The World Wide Web in an Analog Patchbay

Don Derek Haddad, Joseph A. Paradiso
MIT Media Lab
75 Amherst Street
Cambridge, MA 02142
[ddh, joep]@media.mit.edu

ABSTRACT

This paper introduces a versatile module for Eurorack synthesizers that allows multiple modular synthesizers to be patched together remotely through the world wide web. The module is configured from a read-eval-print-loop environment running in the web browser, that can be used to send signals to the modular synthesizer from a live coding interface or from various data sources on the internet.

Author Keywords

Networked instruments, Modular synthesizers, Remote collaboration

CCS Concepts

•**Hardware** → *Analog and mixed-signal circuits;* Digital signal processing; •**General and reference** → Design;

1. INTRODUCTION

The renaissance of modular synthesizers in this age of digital music making raises fundamental questions about the connection between electronic musicians and machines [15]. The concept of sound synthesis using symbolic representations of information, whether in the physical world or on the computer screen, presented new ways of thinking about electronic music composition in the past century [10]. Even when hidden from plain sight, this symbolic representation in music making does exist. For instance, a live coding improviser constructs a mental model of their composition while invoking their musical expression in front of an audience. On the other hand, communication has long influenced electronic music. In the age of telephony, operators would manually connect calls across lines using patch cords, similarly to how sonic artists today route signals on software and/or hardware synthesizers. This paper showcases the integration of modular synthesizers with the world wide web, as presented in a Eurorack module called the 20N02, while also demonstrating the concept of controlling the modular synthesizer from a read-eval-print-loop (REPL) environment embedded in the web browser. Moreover, this paper introduces an online patchbay that allows multiple modular synthesizers to broadcast signals to each other over the internet, or receive data from various sources that are also fed through the network, such as sensor data.

NIME'19, June 3-6, 2019, Universidade Federal do Rio Grande do Sul Porto Alegre, Brazil.

2. RELATED WORK

2.1 Networked Instruments

In 1967, before the ubiquity of networked systems, Maryanne Amacher's pioneering work *City Links* transmitted sound from urban environments to other locations [11]. Networked systems as a musical medium started to leverage remote collaboration among electronic musicians and sonic artists with the development of digital communication, and dates back to the late 1970s [5]. In the mid 1980s, computer networked ensembles like "The Hub" started to emerge. They decided to use a network hub, hence their name, instead of relying on a typical ad-hoc wired connection, resulting in a more robust networked collaboration at the time [3]. With the expansion of the world wide web, and its adoption as a tool for music collaboration, many systems were developed to connect performers, composers, and audiences around the world [21]. Network latency demotivated the creators of such systems from emulating traditional music performance, therefore pushing the boundaries of experimental sound art [5]. New collaborative tools were developed in the early 2000s and used typical client-server configurations, like the daisy phone [7] and the networked laptop ensembles [8].

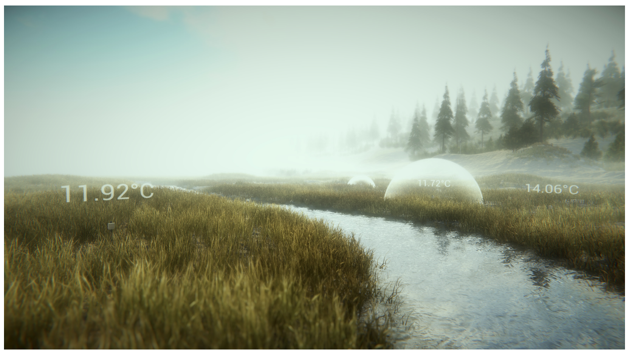

Figure 1: Musical patches running inside the virtual world of Doppelmarsh are driven by streams of data coming from a sensor network deployed in a wetland [12].

