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The D-Box: How to Rethink a Digital Musical Instrument

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Abstract

The D-Box is a novel digital musical instrument that can be modified and hacked by the musician, subverting its original design. The possibility to rethink and appropriate a musical instrument in unexpected ways is not common when dealing with digital circuits and hard-coded software. In this short work, we first briefly introduce the details of the hackable design that characterises the D-Box; we then describe how 3 musicians transformed their D-Boxes into 3 radically different instruments, according to their own artistic needs. Finally we argue why and how this is relevant to the domain of instrument design, music and creativity. This work comes together with a demo session, during which the audience will have the opportunity to replicate step by step the 3 hacked instruments and make music with them.

Keywords

Hacking, Appropritation, DMI, Embedded Hardware

Introduction

The evolution of a musical instrument is often times unpredictable. Designers and musicians continuously revise their instruments, adding and discarding features, likely producing a gradual drift from the original design. This is particularly true for successful musical instruments characterised by a long life span. A good example is the guitar, which has been rethought less than a century ago with the introduction of electric amplification, or brass instruments like trumpets and horns, now featuring piston or rotary valves to allow pitch change. Similar reinterpretations of an instrument may help its diffusion and keep it popular over time.

However, the possibility to *rethink an instrument* and push towards new creative boundaries must not be taken for granted, especially in the domain of Digital Musical Instruments (DMIs). The usage of digital technologies makes available novel musical systems, but often leads to intrinsically "black box" designs, hard-coded, difficult to understand and to modify. In contrast with this trend, we developed the *D-Box*, a novel DMI based on embedded technologies and specifically designed to be appropriated and repurposed in unexpected ways.

Hackable Design

The D-Box is a *hackable instrument*, supporting and eliciting modifications by the performer through circuit bending techniques. These techniques consist of exploring and hacking the circuitry underlying an electronic device, adding/removing components and connections to subvert its functionalities and find novel idiosyncratic musical features (Collins 2008). Although born in the 70's, this practice still deals with the building blocks of modern electronic instruments and is theoretically capable of fostering creative misuses and modifications of DMIs. Unfortunately, circuit benders prefer focusing on toys or inexpensive musical instruments (Ghazala 2005), since latest DMIs are likely to produce silent configurations or even break when hacked. This is mostly attributable to the usage of small and fragile integrated circuits, digital logic and hard-coded software processes.

The D-Box is a first attempt to regain the flexibility and the reintepretability of old electronic instruments even when latest generation digital circuits are used. Although apparently very simple, this instrument is characterised by an innovative rationale, that is the result of more than one year of studies on performer-instrument interaction and design for appropriation. The D-Box appears as a self-contained, 15 cm laser-cut wooden cube carrying a BeagleBone Black[1] (BBB) embedded computer and a full range speaker. Two multi-touch strips are attached on one side of the enclosure, one laying on top of a force sensor. The metaphor of the instrument is fairly straightforward: tapping on the touch strip opposite the speaker triggers a sound loaded on the BBB, with position controlling pitch and pressure determining volume; additionally, a bandpass filter can be controlled touching the second strip, introducing up to 5 independent bands. Sinusoidal partial synthesis is used to playback the samples. Attached to the inside of the D-Box there are also 2 piezo microphones, amplifying the mechanical and acoustic sounds resulting from the interaction with the body of the instrument.

However, the complexity of the hackable design of the D-Box revolves around its internal circuitry and its connections with the on-board software. Opening the side panels of the enclosure it is possible to access a breadboard populated with standard electronic components, as shown in Figure 1. The resulting circuits are connected to the embedded computer

[1] http://beagleboard.org/black

via a custom *cape* (expansion board), which equips the BBB with 8 analog inputs and 8 analog outputs. This network of connections, collectively called the *matrix*, creates feedback loops between the analog electronics (including audio and sensors' input) and the software, which is running on a ultra low latency, hard real-time custom Linux system. Synthesis parameters are extracted from the voltage signals sampled in software and fed back into the circuit as analog outputs, linking most of the mappings and sonic behavior of the D-Box to the current state of the matrix. For more information about feedback loops, technical specs and musical features of the instrument, please refer to (McPherson and Zappi 2015).

