Audio Sampling MIDI Instrument

(Technical Paper)

Environmental Concerns of Electronics Manufacturing

(STS Paper)

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Introduction

Audio sampling has become a cornerstone of music production in the last 30 years. (Sato, 2019) Hip hop artists such as Kanye West, MF Doom, J Dilla, and Mac Miller regularly employ samples in their instrumentals and have turned sampling into something of an art. Sampling, at its core, is when an audio snippet (or sample) is recorded and then is repurposed as a sound in another piece of music. For example, in Kanye's "Bound 2" the vocals from a track by Ponderosa Twins Plus One ("Bound") are used as background vocals in the instrumental that Kanye raps over. Another notable example is in Mac Miller's posthumous "Blue World", where he uses chopped samples of The Four Freshmen's "It's a Blue World" in order to construct his iconic backing track.

As prolific as sampling has become, the equipment needed to create sampled tracks is expensive (*Why Is Music Production So Expensive?*, 2021) and the process is not very user friendly. Generally, audio equipment (both hardware and software) packs extreme amounts of functionality into a small package. While this is great for full time musicians who want the most bang for their buck, it can be highly confusing for someone who is just getting into music production, even if they are experienced musicians. This has led to sampling being fairly inaccessible because of a combination of price and barrier to entry. (Schossberger, 2021) Also, sampled music doesn't transfer well to live performances, as current techniques involve meticulously cutting and pasting samples using a computer in conjunction with other audio equipment.

Technical Topic

As sampling has played such a pivotal role in shaping pop music as we know it today, it is surprising that it has not become more accessible. Before electronic production started to dominate the world of pop, pretty much every song on the radio was recorded using some combination of guitar, bass, drums, keyboard, and vocals. The only barrier to someone playing along to their favorite songs was purchasing one of these instruments. At most pawn shops an acoustic will only run you about one to two hundred dollars. Today, playing your favorite song isn't so simple. How would you go about playing "Blue World"? The track was made on a computer from cut up vocal samples that are stitched together in a way that would be near impossible for even the most talented singer to emulated. Currently, there is no cheap and user-friendly way to have recorded audio used as a sample library for a piano. The closest thing to this is a loop pedal, which is able to record audio and play it back in a loop but, there is no pitch shifting functionality.

As a big enjoyer of music, my technical project for capstone will be a MIDI controlled sampling instrument. My group will design, build, test, and finalize a musical instrument that can record any sound, pitch shift it to the 12-tone chromatic scale, and output polyphonic sound from a MIDI input. In order to accomplish this, a Raspberry Pi 4 (RPi) was used with a custom-built circuit board called a Pi Hat that plugs directly into the GPIO (general purpose input/output) of the RPi. This allows for parallelization of work between the different group members because software and hardware can be developed simultaneously. The Pi Hat deals with the analog sound signals (input from the microphone and output from the RPi) while the RPi is able to digitally pitch shift the sampled audio and output the correct analog signals that correspond to the notes played with MIDI.

The Pi Hat header board has two main functionalities. The first is to convert the analog input from the microphone into a digital signal of ones and zeroes that the RPi can interpret. This is done with an analog to digital converter (ADC) integrated circuit (IC) from Texas instruments. The ADC is able to sample at frequencies up to 500 KHz at a resolution of 24 bits. This high amount of resolution is needed so that none of the audio quality is lost in the conversion from analog to digital. Following the standards of .wav audio files, the ADC will be run at 44.1 KHz. The audio is converted to a communication protocol called I2S (Inter-IC-Sound) to interface with the GPIO of the RPi. The second main functionality of the Pi Hat is to control the volume of the pitch shifted audio before it goes out to the speaker. This is accomplished with a circuit that is able to have an approximate logarithmic response to a potentiometer being turned by a user. The log response is necessary because our ears actually detect audio on a logarithmic scale (this is why we use decibels to describe volume).

