare it to a convolution reverb plugin's recreation of the space. The ability to review the accuracy and quality of an impulse response could help the user to see how effective his or her techniques proved (How To Make An IR In Altiverb 7).

There are two different types of information that an impulse response gives to a convolution reverb plugin: frequency information and time information. The time information has to do with the size and shape of the room. When sound is introduced into any room, the sound reflects off the surfaces in the room. These reflections can be divided into two groups. The first is the early reflections. These are discrete reflections heard from the walls. As the number of reflections quickly grows, they become closer and closer together. This is the second group, called the diffuse field. At this point the reflections cannot be heard individually, but instead are heard as a new sound entirely (Deruty). These two phenomenon are well depicted in a book called *Musimathics* by Gareth Loy. Figure 1 shows six different potential early reflections that may be heard as

Figure 1

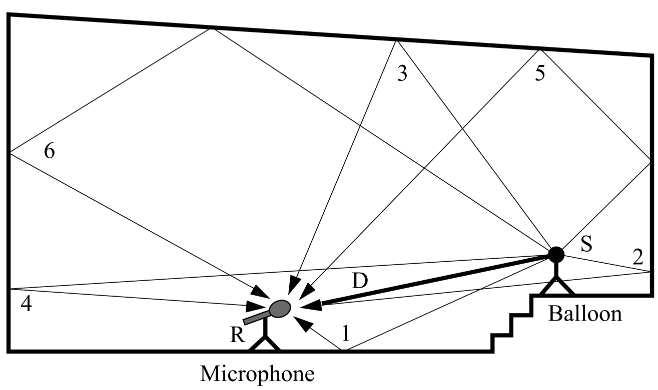
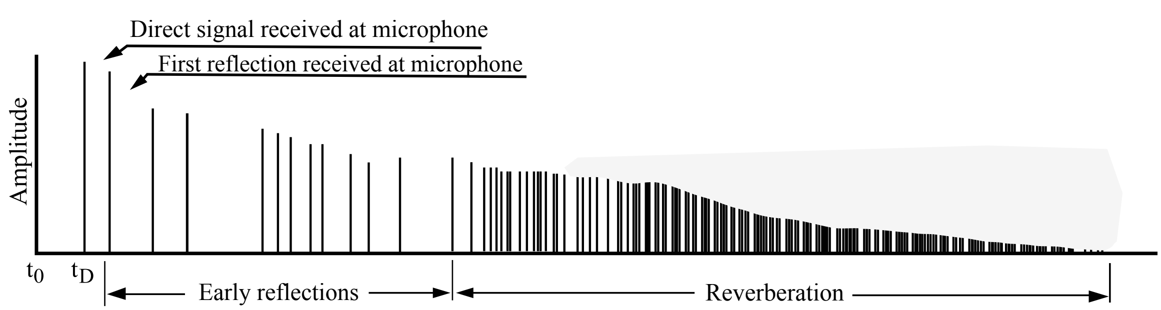


Figure 2



individual sounds before the number of reflections become too numerous. The number of reflections increase exponentially, while the amplitude of the reflections decrease in a relatively linear fashion. Figure 2 illustrates how the reflections grow closer and closer together until they are perceived as one sound. The human ear can only hear sounds discretely if they are more than forty to fifty milliseconds apart (Loy 233).

Independent of the time information is the frequency information. The frequency information comes from the physical makeup of the room. One way to try to understand convolution reverb is to think of it as a complex filter (Deruty). When sound waves meet a surface, some frequencies are absorbed more readily than others. Wood for example absorbs more lows and reflects more highs (Loy 222). Thus each time a sound is reflected frequencies are attenuated, making each reflection drop in amplitude. This fact in conjunction with size and shape of a space is what makes every room sound unique. The filtering effect that the room incurs on the impulse response is replicated by the reverb plugin. Using the information derived from the impulse response, the convolution plugin is able to synthetically manufacture the early reflections and the diffuse field and apply a filter to each sample of any piece of audio (Deruty). This is why convolution reverb plugins are so taxing to the CPU, because each sample of audio requires extensive processing. The longer the reverb time, the more processing the computer has apply to each sample (Walker).