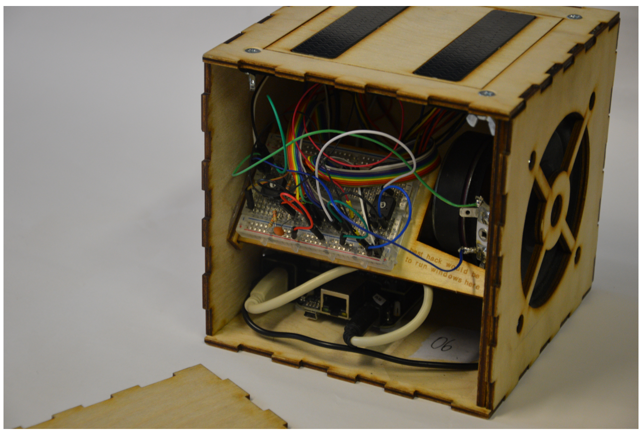

Figure 1: The inner breadboard of the D-Box, carrying the circuits which define the instrument's behaviour. The two touch sensors lie on top of the wooden case while the speaker is embedded on a side.

As discussed in detail in (Zappi and McPherson 2014), the simplicity of the original metaphor encourages the modification of the instrument. Any electronic components can be used to relax constraints, add, modify and remove features. The inner circuitry can be hacked connecting together unrelated parts of the matrix to create unpredictable time-varying behaviors, also feeding back the audio output onto the breadboard. Furthermore, differently from a *modular* approach, the space of possibilities is not defined a priori. In a modular system, strictly connections and sounds pre-thought by the designers are accessible; only the musicians who found themselves comfortable with these set of features will keep on playing the instrument. As opposed, hackable design theoretically gives the possibility, even pushes to drift from the original instrument, engaging with creative configurations unfamiliar even to the designers. This could be particularly relevant in the context of artistic creation and for the development of the instrument itself.

D-Box Hacks

To test the D-Box and the hackability of its design, we ran a user study with 14 musicians. Each participant was given a D-Box and was asked to prepare a live performance in few weeks. Although not forced to hack the instrument, almost all participants decided to modify their box, in some cases thoroughly subverting its original design. Before analysing the global outcome of the study (Section Discussion), in the next sub-sections we will highlight 3 of the most remarkable hacks that we encountered. Technical modifications will be explained step by step, with the aim to explain how differently these instruments evolved and how this process made possible the development of extremely diverse personal playing techniques.

Hack #1 The whole hack from Participant ID 5 (P5) targets precise timing and control, resembling an acoustic or electric instrument. None of the original features of the D-Box were discarded; the performer changed the pitch range of the instrument to comfortably play a tune he composed and then extended the instrument's metaphor with new elements. As first step, P5 loaded 2 custom sounds on the BBB, one sustained, the other percussive. He then added two push buttons to enable pitch control through the manipulation of a Light Dependent Resistor (LDR), one button pulling the pitch up, the other pushing it down. Furthermore, when both the buttons are pressed, the second sample is activated and its attack is enhanced by an abrupt pitch shift, acting as a fast envelope. The buttons and the LDR are exposed on one of the side plates, while the matrix is sealed inside of the closed case, making it inaccessible during musical performance. The resulting instrument is capable of both pitch and rhythmic fine control, mostly based on instantaneous exchange of mechanical energy with the performer, on buttons, touch sensors and tapping the side plates; this makes it ideal for "instrumental interaction" (Cadoz 2009) based on coordinative skills.

Hack #2 P8's instrument is designed to mix sensors and matrix interaction to create rhythms with unpredictable timbral textures. The pressure input from the first touch sensor acts no more as volume control, it is used instead to switch between 2 custom loops, yet leaving position to control pitch. The finger position read from the second touch sensor determines the playback length of the current sound, i.e., the number of samples looped when the sound is triggered. Also audio inputs are included in the hack; one of the piezo signals is shorted to the clock circuit of the system, so that tapping the box interferes with the playback speed of the samples. Differently from P5's hack, the instrument is supposed to be played with the side plate open, acting on the inner circuitry. P8 prepared the matrix with additional jumper wires allowing to quickly short together the pitch and the clock circuits, and to swap between capacitors of different size; this causes musical autonomous processes, like pitch oscillations at varying frequency and glitches. Furthermore, during the performances, P8 used a small vial to pour water on the capacitive pitch sensors; using only one drop, he obtained infinite sustain of a precise note, while wetting the whole surface he triggered continuous and chaotic pitch changes, caused by water evaporation. P8's instrument is a complex device carefully tailored according to P8's needs. It is partially controlled by the performer and partially dependent on some level of self-agency of the system, making available what Johnston et al. defined as "conversational mode" of interaction (Johnston, Candy, and Edmonds 2008).

