DATATONISM: EMULATING HISTORICAL INSTRUMENTS AS A PEDAGOGIC EXERCISE

Derek HOLZER (idholzer@kth.se) [1], **Karolina SHI** (karshi@kth.se) [1], and
André HOLZAPFEL (holzap@kth.se) [1]

[1] *Division of Media Technology and Interaction Design*, **KTH Royal Institute of Technology**, Stockholm, Sweden

ABSTRACT

This paper describes a university course project focusing on the digital emulation of a historical electronic sound instrument, the Dataton System 3000. Students were asked to emulate the synthesis possibilities and user interfaces of individual Dataton modules using Pure Data, based on both documentation and physical inspection of the instrument itself. The course represents one segment of a four year research project into the design of contemporary instruments informed by the history of electronic music in Sweden during the 1960's and 70's. We found that the modular structure of both the Dataton and Pure Data supported a collaborative environment for the students to explore digital signal processing and music instrument design. Our report further demonstrates how the emulation of electronic instruments provides avenues of creative expression and critical thinking among the students, while making a positive contribution to our larger research goals.

1. INTRODUCTION

The Historically Informed Sound Synthesis [1] research project explores historical sound synthesis technology from the 1960s and 1970s used in Sweden at the Royal College of Music (KMH), Elektronmusikstudion (EMS), and by various composers in their private studios. Many of these instruments are archived by the Swedish Performing Arts Agency and the Swedish Museum of Performing Arts. Specific goals of the project include:

1. Developing digital emulations for historical sound synthesizers
2. Developing tangible digital interfaces inspired by the original artifacts
3. Studying and improving emulations and interfaces through collaborative design with composers, students, museum visitors, and an online audience

[1] https://www.kth.se/hct/mid/research/cmt/projects/historically-informed-sound-synthesis-1.1048895

Opportunities for student participation exist at each phase of the project. A recent course project for students within the Sound and Music Computing track of the Master Program in Interactive Media Technology at the Royal Institute of Technology (KTH) in Stockholm focused on the first research goal. The student team produced a unified body of code within a well-documented framework, resulting in a flexible and configurable digital sound instrument which located several affordances of the original analog model within a new context.

In this report, we describe the historical and technical background of the course work, detail how the emulation was carried out, and elaborate some of the benefits which student involvement in a larger research project provides for both the students' own education and the research goals as a whole. The framework supporting the contributions of students to research at KTH has been introduced in [1], and the present paper uses this framework as a basis. For a wider discussion of student involvement in research, see [2].

The historical instrument under study was the Dataton System 3000, an analog modular sound processing and synthesis system produced in Sweden during the 1970's as a pedagogical tool for music teachers [3]. The Pure Data (Pd) multimedia environment was used to program emulations of the Dataton modules, with particular emphasis on the use of the *Automatonism* [2] library within Pd to facilitate collaboration during the coding process.

2. BACKGROUND

2.1 Emulation of historical instruments

Of the manifold reasons for emulating historical electronic sound instruments, several stand out as being relevant in an educational context:

1. Allowing the virtual playing of rare and otherwise inaccessible instruments
2. Enabling the performance of live electronic music reliant on obsolete hardware and software
3. Exploring, understanding, and modifying the design and construction of historical instruments
4. Providing a pedagogic basis for the study of digital music instrument (DMI) design

[2] https://www.automatonism.com/

The obsolescence of proprietary software and specialized hardware is an inherently limiting factor in the longevity of any live electronic music performance [4]. These situations require varying degrees of physical preservation, documentation, and technical or aesthetic reinterpretations to maintain repertoire pieces beyond the lifespans of their composers [5], as well as to enable the study of them.

The commercial marketplace has widely addressed the concern of access to historical, mass-manufactured instruments. Software companies such as Arturia [3], for example, have released emulations of the EMS Synthi AKS, Buchla Music Easel, and other iconic vintage synthesizers. However, while these emulations may offer a comparable playing experience to the original hardware, their closed-source nature provides little learning value for the student of digital synthesis techniques.

