

Exploring further education in Impulse Responses

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Abstract

Impulse Responses are a powerful tool for musicians, giving them the freedom to utilize the sounds of any instrument without the upfront cost of one or easily replicate soundscapes to add to their music. The goal of this project was to think about how educational resources for impulse responses could be developed or improved beyond their current state and produce potential solutions. We gathered information from interviews with both teachers and musicians to learn about their experiences with various teaching styles and understanding of impulse responses.

Executive Summary

Impulse responses, although a powerful tool, are not commonly taught in collegiate-level music education, and that has left them a bit of a difficult-to-understand concept for music students seeking a depth and wealth of knowledge from college. Although independently driven learning resources for IRs exist, like YouTube tutorials, there is little to be found both inside and outside of colleges about how to utilize them in musical ways. Through interviews with the few impulse response educators in the collegiate world and both self-employed & professional music teachers, we discovered more about the depth of IR use in music and how it might be effectively be taught to a broader audience. We discovered that the classroom is one of the greatest environments for deep learning, as the connections between student and teacher aided both comprehension and engagement. Professor Rudolf Haken and Dr. Andre Fludd talked about giving room to allow students to ask for help and guidance when needed, but allowing the self-driven students to push ahead while trying to help those who fell behind. They both mentioned how difficult it was to balance, as creating one curriculum for every student is difficult when every student is different. Asynchronous learning allows for greater flexibility in one's learning, but the quality of the learning suffers without interpersonal connections offered in a classroom.

The greatest struggle that we uncovered through our interviews was the hurdle of understanding impulse responses as both a concept and a musically applicable topic. There was an application for IRs in mathematics, sound design, and music production, and with the lack of resources, it was difficult to pin down which one we were hunting. Professor Rudolf Haken helped us further grasp the musical side of IRs, explaining that they were more akin to modeled instruments, that being they captured the sound of any instrument and allowed it to be seamlessly played back with great quality and modularity. With just a simple electronic controller, someone could sound like any instrument that had been recorded, enabling both cheaper instrument mastery and exploration, as well as enhanced instrument preservation.

Introduction

As our project group began looking into the world of impulse responses, it quickly became apparent that there aren't really any solid ways for students in formal education to learn about impulse responses (or IRs for short). We noticed that at the collegiate level, professors may briefly cover IRs in a music technology course, but we couldn't find a single course that solely handles the technology. In addition to this, we found many informal sources of education on platforms such as YouTube or Wikipedia. Since the information was so difficult to find, we originally decided to investigate the possibility of providing a more accessible format for teaching impulse responses. Below you will find the results of this investigation where we conducted three interviews with a professor who creates educational content on YouTube, a music professor and one of his former students who employ IR technology in an electric strings program, and a software developer who has worked with capturing and manipulating impulse responses.

Background

In the vast world of music education, there are a seemingly endless number of topics to be explored. One such topic – impulse responses – is one that is not well known but has very powerful applications. While an impulse response is perhaps better known in the math world as a form of differential equation, it remains an important aspect of current music production. Differential equations are mathematical equations that relate a variable to its various rates of change. In the area of mathematical studies, many types of differential equations are applied to predict the outcomes of complex growth and decay problems such as “how populations change, how heat moves, how springs vibrate, how radioactive material decays and much more” (Pierce, Rod, "Differential Equations - Introduction"). One of these equations is the impulse response equation: an equation used to predict the outcome of a room’s response when a sound is made in it. In simplest terms, an impulse response is a digital image of the sound characteristics of a room. For example, the impulse response of a large open hall will carry a lot of reverb and potentially echo, whereas the impulse response of a small sound treated room will carry low reverb (the effect when sound reflects off of surfaces) and deadened sounds. When put to proper functionality, impulse responses can be applied to digital recordings to morph an audio recording into a new sound. This means that a recording of a singer in their basement can sound like they are singing in a cathedral on the other side of the world. Although this explanation seeks to summarily capture the role of impulse responses in music, it is likely that many questions persist.

Impulse response technology is a very complex topic that may be unfamiliar to many college music students; impulse responses can be very difficult to present in the typical formal learning experience and their practical value to musicians is not widely known. While researching formal courses in this area, only the aforementioned math applications came to light; in these instances, the math courses that covered IRs were not primarily focused on IRs but rather covered them in a part of the course.

Our team identified a small number of college courses where IRs were mentioned or applied in some musical context as well as the educators teaching these courses. One of our interview candidates, as well as one of the only people we could find who teaches a collegiate musical IR course, Rudolph Haken, teaches a program on electric strings where the strings are processed through impulse responses to imitate other instruments. Instruments are imitated through a processor that “applies” the desired sound to the inputs of your instrument. This, however, is a rather rare case of collegiate education providing an opportunity to explore impulse responses in music. The informal and self-directed learning field, however, has been growing and currently provides plenty of resources to allow individuals to explore IRs on their own.