The ramification of the internet in everyday life, through social media, also opened a new horizon for experimental music collaboration. The massively multiplayer online drum machine (MMODM) for instance used the social platform Twitter as an interface for musical collaboration [19]. Although controlling electronic music instruments from the internet has been long explored in academia, the internet of musical things is on the rise (IoMusT), and that is due to the deployment and commercialization of ubiquitous sensing in our daily life [20]. In 2012, a system called *Patchwork*, by

B. Mayton et. al, allowed the control of a massive modular synthesizer patch from within a web-interface [13]. Accessing streams of internet-based slow-control and audio data is standard practice in the world of PCs, handhelds, and IoT, but has yet to appear in the world of modular synthesizers.

This paper expands on prior work by facilitating the connection of modular synthesizers through the internet, plus enabling them to connect to ubiquitous sources of online data and audio (both cached and streaming), augmenting the modular paradigm with data and sound sources coming from everywhere.

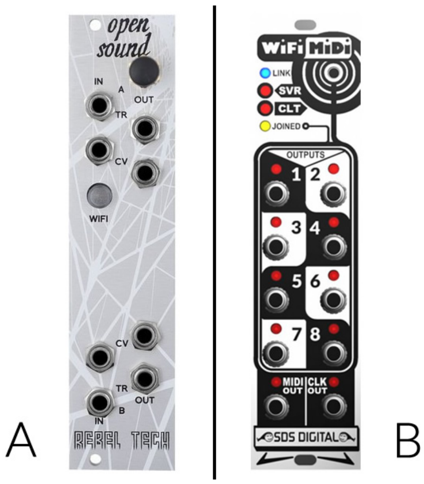

Figure 2: Two WiFi powered Eurorack modules in market as of today. A - Developed by Rebel Technology, allows sending and receiving osc messages, and B - by SDS Digital, does only MIDI output on 8 different channels.

2.2 Modular Versatility

Advances in digital embedded systems in combination with analog synthesizers flooded the market of modular synthesizers with interesting hybrid and versatile modules. Various manufacturers embrace the flexibility of digital technologies in designing their Eurorack modules today. The Disting mk4 by Expert Sleepers [2], for example, can morph into more than 60 different modules with different functionalities. ALM's PAM module does more than a traditional clock/gate module [4]; it includes multiple low-frequency oscillators, envelopes generators, Euclidean sequencers, random voltage sources and more, and is programmed with a single rotary encoder and a tiny display.

From the halls of academia came a hybrid module called "Salt" that also embodies this duality of analog and digital, and is powered by the Bela.io platform [14] and Pure-Data (PD) [16]. This module enables exporting PD patches right into a modular synthesizer, turning digital signals from the computer into control voltages or audio sources, and therefore extending the possibilities of a given patch.

Similarly, the modular synthesizer emulator VCV Rack, in combination with an audio interface like the ES-8 by Experts Sleepers, can also be used to send signals back and forth to a modular synthesizer, putting us in the age of hybrid physical and virtual modular synthesis [18]. On the other hand, digital audio workstations have also integrated with hardware interfaces and symbolic patching. Namely, Max for Live that enables the creation of Max/MSP patches from within Ableton Live, to facilitate composing and improvising with other hardware and software synthesizers [1].

2.3 Data Sonification

Turning data into sound in musical compositions has been a subject of research since the 1980s. Much remains to be learned about how sonification works in the scientific field. In order to extract meaning from sound, listeners need to learn and adapt to a "sonic legend" as well as have some kind of visual guidance in a performance [6]. Today, mapping ubiquitous real-time streams of data into sound presents a burgeoning new medium for musical expression, for example sonifications done on particle collisions from the ATLAS detector at CERN by various composers and electronic musicians using digital technologies [9]. More recently, data gathered from plasma fusion research from MIT's Alcator C-Mod Tokamak, were sonified on a massive analog synthesizer [17].

3. DESIGN

3.1 Hardware Design

At the core of the 20N02 module resides the esp-8266, a low-cost WiFi chip manufactured by Espressif. The chip can be purchased as a surface mount device (SMD) module, packaged with other required components like an antenna, level shifters, capacitors, pull-up resistors and protective diodes. The inclusion of a second microcontroller on board turns the esp8266 into an IOT device capable of connecting to sensors and actuators and engage with streams of data through the internet.