Several examples of historical instrument emulation as pedagogic exercises can be found within the Pd community. For example, undergraduate students in Tom Erbe's Computer Music I course [4] at UCSD were asked to emulate either the Moog Minimoog, ARP Odyssey, Sequential Circuits Pro-One, or OSC OSCar using Pd. At least two of the projects demonstrated high levels of execution and are archived online, however none of these efforts were documented systematically in publications of any kind.

Likewise, the *Pure Data Repertory Project* [5] provides Pd patches emulating several canonical computer music compositions which otherwise rely on custom, inaccessible technological solutions, for both study and performance. And finally, Ezra Teboul's doctoral research into handmade electronic music [6] invokes Chikofsky and Cross' definition of "reverse engineering" [7]. Teboul describes his own emulations of works by Reich and DeMarinis as "increas[ing] the comprehensibility of the original project[s] and open[ing them] to further developments" [6].

For our own course project, we see the emulation of the Dataton as a pedagogical opportunity for students to learn more about the craft of DMIs, while also contributing to the accessibility and understanding of historical instruments. This craft includes not only the digital signal processing necessary to emulate the Dataton's synthesis capabilities, but also the study of its affordances as an playable instrument, its learnability, the diversity, reproducibility, and efficiency of its musical output, and other factors essential to the practice of digital lutherie [8].

2.2 Dataton overview

The Dataton System 3000 was designed by Björn Sandlund, and manufactured by the Dataton company between 1973 and 1980. Sandlund's intention was to create a modular instrument with a robust physical interface and an open ended architecture. Its functions spanned those of a sound synthesizer, effects unit, and mixing console. Apart from a digital controller module added towards the end of the 70's, the system was entirely analog. The modules available to us were previously used at KMH, at the Sibelius Academy in Helsinki, and by composer Leo Nilsson.

Figure 1. Interconnected Dataton modules. Note the hardware connections on all four sides of each module.

The simple building blocks of the Dataton easily lend themselves to educational activities. The system contains four classes of modules, with each module often containing four identical copies of the same basic circuit:

- Source modules include both electronic sound generators and interfaces for microphones and reel-to-reel tape recorders
- Manipulating modules are comprised of various filters, dynamics processors, effects, and modulators
- Editing modules mainly address the output of system sounds for recording, monitoring, and diffusion on loudspeakers
- Power and control modules take care of system power and digitally stored sequences

These modules are interconnected through a novel matrix patching implementation, using rugged, multi-pin industrial connectors to plug the modules together from all four sides (see Figure 1). The main stereo busses are routed via two connectors on the sides of each module, while four individual channels run top to bottom. Power is made available to every module through the same connectors.

Participants of a previous workshop [9], which focused on analyzing the Dataton's affordances through playing it, indicated that the instrument was exciting, immediate, and hands on. But they also found it frustrating at times due to its high degree of unpredictability. They also felt that the Dataton did not afford them the possibilities of composing conventional rhythmic or tonal music, instead favoring more radical sonic experimentation. One concern of the current project is how far these affordances may be preserved, re-shaped, or even abandoned in the context of an emulation.

3. METHODS

3.1 Student work group

The specific course in which the project took place was DT2213 Musical Communication and Music Technology

[3] https://www.arturia.com/store/analog-classics
[4] https://lists.puredata.info/pipermail/pd-list//2005-03/026839.html
[5] http://msp.ucsd.edu/pdrp/latest/doc/

(second cycle, 7.5 ECTS). There were seven course participants, and all participated in the project together as a team. Supervision meetings and tutorials were held in Zoom, while most of the inter-student communication and work was coordinated on Discord. Throughout the working process, the students referred to the following research questions:

1. What are the limitations of creating a digital emulation of an analog instrument?
2. What compromises and design choices are required for the emulation?
3. How does one evaluate such an emulation?

The students were provided with physical access to a number of Dataton modules, a series of video tutorials [6] on their use, and documentation containing written descriptions of the system's features and parameters, photographs of the interface and interior of each of the modules, and schematics of their circuits [3]. The majority of the students implemented two Dataton modules each. A public archive of the code was released under the title *Datatonism* [7], and the results were also demonstrated at the Swedish Performing Arts Museum.