Hack #3 P10 is an experienced circuit bender and he modified his D-Box making use of typical circuit bending tools and techniques. We gladly acknowledged that, for the first time, P10 managed to make use of his hacking skills to probe and modify a DMI, rather than cheap/old instruments and electronic toys. His hack revolves around 4 potentiometers, that can be used to dynamically connect different parts of the matrix and modify the electrical behavior of the circuits. Each potentiometer is configured as a variable resistor, using two wires: the first one is steadily fixed to a specific circuit (the clock rate, the partial waveform generator, the sound selection and the amplified audio output); the other is floating and can be attached anywhere on the matrix through a crocodile plug. Moving these connections and playing with the indeterminacy of floating wires it is possible to assemble complex circuits, characterised by unstable/time-varying electrical configurations. These autonomous processes gain primary control over synthesis; the touch sensors are almost dismissed, while the performer directs, combines and shapes sounds using the matrix, leveraging his intellectual skill in an "ornamental mode" of interaction (Johnston, Candy, and Edmonds 2008).

Discussion

Other participants showcased intriguing hacks and unexpected playing techniques. One performer directly touched the circuits with his hands, leveraging his own skin conductance to inject electrical interferences into the matrix and generate glitches. Another participant hooked up to the matrix an Arduino, programmed to switch between samples according to the level detected by the piezos. Another one added potentiometers to precisely control speed and pitch of his samples and play along with DUB sequences running on his laptop.

It is immediately clear the wide variety of personal style (Gurevich, Stapleton, and Bennett 2009) that characterised the study. The instrument has been interpreted and (mis)used in several different ways, exploring diverse sets of affordances, using techniques that go beyond the imagination of the designers and playing a wide range of music genres. Interviews with participants suggested two main motivations for physical modifications of their D-Boxes: as a means of overcoming limitations of the device and as an expression of personal performance technique. Both these cases proved beneficial to the creative process of music making, using disruption to open up new musical features more in line with each performer's attitude. Furthermore, the same process helped the performers master the instruments in few weeks of practice, by means of converging physical skills' development and instrument adaptation.

The complexity of some hacks, often quite obscure and unexpected even to the us, D-Box designers, suggests that the space of possibilities accessible through hacking is ultimetly determined by the performer's creativity, rather than fixed by the choices from the original designers. However, it is still unclear whether and how these hacks could consistently be part of the evolution of the instrument's design, and be accepted as standard features by future D-Box performers.

Conclusion

The D-Box is a DMI specifically designed to be completely reinterpreted by musicians, by means of circuit bending. We introduced 3 hack examples we documented during a collaboration with a group of musicians. Each hack differs in terms of internal working, interaction and skills necessary to master the instrument, showing how quickly and divergently the D-Box can evolve when played by different artists. As suggested by the whole group of musicians, these features are likely to benefit creativity, musicianship and virtuosity.

This work comes together with a practical demo session on D-Box hacking. The demo will first introduce the hackable design of the D-Box; then some copies of the instrument will be made available and used to recreate step by step the 3 hacks described in detail in the paper. Technical/critical analysis will include circuital configurations, mappings and specific playing techniques. Finally, participants will be encouraged to add original modifications to the instrument. Reactions will be annotated and the different interpretations triggered by the hacks will be discussed with the audience.

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Victor Zappi is a Marie Curie Fellow in the MAGIC Lab at UBC and the ADVR Department at IIT. As an electronic engineer and a New Media artist he is focusing on Music Technology research, designing and developing new musical instruments and exploring the usage of novel Virtual and Augmented Reality technologies in live performances.

Andrew McPherson is a Senior Lecturer (Associate Professor) in the Centre for Digital Music at Queen Mary University of London. A composer and electrical engineer by training, his research focuses on new musical instruments, especially augmented instruments which extend the capabilities of the piano, violin and other familiar instruments.

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