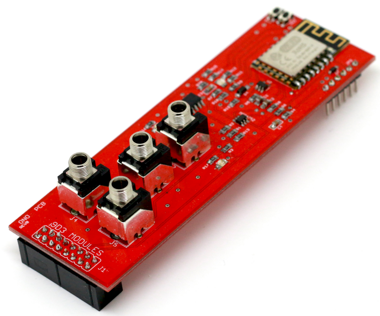

Figure 3: This picture shows the two-layers printed circuit board of the first revision of the 20N02 module. Photo-credit: Gabriela Bila

The first revision of the module requires 3.3V to operate, therefore a voltage regulator is needed to transform the incoming 5V from Eurorack power supplies into a stable 3.3V. The incoming stream of data through WiFi is converted into control voltages (CV) by an external single channel 12-bit digital to analog converter (DAC) that communicates with the esp-8266 module via the I2C ports. The output of the DAC is amplified and buffered with an op-amp, powered by the -12V and 12V rails of the Eurorack power bus, into 3 identical outputs that in-turn are connected to envelope followers with LEDs used as signal indicators. The esp-8266 module includes a single analog input, and can only accept 1V signals. A voltage divider was used to turn CV signals coming from the modular synthesizer into the allowed range. Lastly, an FTDI module is required to flash the esp-8266 chip via its RS232 serial ports, which could be done using the Arduino IDE. Once flashed, the module can allow over the air updates (OTA), making swapping programs and installing updates an easier task.

3.2 Software Design

The preliminary program uploaded to the 20N02 module runs a Websocket client that accepts streams of data from other connected clients. Network latency could be noticeable especially that the Websocket protocol runs over TCP, not to mention networked latency over WiFi. This will not affect the integrity of the signals being sent or received, as the program waits until the entire signal is in memory before writing to the DAC. This approach pushes composers away from replicating conventional instruments. Unlike the Open Sound module by Rebel Technology that promotes such replicas. (Example: TouchOSC app that sends messages from a virtual piano running on an iPad over WiFi into a Eurorack synthesizer). Multiple 20N02 module could be connected and configured from within a REPL environment running on a web-browser. A live-coding-like interface is used to generate digital signals, that in turn are streamed into the module over WiFi. These signals could take various forms and shapes. For instance, a simple linear attack/decay envelope could be implemented through a simple script that draws an ascending and descending line on a 2D X-Y plane. Moreover, many more complex waveform could be computed by using the Javascript built-in Math object. Figure 4, shows an example of a couple of complex waveforms generated using trigonometric functions. Many types of signals could be generated this way: attack, decay, sustain, release, complex oscillators, pitch sequences, and random numbers to name a few.

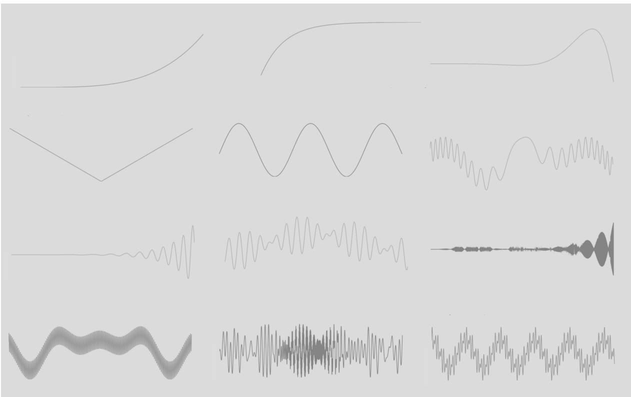

Figure 4: Various waveforms generated from the 20N02 REPL environment using Javascript.