3.2 Evaluation

As part of the evaluation process, the students made limited user testing in the form of an online survey. Users were asked to download and freely explore the Datatonism system, and then answer several questions about their familiarity with modular synthesizers and Pd or Max on a Likert scale, where 1 indicates not familiar at all and 5 indicates very familiar. Finally, users were asked about their experiences using Datatonism with either yes/no or open ended questions. In total there were seven respondents, all of whom were familiar with modular synthesizers and most of whom were familiar with Pd.

At the end of the course, the students submitted one group report describing the implementation of the Datatonism code and self-assessing its usability (see sections 4.1 and 4.2.1). Results of the user testing were also summarized and discussed in this group report (see section 4.2.2). The group report was further supplemented by individual feedback reports, where each student reflected on the learning process within the course (see section 4.2.3).

4. RESULTS

4.1 Datatonism

The Datatonism system consists of a top level Pd patch which serves as the primary working canvas for the user, and an abstraction patch for each of the twelve emulated Dataton modules (see figure 2):

- Quad Input Amplifier 3001
- Quad Sound Generator 3002
- Noise Generator 3004
- Stereo Octave Filter 3101
- Stereo Electronic Echo 3102
- Quad Universal Filter 3103
- Quad Envelope Shaper 3104
- Ringmodulator 3105
- Master Mixer 3201
- Sub Mixer 3202
- Dual Panorama Unit 3203
- Universal Mixer 3205

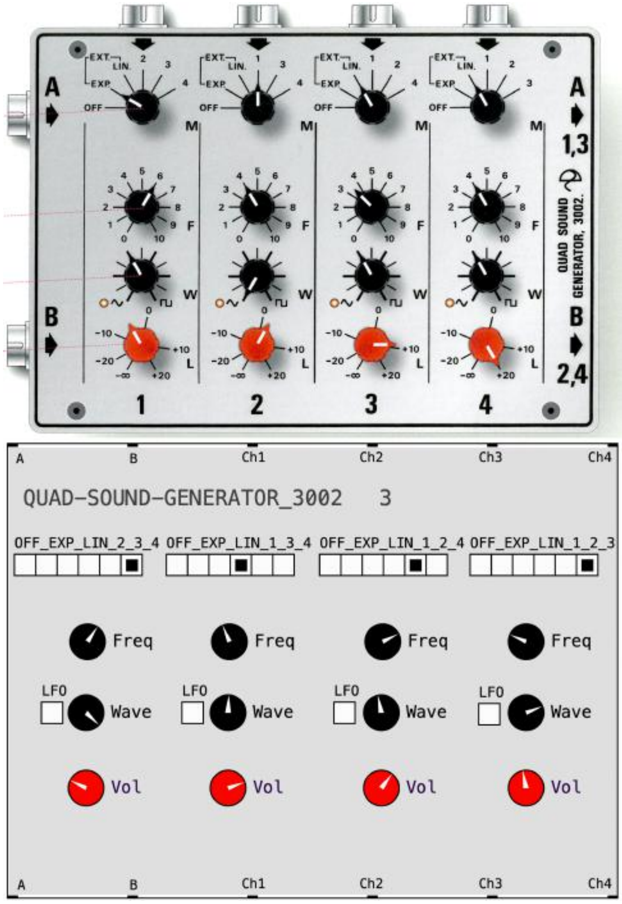

Figure 2. Comparison of the original analog (top) [3] and digital emulation (bottom) versions of the Quad Sound Generator module.

The digital modules can be connected together by graphical patch cables to recreate many of the amplitude or frequency modulation and signal processing capabilities of the original Dataton (see figure 3).