There are also a variety of more abstract ways to use a convolution reverb plugin. Generally impulse responses are of spaces in which people are accustomed to hearing sound, but some have tried taking impulse responses of less thought of places. The idea behind IRs is to capture the quality of a desired space. Is not a piano or a guitar a resonant space? There are no rules when it comes to impulse responses and convolution reverb. Attempting to capture the resonance of the inside of a violin could have highly desirable results. One must simply experiment, and trust one's ears to determine if an IR has any use in an audio project. To take it even further, any .wav file could be uploaded into Altiverb to be used as an impulse response. Some have used things like drum loops or synth arpeggios. The results are unpredictable, but could produce some peculiar effects (Walker).

With some creative thinking, one can create a number of innovative impulse responses that make exceptionally interesting reverb presets. Though convolution reverb plugins may be rather CPU hungry, they give the user the freedom to use the acoustic properties of real spaces in the world. With programs like Altiverb and Space Designer, access can be had to some extensive libraries of famous acoustic environments from around the globe.

Personal Experience

I took nine different impulse responses. Six of these IRs were traditional impulse responses of various sized spaces and the other three were more experimental. The majority of my IRs were performed with the same equipment in a mono to mono configuration but for a few exceptions. All of the IRs were captured in Logic's convolution plugin called Space Designer. Space Designer uses a program called Impulse Response Utility to generate sine sweeps as well as capture and deconvolve impulse responses. Once deconvolved, the IR is automatically uploaded into the plugin and ready for use.

My first impulse response was of a 250-square-foot living room. The room was rectangular, 12 by 24 feet. The floor was tile and the walls were sheetrock, making it a highly reflective room. In the room was one couch, a table, and a TV cabinet. The couch was the only object in the room that was absorbing a large amount of sound.

The room had a slight flutter echo on one end of the room that I chose to address. I was able to greatly reduce it by using the large table. I placed the table on its side and turned it at a forty-five degree angle to break up the flutter echo. This did not completely eliminate the problem, but it was greatly lessened.

This impulse response was recorded mono to mono, or one speaker to one microphone. I used a KRK Rokit 5 monitor to a Rode NT-1A microphone. The microphone was placed twelve feet from the monitor. Both were placed equidistant from the walls of the space. This configuration maximized the distance between the speaker and the microphone without placing either speaker or microphone too close to a wall. Especially with microphones, being placed to close to a reflective surface can drastically affect the overall sound.

The reverb created by this impulse response had a very desirable sound. It was not a particularly long reverb, but would give a mix a good sense of space. This reverb works very well for mixes that need reverb for unifying purposes. In some mixes the majority of the tracks may sound perfectly fine without reverb, but this IR helps place all the instruments in the same space without having a tremendous effect on the overall sound. This has much to do with the fact that it was a small yet reflective room. Convolution reverb performs very well when emulating small spaces. Small spaces like this can be very useful in mixing. Small room reverbs in digital plugins can sound highly unrealistic, but IRs like this allow for much more experimentation with small room reverbs.

My second impulse response was of a very small bathroom. The floor and two walls were tile while the ceiling and remaining walls were drywall. All these hard surfaces made for a highly reflective space. As the room was only about 29 square feet, the reverb time was extremely short. Everything soft in the room was removed to maximize reflections and minimize absorption. There was no issue of flutter echo due to the size and shape of the space. The walk-in shower had a lower floor and a lower ceiling than the rest of the room. This irregular shape helped to diffuse the reflections of the room.

For this impulse response, I used the same equipment and setup as before. The microphone was placed only three feet from the speaker. This room was problematic for a few reasons. Because of its small size, it was a challenge to even fit all the necessary equipment in the space. My first configuration of speaker and microphone was highly unsavory. I placed both in the walk-in shower lengthwise through the space.

The problem with this configuration was that both the microphone and the speaker were placed much too close to the tile wall of the shower. The resulting sound was impossibly rich in low frequency content. The equipment's proximity to the tile wall resulted in a highly inaccurate representation of the space. I repositioned the speaker out of the shower and pulled the microphone slightly away from the wall. The new configuration was shooting diagonally through the room. The change in placement made an impressive difference in the impulse response, with a much more flat and even frequency content.