The esp-8266 is equipped with 80 KiB (81.92 KB) of user data, the incoming stream of data is cached and saved onto the chip, and could be looped based on user's input or until overridden by a new stream. The web server in use is implemented with Node.js and runs a Websocket and an HTTP server. The Websocket server is used to route the incoming streams of data to their appropriate destinations, whereas the HTTP server is simply used to serve the REPL environment. The 20N02 module could be also configured to accepts other types of data through application program interfaces (APIs). It was tested with historical sensor data coming from sensors deployed in an outdoor environment, sonifying the history of slowly-changing temperature, humidity and pressure over a year, accelerated into a complex envelope waveform lasting just a few minutes. In other terms, analog sensor readings are converted from voltages to digits, sent over the network to be converted back into voltages, then used to drive a patch of a modular synthesizer, either in real-time or cached and output with a varying timebase.

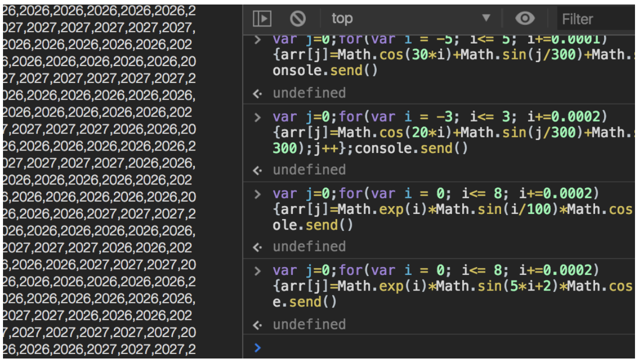

Figure 5: A live coding interface is presented in the web-browser using Google Chrome's developer console. The theme of the web-app matches the colors of the console in dark mode.

3.3 Interface Design

The face-plate mounted on top of the module is also manufactured with FR-4 PCB material. By design, certain areas on the face-plate were left without the silk-screen overlay and without the copper-layer, allowing light coming from the LEDs to diffuse in an ambient fashion while indicating signals. The module is 8HP (1.6') wide and matches the Eurorack format with 3 rack units of height (3U). The design of the REPL environment extends the developer console found on modern web-browsers as shown in figure 5.

Figure 6: A picture of the 20N02 Eurorack module.

4. PROTOTYPE

An early prototype of the 20N02 module has been made, with a single analog input and 3 buffered outputs. It was manufactured and tested by a handful of electronic musicians and sonic artists. The feedback of this short survey will highly influence the future features that will be added to the module.

5. FUTURE WORK

A second revision of the module is in the works, capable of handling multiple inputs and outputs up to audio rates, as well as adding an audio CODEC chip allowing

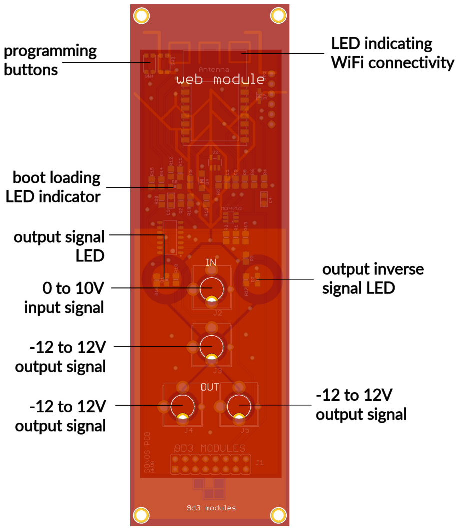

Figure 7: A brief annotation of the 20N02 module.

streaming samples to be provided into a modular synthesizer over WiFi. The web-platform is also getting a renovation, as more functions will be added to the REPL environment to improve readability, also allowing a quicker access to common operations. A basic security layer will be also added to prevent users from getting unwanted signals through their synthesizers. Ultimately, a REST API could be developed to facilitate the integration of the 20N02 with common IoT standards, while inviting other developers to contribute with creative applications that could be deployed on what can resemble an app store for smart modular synthesizers.