The Automatonism library for Pd, designed explicitly to emulate the functions of a modular synthesizer, allows the user to add these module abstractions directly to the main

[6] https://www.youtube.com/playlist?list=PLAz5IzRCksDJf9ENkU_qYhac3TlgE09Df

[7] https://github.com/kx-shi/Datatonism

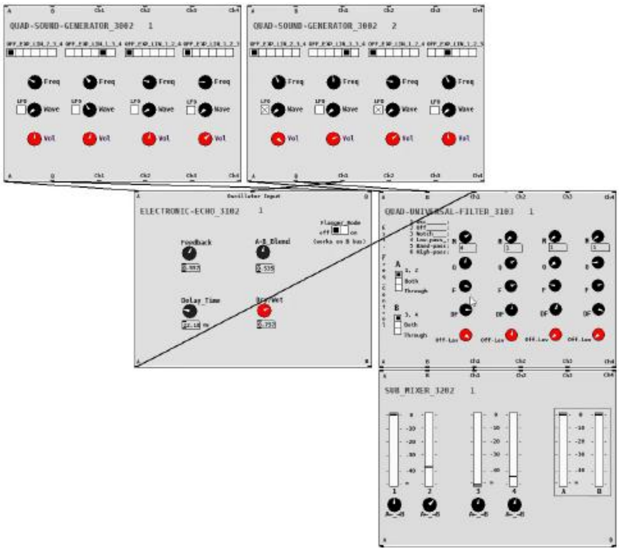

Figure 3. Interconnected Datatonism modules, with Pure Data patch cables replacing the hardware connections at top and bottom only.

canvas from a clickable menu, as well as to access documentation about each module. Automatonism also manages the state saving, randomization, and interpolation between states of all module parameters, even across multiple copies of the module.

Additionally, Automatonism provided a crucial collaborative framework for the project through its modular structure. This encouraged the creation of module templates so that features such as on screen size, interface color and layout, and the order of input and output channels would be standardized across the project to best reflect the look and feel of the Dataton. Other aspects such as fader and panning curves were also coordinated between the various modules for further consistency.

Apart from the features proved by Automatonism, the emulations were hand coded by the students based on class tutorials, available Pd literature such as Kreidler's *Load-bang* [8], the Dataton system itself, and Sandlund's documentation [3].

4.2 Feedback

4.2.1 Student usability feedback

The group and individual student reports contained a number of observations on the digital emulation of analog instruments. They noted that keeping the look of the emulation modules as similar as possible to the originals involved compromises between screen area, the size of a module and its GUI controls, the amount of information each module should communicate, and the ease of patching them in Pd. For example, Pd's top-to-bottom signal flow layout prevented the digital modules from being patched the same way as the hardware ones. Thus the Dataton's unique tiled interface (Figure 1) was lost in favor of an entirely vertical arrangement.

[8] http://www.pd-tutorial.com/english

A recurring point was that on-screen control of a complex modular synthesizer with a mouse is far from optimal, and having physical controllers for the synthesizer parameters would improve the user experience. One student noted that sounds are usually the result of physical actions, while another described the "slight tactile resistance of a knob or fader" as contributing to the feeling of creating sound with one's hands. "Without this," he continued "it feels more like engineering than playing an instrument."

The group took a balanced view of the emulations' benefits and shortcomings, realizing that many suggested improvements (sideways patching, physical controllers, etc) were not provided within the Pd environment itself. Several students found that while the Pd implementation contains drawbacks in terms of usability, it is also much more flexible in terms of customization and routing. For example, modules could be freely added to a patch, leading to very different practices than those limited by hardware resources.

On the whole, they observed that even when the original circuits were modeled very closely, the resulting digital sounds were fundamentally different from the analog ones. Situations such as feedback and cross-modulation are also handled quite differently in discrete versus continuous systems, leading one student to conclude that it would be "impossible to create a 100% replica of an analog system" in this particular digital context.

4.2.2 User testing feedback

The limited user testing supported many of the students' observations. Users commented on the lack of precision in the on screen controls, coupled with audible stepping in some parameters. Users also noted the differences in digital versus analog sounds, and the feeling of physically touching and connecting modules being missing.