The results of this IR were actually not very desirable. The IR still sounds realistic and accurate, yet highly unmusical. The space is so small, that it sounds odd in a mix. I think this IR could have some use in experimental or extreme circumstances, but generally people are not accustomed to hearing music in such a small space. People are not accustomed to such small reverbs probably because throughout history music has not traditionally been performed or recorded in such small spaces. Digital reverbs are able to create very small reverbs, but they sound less natural and equally unmusical.

My third impulse response was of a small old fashioned church. The space was about twelve hundred square feet with a high vaulted ceiling. At its highest point, the ceiling was twenty five feet high. The floor of the entire room was carpeted and about two thirds filled with chairs. The chairs were completely cushioned and absorbed a substantial amount of sound.

This was the only impulse response where I used a stereo to mono configuration with two speakers and one microphone. Stereo to mono is not the most common configuration for an impulse response because a single microphone cannot capture a stereo image. I used two speakers simply because one speaker would not provide enough amplitude by itself. I needed enough signal to saturate the entire space. I placed the speakers close to where the house speakers of the church were placed on stage. I wanted to keep my speakers close to the house speakers so the impulse response would resemble the sound of the space the way it is usually used. I pulled both speakers in slightly which narrowed the stereo field of the speakers, but kept them six feet away from the walls of the church. I positioned the mic in the back of the church, 37 feet away from each speaker and twelve feet from the back wall.

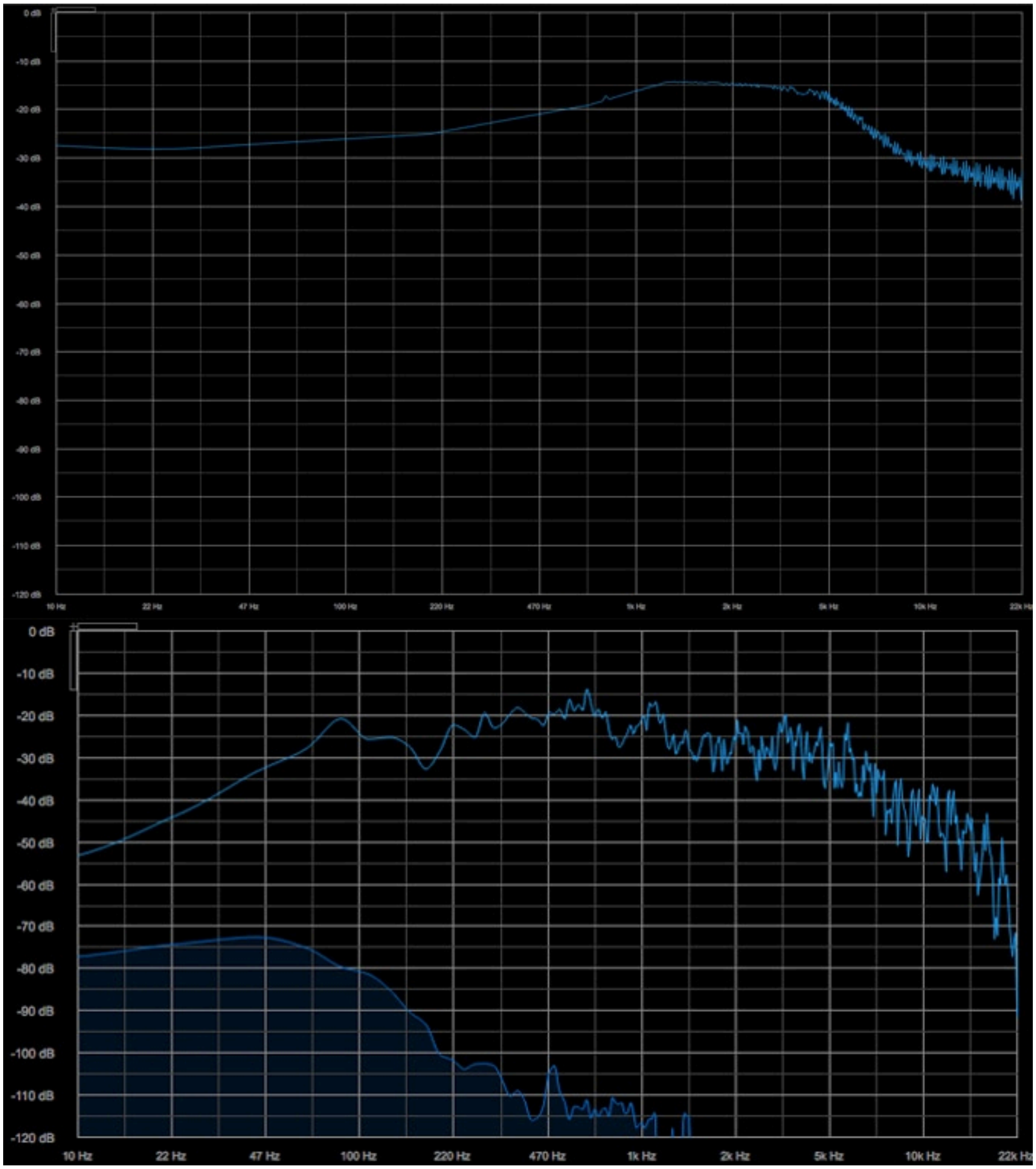
The IR created from this space is highly usable and pleasing to the ear. This space was created to house live music, so it has a sound that will not be unfamiliar to the listener. I have attended and played music in this church for many years, so the sound of this space is very familiar to me. This is an advantage of convolution reverb that is often not mentioned. Creating mixes with spaces I have known for many years creates a sense of nostalgia. When I listen to those mixes I instantly think of the church in which I grew up.