6. CONCLUSION

This paper extends the field of networked instruments into the world of modular synthesizers. A Eurorack module called 20N02 was developed to connect modular synthesizers together through the world wide web as well as to provide outputs that produce control voltages and audio from internet sources (real-time or cached). Moreover, multiple use cases were presented to show the benefits of connecting an analog synthesizer to the internet, like facilitating data sonification of various sources through APIs. Finally, this module made it possible to perform remote live coding operations on a modular synthesizers from around the world, through a web interface using Javascript.

7. ACKNOWLEDGMENTS

This project wouldn't be possible without the help and mentorship of Mark Feldmeier. We would also like to thank two electronic music composers and modular-synth builders: Mr. John Debo, and Mr. Joseph Junior Sfeir who have helped tremendously in the early development of the project, and who's feedback will be incorporated in future revisions of the 20N02.

8. REFERENCES

[1] Abelton live, a software music sequencer and digital audio workstation for macos and windows. *URL: https://www.ableton.com/.*

[2] Experts sleepers disting mk4 many-in-1 multifunction module. *URL: http://www.expert-sleepers.co.uk/disting.html.*

[3] The hub: computer network music ensemble. *URL: en.wikipedia.org/wiki/The Hub (band).*

[4] Pam: compact programmable clocked modulation source for your eurorack. *URL: http://busycircuits.com/alm017/.*

[5] Á. Barbosa. Displaced soundscapes: A survey of network systems for music and sonic art creation. *Leonardo Music Journal*, pages 53–59, 2003.

[6] S. Barrass and G. Kramer. Using sonification. *Multimedia systems*, 7(1):23–31, 1999.

[7] N. Bryan-Kinns. Daisyphone: the design and impact of a novel environment for remote group music improvisation. In *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques*, pages 135–144. ACM, 2004.

[8] J. Freeman and A. V. Troyer. Collaborative textual improvisation in a laptop ensemble. *Computer Music Journal*, 35(2):8–21, 2011.

[9] E. Hill and S. Goldfarb. Atlas data sonification: a new interface for musical expression and public interaction. Technical report, ATL-COM-OREACH-2016-018, 2016.

[10] V. Lazzarini. The development of computer music programming systems. *Journal of New Music Research*, 42(1):97–110, 2013.

[11] A. Licht. Sound art: Origins, development and ambiguities. *Organised Sound*, 14(1):3–10, 2009.

[12] E. F. Lynch. *SensorChimes: musical mapping for sensor networks toward augmented acoustic ecosystem.* PhD thesis, Massachusetts Institute of Technology, 2016.

[13] B. D. Mayton, G. Dublon, N. Joliat, and J. A. Paradiso. Patchwork: Multi-user network control of a massive modular synthesizer. In *NIME*, 2012.

[14] G. Moro, A. Bin, R. H. Jack, C. Heinrichs, A. P. McPherson, et al. Making high-performance embedded instruments with bela and pure data. 2016.

[15] J. A. Paradiso. The modular explosion-deja vu or something new? In *Presented at the Voltage Connect Conference, Berklee College of Music, Boston MA*, 2017.

[16] M. S. Puckette et al. Pure data. In *ICMC*, 1997.

[17] P. Rivenberg. Spinning data into sound: An interdepartmental collaboration brings out the music of nuclear fusion. *URL: http://news.mit.edu/2018/mit-collaboration-uses-nuclear-fusion-data-to-create-music-paradiso-resynthesizer-0509*, 2018.

[18] Synthhead. How to create a hybrid modular system with vcv rack. *URL: http://www.synthtopia.com/content/2018/02/16/how-to-create-a-hybrid-modular-system-with-vcv-rack/*, 2018.

[19] B. Tome, D. D. Haddad, T. Machover, and J. A. Paradiso. Mmodm: Massively multiplayer online drum machine. 2015.

[20] L. Turchet, C. Fischione, and M. Barthet. Towards the internet of musical things. In *Proceedings of the Sound and Music Computing Conference*, pages 13–20, 2017.

[21] G. Weinberg. Interconnected musical networks: Toward a theoretical framework. *Computer Music Journal*, 29(2):23–39, 2005.