The users also brought up the additional and possibly unforeseen issue of the clarity of the interface. As the students had focused on emulating the look and feel of an existing instrument, they brought any confusing aspects of the Dataton's controls into their emulations as well. This resulted in criticism of the emulations which may have been more appropriately aimed at the original. The single user who had previous experience with the Dataton was more aware of its limitations, and took those into consideration during testing.

4.2.3 Student learning feedback

Each of the students presented very different personal feedback on the course. Generally, they found the provided documentation essential, particularly when the physical module to be emulated was not available. Some students found that the physical modules were useful either to compare against the emulations or to clarify a confusing or badly documented feature.

One student felt it was difficult to find appropriate reference material for the assignment, despite the fact that each of the modules was built from very basic DSP functions. However, another spent quite a bit of time emulating one particular module, the Stereo Electronic Echo, for which we had no analog version. He discovered a wealth of sources to effectively model many of its original functions, such as delay, echo, reverberation, chorus, flanging, etc.

Most reported enjoying the learning experience. Some explicitly appreciated the opportunity to learn about synthesis and how to translate analog instruments into the digital domain, including both the DSP and the user interface aspects of the project. Another benefited from the chance to practice useful teamwork, organizational, and leadership skills. Additionally, several students felt that the solid framework of the assignment helped organize the tasks across the team.

5. DISCUSSION

The usability observations made by the student group may not be groundbreaking in terms of research into new interfaces for musical expression or other types of human-computer interaction. But they do represent important realizations towards their own individual mastery of digital music instrument design. The connection of bodily movement and tactile feedback to sound production, for example, is a key facet of many successful NIME projects.

Another key realization for the students is that emulation is not a task of engineering a perfect copy, indistinguishable from the original. Modeling or emulating a historical instrument is often more a task of reinterpretation within the affordances provided by a new context. The students quickly understood which of the Dataton's physical affordances simply did not work the same on-screen, and which were impossible to replicate, thus requiring ingenuity in their approach. This awareness steers the project away from being a practical exercise with precise and quantifiable results. Rather, it becomes a creative endeavor involving fuzzy logic, noisy transmissions, and random deviations appropriate to the analog unpredictability of the Dataton itself.

The authors took interest in comparing the methods of this project with those of an earlier workshop involving the exact same instrument. Previously, we worked with students at KMH to first create compositions using the Dataton, and then to imagine instrument design fictions based on it [9]. The KMH group's approach of learning by playing tended to disregard the documentation over direct experience with the object itself. Conversely, the KTH group's approach of learning by emulating prioritized the documentation as primary source, with the original Dataton serving as a point of comparison. We do not find this surprising, as the students in each group came from very different backgrounds. Consequently they used different means to achieve the same learning objectives — that of understanding and reinterpreting a historical instrument — with equally relevant results.

Finally, we would like to draw a parallel between the original pedagogic function of the Dataton and its implementation in Pd using the Automatonism library. As modular systems, both the Dataton and Pd/Automatonism break down instruments into discrete units which can be studied individually before being combined into more complex workflows. In our case, this allowed each student to program their contribution within a well defined set of constraints, and it ensured that everyone's output would be mutually compatible with the final system as a whole. We see this as another level of emulation, that of emulating the ethics [10] of the original instrument — for instance the aims it was designed to achieve and the social structures to which it relates — as discussed in previous work with the Dataton [9].

6. CONCLUSIONS

We have described the emulation of the Dataton System 3000, a historical electronic sound instrument from the 1970's. This emulation used Pure Data and was carried out by students of media technology and interaction design as a course project. We found that a structured and methodical workflow was supported by the modular environments of the Dataton and Pd. By comparing and contrasting the original instrument and its digital emulation, we discovered key aspects of the analog Dataton which demanded reinterpreting during the students' work. We assert that these reinterpretations constitute a creative act outside the bounds of a practical programming exercise, and position them favorably next to artistic research of the same instrument. We conclude that the practice of emulating historical instruments provides rich benefits to students' learning experiences through the exercise of technical skills, teamwork, and creative thinking. We are confident that the insights gained from this project, as well as the methods developed for it, will contribute positively to the long term goals of the historically informed sound synthesis project and help create electronic instruments of the future.

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