In the same church I took two other impulse responses. The first of these was one of the men's bathrooms of the church. This bathroom was slightly larger than than the the first bathroom I recorded in. This room was about fifty square feet. It had a tile floor and sheetrock walls. There were not any absorptive materials in the space. Despite the small size of the room, the space had a considerable reverb tail. The shape of the room was slightly irregular which took care of any flutter echo problems. Half of two parallel walls are pushed back making the surfaces uneven. This is helpful for diffusion of sound as well as preventing flutter echo.

Because of the odd shape of the room, I recorded diagonally like I did in the first bathroom. This diagonal approach seems to help maximize the use of the space. The distance between the microphone and the speaker is achieved without having to place either too close to a wall. If the microphone is too close to the speaker, the impulse response will be extremely dry and not add too much coloration to the signal. In this bathroom the microphone was placed six feet away from the speaker. There was audible construction noise coming from across the street when I took the impulse response, but it seems to not have greatly affected the overall sound. The makers of Altiverb have said, "We've made some very good Impulse Response recordings even with clearly audible traffic noise" (*Making Impulse Responses*). Silence is ideal for recording impulse responses, but sometimes noise is inevitable.

The IR captured in this room is by far the brightest reverb of all my IRs. Initially this seemed like it would be a great quality in a reverb, but it is not as usable in a mix as I originally thought. The high frequency content of this reverb is so present that it can be distracting. This quality can cause the reverb to upstage the track on which it is placed. It is unclear if this kind of reverb sounds out of place in a mix because of its inherent nature or the fact that it has rarely been used in the past. This reverb may sound good on instruments with less high frequency content, but it emphasizes the sibilance in vocals in an over-present way.

The third impulse response I took in the church was of a very long carpeted room. The space was fifty three feet long and fifteen feet wide with only eight-foot ceilings. The speaker and microphone were placed thirty four feet apart. I could have pushed them farther apart, but I did not want the impulse response to sound too dark, or devoid of high frequencies. Because high frequencies are more readily absorbed by the air and walls, this space was likely to sound very warm and dark. A long tunnel-like room like this is generally susceptible to what is called slap back delay. In a long tunnel that is closed at one end, this is common. The sound traveling perpendicular to the tunnel has time to completely diffuse before the sound that travels all the way down the tunnel and reflects off the closed end. The sound traveling parallel to the tunnel reflects back all at once sounding like a completely different sound source. Because the end walls of the space were irregularly shaped, the sound was diffused on both ends. One wall had a depression filled with tables and the other was half covered with cabinets. This irregularity was just enough to break up the sound at both ends.