On the software side of the instrument, the audio needs to be converted from I2S to .wav, pitch shifted, and then triggered to play with a MIDI input. First, the original sampled audio is saved to a .wav file. This wave file is then run through an algorithm called PSOLA (Pitch Synchronous Overlap and Add). PSOLA is able to change the pitch of an uncompressed .wav file without changing the length of the audio which is perfect because no matter what note you play; it will be the same length but still in tune. Finally, when a MIDI input is received, the RPi sends the corresponding wav file to a digital to analog converter to be output back to the Pi Hat.

All of these subsystems combine to create a device that is able to record a sample and play it back without any extra equipment. The design also lends itself greatly to being played live as samples can be recorded and replaced on the fly while the instrument is still being played.

Having the entire system be self-contained not only makes the process of creating sampled music more accessible, but also makes it more fun to play.

STS Topic

In modern day society, technology improves at an almost alarming rate, and it only seems to be getting faster. With this increase in technological development comes the need to replace outdated systems, namely electronics. Vast amounts of resources go into creating electronics and much of it ends up going to waste within a few years. (EPA) This raises many questions about the sustainability of the manufacture of electronics and what should happen to this electronic waste (also known as E-waste).

In this research paper, I intend to focus on the environmental impact of printed circuit boards. Some important questions to answer are: “What effect on carbon emissions does the manufacturing process of PCBs have on the atmosphere?” and “How can PCBs be made more sustainably?”. As an electrical engineering student and someone who tries to be environmentally conscious, this is something I’ve found myself wondering for a while. Because almost everything we use has a PCB inside of it now, reducing the effect on the environment from manufacturing them could be another step towards protecting the planet. There are two main areas I intend to focus on: the environmental impact of the manufacture and disposal of electronics.

This research project is loosely coupled with my capstone project. Other than the fact that the audio sampler is an electronic device, it doesn’t directly connect to the environmental focus of my thesis. Despite this, our capstone group had to compile a list of the environmental concerns of our device. This raises questions about the sustainability of each component in the

system and the intended longevity of the device. Ideally, every device can be sustainable, but there is no such thing as a free lunch. Often times, the sustainability of a product is sacrificed in order to cut costs. Environmentally friendliness is usually an afterthought, especially in non-consumer grade devices.

Printed circuit boards (PCBs) are a cheap and space efficient way to implement a circuit into a device and are present in virtually all electronics. But, the manufacture of PCBs is extremely chemically intensive. (Gordon) These chemicals are used to etch the boards with strong acids along with lead-based solder to electrically connect components to the silicon boards. These materials are very damaging and pose major environmental risk if they end up local water supplies via spills or mishandling. Another major concern related to the manufacture of PCBs is the sourcing of materials. Many sources of clean energy require rare earth metals such as cobalt and dysprosium in order to function properly. (EPA) The mines for these metals are often in places where the environmental regulations are lax, resulting in destructive mining techniques and chemical spills.

Every year the world produces more E waste than the last. (EPA) Currently, most E waste is sent to landfills to be buried with other trash. Electronics commonly have lead, bismuth, and other dangerous heavy metals in them that pose risks to environmental damage if they aren't properly contained. Also, landfills are not great long-term solutions as there is only so much space on earth that we can bury our garbage in. One common alternative to dumping in landfills is to recycle the E waste. This way, precious metals such as gold, platinum, and cobalt are not wasted. (Gordon) But recycling doesn't come without its own issues. Recycling is expensive and often times not profitable to do so without government regulation. Also, recycling facilities are

often in places with little to no labor laws, resulting in many E waste recycling centers taking advantage of child labor and dangerous working conditions. (EPA)

Conclusion

Audio sampling has become a cornerstone of modern music production. Many artists have utilized sampled audio in their songs. Despite this, Sampling remains largely out of reach of most musicians. Our capstone project aims to create a solution to this with our self-contained audio sampler.

On a broader note, the production and fate of electronics has many environmental and ethical implications. Namely, if technological progression is inevitable, how can we ensure the production and disposal of electronic devices causes as little harm to the planet as possible. Also, how can these services be provided by more ethical labor sources.

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