With online resources such as Google, YouTube, Khan Academy, and any number of subscriptions based educational companies, informal learning is at an all-time high. With simple search commands, Google and YouTube will call forward thousands of accessible resources that cover your desired area of interest. Google provides links to websites, videos, PDFs, and many other forms of media while YouTube provides videos that can be created by anyone who has access to a camera, a free Google account, and a computer connected to the internet. Of course, music companies and YouTube creators have taken advantage of their online platform to build videos and courses that help teach individuals about impulse responses. One such company is Sonic Academy. (“Sonic Academy”, 2014.) This company focuses on equipping individuals with knowledge on thousands of sound reductions topic from industry experts. One of their courses specifically teaches a method of capturing impulse responses and converting them for musical applications () The problem that often arises in these scenarios is that these tools may not be well developed or professionally backed. In fact, according to scientific experts in the biology medicine and engineering fields, “YouTube contains a wide variety of unverified content that

may promote unhealthy behaviors and activities” (Osman, W, 2022) This results in a poor learning environment that might make it more difficult for people to study the topic.

Misinformation and poorly-researched media can guide people down the wrong path when directing their own learning, so there is always a need to be wary of the media being consumed. This, of course, somewhat defeats the simplicity of these easy-to-digest forms of media by insisting someone does their own research to validate the claims of teachers, but until collegiate education brings impulse responses into the greater musical sphere and integrate it into the common topics of electronic music composition and performance, these self-guided options are the most accessible and easiest option.

Another area in which companies have sought to simplify and enhance traditional education is through gaming. Along with online learning's exponential development, video gaming has reached a high point in its lifetime. As the games continue to grow to be more complex and in depth, educators have begun to look at the potential applications of video games in the classroom. Recent explorations into this concept consist of game creation tools that allow teachers to create a video game that is specifically geared toward whatever lesson they are teaching. One example included a teacher building a game that required students to search for the six simple machines. This process allowed the students to engage with the material in a new way that quickly aided them in forming an informational foundation upon which they could further build their knowledge. *Insert reference here*. If this idea is adapted to fit impulse response lessons or courses, it could potentially bear great results.

Though these methods may be helpful for individuals with prior experience and knowledge in the music production field, they are still riddled with complex terms, potentially confusing explanations, and a lack of human connection. The complexity is often due to the fact that the formal courses are oriented toward people with experience in music technology and the

confusing explanations and lack of human connection come with the nature of an online resource that can be created by anyone. (Baum, S., & McPherson, M. S. (2019). *Improving teaching: Strengthening the college learning experience.*) With the hopes of solving these issues, this project carries out interviews with audio and musical educational professionals to find out what can cause difficulties in teaching about impulse responses, as well as provide guidance to the further teaching of impulse responses, as well as validate their continued integration into collegiate settings.

Methodology

Our methodology includes an interview component in which we talk to musicians and teachers about impulse responses and impulse response education to solidify our understanding of and further develop pedagogical methods for impulse response education. We will conduct three interviews with individuals with varying expertise that relate to our project goals: an impulse response and software developer, a classroom music educator who works with impulse responses, and a virtual music educator and vlogger who also maintains a social media channel through which the connections between emerging technologies and their practical value for musicians are often discussed.

Our first interview was with Jake Pelrah, a software developer and practitioner of impulse responses. We are interviewing him to get a definitive and clear idea of what an impulse response is, as well as a timeline of the “IR capture and implementation” process. We want a second opinion before pushing further with our research. To get an extra reinforcement for our foundational knowledge about IRs, we will ask questions about how impulse responses are

captured and utilized, and asking clarifying questions to ensure we have a very solid base understanding of IRs to work from.

Our second interview was with Rudolf Haken, a professor of electric strings at the University of Illinois Urbana-Champaign. We are interviewing him for a perspective on formal teaching and to ask some questions about his electric strings course, which contains impulse response topics. We would like to glean some information about teaching complex topics like electric strings and impulse responses in a formal setting and understand the strengths and weaknesses of that style of teaching, especially for the more difficult-to-understand subjects. We would be asking questions about the challenges of teaching musical subjects, his teaching methods, and his classroom environment.

Our third interview was with Andre Fludd, an independent guitar teacher and post-doctorate researcher at the City University of New York. We are interviewing him for a lens into personalized learning and the value of an education built around students learning from themselves. We would like to ask questions about teaching students one-on-one, as well as how a teaching structure formed entirely by himself, as opposed to curriculum enforced by a higher management, can prove beneficial or harmful.