This IR resulted in an extremely dark reverb. The first image above shows a spectrum analysis of the dry sine sweep, and the second image shows an analysis of the wet sweep. The wet sweep shows just how much the low frequencies are emphasized by this room. There is quite a large bump in amplitude just below 100Hz. Usually rooms of this size do not loose this degree of high frequency presence. It is likely that the tunnel-like shape of the room lead to the dark sound of the IR. If the floor of the space had not been carpeted, the room would have sounded much brighter. Despite the extreme coloration of the room, this IR is very usable. This space sounds highly consistent with many digital hall reverb settings. This IR will likely not get much use because of this fact. The IR captured in this space could very closely be replicated with digital reverb.

As an experiment, I took two impulse responses of the inside of a nine-foot Steinway D piano. For these impulse responses I recorded mono to stereo. Instead of the Rode NT-1A microphone used in all the previous recordings I used a pair of Audio-Technica 4050s. The speaker I positioned at the end of the piano, opposite of the piano keys. The microphones were positioned four inches over the hammers of the piano. There was two and a half feet of space separating the microphones. The sine sweep was shot across the strings of the piano to attempt to capture the natural resonance of the piano.

The first impulse of the piano was with the sustain pedal up. This IR was intended to capture only the natural resonance of the piano as a space. The second IR of the piano was captured with the sustain pedal down, leaving the strings free to vibrate sympathetically to the sine sweep. The idea of this second IR was to see if it could capture and recreate the sympathetic resonances of the strings of the piano. With the sustain pedal down the strings of the piano are able to ring for a very long time. My goal was to see if the long vibrations of the strings could be captured just the same as the reflections of a room. In theory, only the specific notes of the piano should retain these long resonances. I was curious how a convolution plugin would respond to a note that was in between the frequencies of the piano strings. If an A note is tuned to 440Hz and A# to 466Hz, how would the plugin respond to a frequency 453Hz? (Suits) As there is no note on the piano tuned to this frequency, there should be no extended resonances.

These experimental impulse responses have very little practical use in mixing. Because the inside of a piano is such a small space, there is virtually no reverb tail. This fact makes the IR more of a filter than a reverb. As discussed earlier, placing microphones and speakers close to walls can emphasize low frequencies. This phenomenon is present in these impulse responses. With such a small space, it is virtually impossible to keep the speaker and microphones far enough away from the walls of the piano. The IR of the piano with the sustain pedal down could have some use as an effect because of the long resonances of the open strings. The IR did an excellent job of capturing and recreating those resonances. The resonances are most present in the mid range frequencies. This is most likely because the high strings simply do not resonate very long and the low strings are so heavy that they are able to resist the vibrations in the air.

The eighth impulse response I took was of yet another bathroom. In the music building of Cal State Monterey Bay, the bathroom is almost completely covered in tile. The space had a square footage of only about 90 square feet, but the hard, smooth walls and floor of the room made it a highly reverberant space. The room had an irregular shape that helped to diffuse the sound. Not being a standard rectangle and having bathroom stall walls to spread out and break up reflections allowed the room to be free of flutter echo. For this recording I also used the Audio-Technica microphones again. The microphones were placed three feet apart on one side of the room. The speaker was placed almost in the center of the room because the bathroom stalls took up nearly half of the room. The speaker was eight feet away from each microphone.

This IR sounds very similar to the church bathroom. There is a great deal of high frequency presence and a long reverb tail for such a small space. The biggest difference between the two IRs is the amount of diffusion. The church bathroom was empty, allowing the sound to reverberate in a slightly more uniform nature. The bathroom in MPA had stalls and a more inconsistent shape. This caused the sound to scatter more and reflect in an irregular manner. With some slight work to tame the high frequency presence of this IR, it becomes a very desirable reverb.