Data and Analysis

Overview

In our three interviews, we focused on three separate areas of discussion: music teaching techniques, teaching about and implementing impulse responses in music, and the process of capturing impulse responses. In our interview with Andre Fludd, we discussed different difficulties and solutions to teaching music to an intellectually diverse audience. The main point

that we focused on was the idea of keeping explanations as simple as can be so that many people can understand what you're saying. The trouble that comes with this is finding the balance between simplicity and not leaving out crucial details of what you are trying to teach. In our interview with Professor Rudolf Haken and his former student, Adreas Ruiz-Gehrt, we talked about implementing impulse response technology into music programs at universities. The two shared experiences performing with impulse responses to replicate ancient instruments. They also brought up the different ways they used IR technology in their educational and academic pursuits. In our final interview with Jake Pelrah, we talked more specifically about what the process of capturing an impulse response looks like. Additionally, we explored the technical steps that must be taken to apply an impulse response to a device for musical use.

Andre Fludd

Our interview with Dr. Andre Fludd, an independent guitar teacher with experience teaching both one-on-one as well as in a formal group setting, was namely about how to tackle education in an accessible way. The most important takeaway from our interview was that “[success] in making a resource as accessible as possible must assume absolutely zero knowledge.” (A. Fludd, personal communication, July 18, 2023). The most accessible resources are the ones where anyone from any walk of life can approach your subject with essentially zero understanding of what you're talking about, although there are some complexities in discussing impulse responses from a baseline of zero knowledge. There are other similar musical concepts, like convolution reverb, cabinet simulations, and sampling, so there is a need to distinguish IRs from the others before you start talking about them.

Dr. Fludd also shared his experiences teaching one-on-one and in groups, and how it has impacted his teaching. He talks about how “we make connections between our learning and the person teaching us” (A. Fludd, personal communication, July 18, 2023), and how our perception of them will affect our enjoyment of the subject matter. This potential connection is his favorite aspect of in-person teaching. He does, however, share that teaching like that means the human connection may be lost when teaching students who are focused on notetaking. He does, however, value notes and information storage, which may be lost when the teacher is working to entertain and teach at the same time. He also touches on the unique challenges he faced when working with groups of students. “Not everyone wanted to be there”, “[you] need to teach everyone from the same baseline”, and “how important it is to try to keep everyone engaged [by] balancing performance and education.” (A. Fludd, personal communication, July 18, 2023). The difficulties of teaching in groups is that not everyone will require or want the same amount of guidance, and the needs of each student will vary wildly, and it is the job of the teacher to manage that as best as possible, which proves challenging. Not everyone will be able to acquire the baseline knowledge at the same rate, and not everyone will perform the same in-class, so the teacher must manage everyone in the most efficient way while still trying to provide unique help for those who need it.

Rudolf Haken

Our interview with Professor Rudolf Haken gave us some great insight into the world of musical impulse responses, detailing the wide range of impulse response applications specifically in music and how they might change the musical world at large should more people get acclimated to them. First, we talked about impulse responses as a simple concept and how Professor Haken

& Mr. Ruiz-Gehrt would explain them to those with little musical experience & knowledge. Mr. Ruiz-Gehrt described it as a “filter that could be applied to instruments” to quickly and easily alter their sound to whatever the user desires. (R. Haken & A. Ruiz-Gehrt, personal communication, July 28, 2023). He added that it would be a difficult concept for a beginner to grasp because IRs create a degree of separation between the instrument and the sound, and your instrument turns into a controller instead.

One of the greatest hurdles overcome by IRs is allowing more people to utilize more instruments for a lower cost. IRs give everyone access to most any instrument without the need to have them specially recreated and practiced. If someone knows how to play an electric violin, they would be able to play most stringed instruments to some degree and wouldn't need to go through an artisan to acquire an old lute or fiddle (for example) and then learn how to play it. Professor Haken notes how few people he has ever seen play incredibly old instruments, and how “he’s only ever seen them in museums...but it’s to be able to sit down and hear [historical instruments] is remarkable.” (R. Haken & A. Ruiz-Gehrt, personal communication, July 28, 2023). Should IRs get their time in the spotlight, Professor Haken talks about the issues that the musical world faces, namely how gathering a concert worth of instruments is “impossibly expensive”, but “a bunch of electric instruments and impulse responses [can be acquired] for almost *no* money.” (R. Haken & A. Ruiz-Gehrt, personal communication, July 28, 2023).