The final impulse response I took was of a piece of hardware. The convolution process is often used for much more than reverb, it is also used to model famous analog gear. I tried to see how well Space Designer could emulate the sound of a Line 6 Spider III guitar amplifier. As is shown by the name, Space Designer is meant to be a reverb plugin. It was designed to emulate reverb, not other modulation. It is easily capable of emulating digital reverb hardware, but compressors and preamps are a different matter. All this considered, I tried to see how well Space Designer would perform when emulating a guitar amp. This experiment was done completely internally, meaning that no sound actually passed through the air. I sent the sine sweep into the input of the amp, and recorded directly out of the amp head. No sound actually made it to the cab of the amplifier.

The results of this experiment were highly conclusive. Space Designer does not emulate non-reverb gear with much accuracy. These results do not surprise me, but I thought it a worthy test. The IR sounds much cleaner than the actual guitar amp. It could not recreate the same level of distortion and overdrive. Space Designer is not the program to use when sampling anything other than reverb.

Survey

I created a survey in which I asked a dozen music students at California State University Monterey Bay to see if they could tell the difference between the reverb of a real space and the reverb of a convolution reverb plugin (Kantorik). Each time I took an impulse response of a room I also recorded a reference track in the space. I used the room like an echo chamber by amplifying the reference track into the space and recording the effect of the room on that audio. After acquiring this wet audio, I could take the same dry reference track and run it through the Space Designer IR I just created. It was the music students' job to tell the difference between the two. They were given this test for three different rooms. All but one person guessed correctly on one room. For another room, three of the students guessed incorrectly. And for the last room, six students guessed incorrectly. The first of these three rooms should probably be thrown out. There was a large amount of ambient noise from the air conditioning. The remaining results however, are highly conclusive. The results of this test suggest that convolution reverb most accurately emulates smaller spaces. The space the students had the most difficulty with was the church bathroom. This was the second smallest space I recorded. Space Designer does a fantastic job of emulating the brightness and tone of the space. In the larger spaces there is more ambient noise and slightly less low frequency content.

These findings are odd because convolution reverb is best known for its use for large spaces. It is known for its large spaces yet it performs much more accurately with smaller spaces. I see convolution reverb creating the ability to mix with much smaller room sounds. Other forms of artificial reverb provide very pleasing large room sounds. Convolution reverb has many practical uses, but consideration should be taken before choosing what kind of reverb to use. The accuracy provided by convolution is not always worth the CPU usage it demands.

The differences between the sound of an IR and an actual space are extremely subtle. When asked which they preferred, the majority of the music students from my survey said they preferred the convolution recreation more than the audio recorded in the space. The two major differences between a real space and a convolution reverb are both generally seen as improvements. Real spaces tend to have a higher noise floor that is often audible in recordings. This is much less present in the digital emulation. The noise of a real space could be seen as natural, and in some cases desirable. But generally less noise is better in a recording. The second difference between convolution reverb and a real space is an emphasis of low frequencies. Some spaces can have a very high presence of frequencies below 100Hz. In many cases this low end emphasis would need to be lessened with equalization, but convolution reverb makes this EQ fix less necessary.

As discussed earlier, convolution reverb plugins have their drawbacks and their advantages. Convolution can be more CPU intensive, but yields higher accuracy to an actual room. Often times this kind of accuracy is not necessary and can do more harm than good to a mix. Depending on CPU power, it only takes a small amount of convolution plugins to bog down the computer. When using shorter reverb times, convolution plugins require much less CPU power. Because the plugin adds a reverb tail to each sample of audio, a shorter reverb time greatly reduces the amount processing done by the plugin. Practically, it makes sense to use digital reverb plugins for dense mixes that require more than a few different reverbs. In a more sparse mix where the reverb needs to be more realistic, a convolution plugin can add a clear sense of space. In my experience with using both my own impulse responses and others, I feel that convolution plugins tend to perform significantly better than digital reverb plugins when it comes to small spaces. Very small rooms can be hard to recreate with digital reverb plugins. They often sound highly unrealistic and sometimes just bad. A convolution plugin can give a mix a small room sound without sounding unnatural. Plugins like Altiverb and Space Designer can be powerful tools in mixing to add incredible realism.

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