Professor Haken and Mr. Ruiz-Gehrt also touched on the educational challenges of teaching such a complex subject, as well as the general complexities of being a teacher. Professor Haken notably talks about the merits of tutorial-based education being a very straight-forward method of learning, using language as an example. “You learn basic grammatical structure, and then you can start replacing words, and before you know it you’re creating your own sentences.” (R. Haken & A. Ruiz-Gehrt, personal communication, July 28, 2023). He sees great value in

providing a solid base for his students to experiment with, but he is wary of the unique identity of each student. He doesn't want to "overwhelm students by asking them to experiment [on their own]", but he is "careful to not come off as patronizing" so as to allow those students who come in ready and capable to flourish while helping the struggling students get their foot in the door. "You need to gauge each student" he says, and Mr. Ruiz-Gehrt adds that he directs his students to communicate with him as well as each other so they may find someone who they can interact with and learn from on their own. The balance between student autonomy and guidance was also noted in

Jake Pelrah

As the overview explained, our interview with Jake Pelrah consisted of the more technical side of impulse response technology. We began by asking Mr. Pelrah to provide his definition of what an impulse response is. He explained that an impulse response is a method of "capturing [the] sonic profile of anything" (J. Pelrah, personal communication, July 29, 2023). He then expanded on this idea describing how impulse responses allow individuals to "capture the frequency response of a room and then use that in a process called convolution to take the signal" of an audio source and "mimic the sound of the room" (J. Pelrah, personal communication, July 29, 2023). From here we shifted the conversation to get some insight into the process of capturing impulse responses. Mr. Pelrah brought up two starting methods for capturing impulse responses. The first of which he described is called starting pistols. As explained by him, starting pistols are impulse sounds such as "clapping your hands" or "balloon pops" (J. Pelrah, personal communication, July 29, 2023). The second impulse sound he brought up was "sine wave sweeps" which provide "probably [...] the [best] quality of the impulse

response”. He continued, stating that both methods require “good microphones [and...] good speakers” (J. Pelrah, personal communication, July 29, 2023). We then continued in the process to ask how the impulse response is then converted into something that’s actually usable.

According to Mr. Pelrah, “there's software Altiverb, which takes care of a lot of [...] post processing” then “usually you trim the [...] tail end off and then you have to trim the beginning, the silence” (J. Pelrah, personal communication, July 29, 2023). He also explained how there is a lot of math involved in applying the impulse response but that “there's actually a convolution node that you can use in a web browser. You can take a signal and then the impulse response. And it does all that math for you. You don't have to actually rewrite the algorithm” (J. Pelrah, personal communication, July 29, 2023). We then wrapped up the interview by asking about what can be done with the impulse response once it is collected. Mr. Pelrah explained that “you can trim the impulse response. So the longer the tail, the longer the reverb”, “you can trim them down to isolate certain sections of the impulse response you want to use”, “you can add other filtering effects”, and “you can apply multiple impulse responses to [your audio] signal” (J. Pelrah, personal communication, July 29, 2023). He also covered how the IRs can be applied in Ableton Live through a “package called Convolution Reverb” (J. Pelrah, personal communication, July 29, 2023). He also informed us that impulse responses are often employed in “a lot [of] movies so [that if...] they're filming on a green screen but they want to capture the sound of a church like an actual space [...] they'll send someone out to capture the impulse response of the church and then they'll add it to the [...] post production [of] the audio. [...] Then they're filming in the stage but they'll run the dialogue and all the background sounds through the convolution so it sounds like they're actually in a church” (J. Pelrah, personal communication, July 29, 2023). He furthered this by explaining that IRs are “used in movies, music, [and] games [,] so it's a pretty wide application” (J. Pelrah, personal communication, July 29, 2023).

Our interviews demonstrated the complex nature of impulse response education, as it is a somewhat complex subject that may not be immediately acquired by many, but to accommodate the needs of those who fall behind, virtual and self-directed learning may not always be adequate. While some are able to get by entirely on YouTube tutorials and forum posts, others benefit greatly from directed learning and professionals who can offer them correct and nuanced information in ways that are altered to help them. While self-taught avenues continue to open and already exist in a vast supply, the collegiate and formal worlds would benefit greatly from an increased quantity of classes specializing in impulse responses and their wide array of applications, comprised mainly of small class sizes so professors would have the freedom to work somewhat individually with each student should they need extra help while still teaching to more than one student at once. There is a great deal of IR knowledge that is widely unknown simply because of how obscure the subject still is in the greater music world, and gradual integration of such a subject in frequently utilized avenues of education, like universities, would allow for wider understanding of IRs and an even greater boom in self-guided IR education productions. Having resources like these in colleges would give complete beginners a chance to explore it in a very guided environment with lots of support. The greatest challenge currently facing the self-directed learning community is how those without access to higher education could get such succinct information and begin their jump into impulse responses without the value of a teacher to help them. There are only so many YouTube videos one can go through before getting frustrated and feeling demotivated. Therefore, it would be in the best interests of these self-guided creators to make videos or write-ups demonstrating impulse responses without anything extra, like creating a very simple single-track song to demonstrate what an IR does to a sound and nothing else. Make a video explaining what an impulse response is in the most

simplified way possible, using visual aids and analogies and avoiding complex musical language whenever possible. This would be difficult, considering the inherent complexity of IRs, but with ever-evolving technology, they will only become more and more technologically accessible, and it is up to those with knowledge to pass it on.

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