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Editorial

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The Ubiquitous Music Journal (j-ubimus) has been in the making for quite a few years. Given the variety and the breadth of edited ubiquitous music (ubimus) publications released during the last decade, how could a ubimus-specific journal furnish something that's not just a collection of materials, while helping to expand the boundaries of our research community? Should we post an open call for papers and wait to gather proposals as they come? Should we invite our research partners to act as guest editors? How many topics should we target for each volume? Should we also adopt non-standard formats? And what about the language? Should we employ only English or should we apply the usual UbiMus Symposium options of Portuguese, Spanish, and English? Should we expand the range to encompass most languages available within our community? These were some of the dilemmas we faced during the elaboration of this project.

These are not easy questions because they trigger a chaico of decisions that shape our working methods with potential impact on the end results. Multiple languages imply the need for enough expert readers who can handle both the technical and the idiomatic aspects of academic writing. If ubimus research groups were limited to the Luso-Iberian countries, a bilingual journal following the model of the special issues published by our community on Sonic Ideas (6), Vortex (8) and (7) or JDMI (10) would be sufficient. This is not the case. Several of our partners are located, for instance, in Australia. And the presence of other partners based in Europe indicates that a diversified language base is one of the prerequisites of an inclusive ubimus publication.

Another highly polemic topic involves adopting alternative formats for our brand-new venue. From an artistic perspective, this would make sense. A key byproduct of ubimus research is sound. But it is, of course, not the only product. Several ubimus projects highlight the multimodal dimension of the musical experience. Hence, for instance, a podcast-based format would not do justice to the diversity of byproducts featured in ubimus projects. Audiovisual outcomes are also prominent. This format supports aspects of musical-interaction knowledge that are difficult to describe in words. Still, something is missing. Recent ubimus endeavors, such as gastrosonics, explore the potential for crossmodal information exchanges, including senses such as taste and smell (cf. 7). The tactile dimension of creative practice has also been supported through the development of ecologically grounded frameworks, recently featured in a theme-oriented Organised Sound volume (3).

The support for alternative formats was not discarded. Our publishing policy strives to include artistic products while attempting to accommodate the diverse demands that characterize ubimus artistic practice. Nevertheless, we opted for the standard text-based report of research results because this seems to be a reliable way to handle peer-reviewing. Given the multidisciplinary characteristics of ubimus research, focusing purely on sonic or audiovisual presentations would have added a new layer of complexity to the assessment of the research outcomes.

Furthermore, despite the advances in indexing techniques of the last few decades, effective citation of sonic and audiovisual resources is not sufficiently reliable yet. As state-funded, open-access repositories become a standard feature of research sharing, we plan to embrace non-textual resources as fully citable material. Given that six corporate conglomerates control half of the worldwide internet exchanges, the current internet is definitely not a ubimus-friendly platform.[1]Beyond language and format, there were other aspects of the initially drafted proposal that triggered multiple questions. A tendency toward an ecosystem of ubimus venues and activities has emerged as a result of the decentralized and the strongly collectivist endeavors of our community. Despite a Brazilian origin and active presence that gave an imprint to the first ubimus initiatives, the current ubimus community cacrries on activities in multiple countries. Take, for instance, the profile of authors of the UbiMus Symposium held in 2023. Given the locale of the event, Ulster University in Derry, Northern Ireland, European submissions were the majority. There were also some proposals from Asia and Africa. Of a total of 59 authors, 11 were from Brazil. The only region missing was North America. So despite the prevalence of European presence, the international profile tended to be balanced. Thus, basing a ubimus publication in Brazil is not an obvious choice. What factors were decisive regarding the chosen home of the j-ubimus? A key consideration was sustainability, not just toward a short cycle of publications but also toward the survival of the initiative given any changes in the support team. This requirement implies the existence of an institutional base, ideally a university press.

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[1] Google, Meta, Netflix, Amazon, Microsoft and Apple control 56% of the current flux of internet-based information, worldwide.

Table 1: Profile of authors that sent submissions to the last UbiMus Symposium (N = 59).

Country	Authors
Argentina	1
Australia	1
Austria	1
Brazil	11
China	1
Cyprus	1
Estonia	1
Finland	3
France	1
Germany	1
Ireland	15
Italy	2
Kenya	1
Macao	3
Portugal	7
Russia	2
South Korea	1
United Kingdom	6
Total	**59**

Why a university press and not, for instance, an international press, such as Elsevier, Springer or Routledge? The second option would involve a financial barrier either to publish or to access the materials. Ensuring funding for artistic research outside of the central countries has always been difficult and there are no signs this reality will change in the foreseeable future. The adoption of the misleading label "open access" by corporate publishers, in practice means the enforcement of a quality metric based on wealth. Research groups that have access to generous funding may afford APC charges ranging from 2000 to 9000 US dollars per article. The average income per capita in Brazil (a country considered a mid-level economy and consequently excluded from waivers) is around 400 US dollars. A productive group, with a yield of around 10 papers per year, would need a minimum of 20000 dollars just to cover publication expenses. The chances of securing this amount of funding in the arts in Brazil are almost nil.

Thus, the choice of a public university press as a home for the Ubiquitous Music Journal was mainly motivated by sustainability and accessibility. Furthermore, the choice of location carries a message regarding the values being discussed within our community. In this respect, simplistic labels, such as those adopted by the corporate news outlets, are not necessarily accurate or useful. Consider the geopolitical label "The West".

Does Western mean located in Europe? Does it include North America? Does it also include some former British colonies such as Australia? If so, how do we classify places like Jamaica or Saint Lucia? And if the territories or former colonies are fair play, why not add the French Guyana or Martinique? What about the Seychelles or Mauritius? Despite the limitations of such labels, handling multiple locations as a single construct may enable analyses of social and economic trends, thus this usage is justified in some areas of ubimus research. Furthermore, there have been developments in ubimus that address aspects of geopolitics and its impacts on design. These factors have also been mentioned in archaeological ubimus initiatives. Despite a potential for development, geopolitical aspects of ubimus practice have not yielded a comprehensive framework yet. In any case, the choice of a peripheral region within a peripheral country as a home of the j-ubimus seems to be aligned with the counter-hegemonic tendencies of humanities-oriented ubimus perspectives (cf. 14).

This first section has addressed part of the motivations that set into motion the project of a journal dedicated to ubimus research, highlighting the constraints and dilemmas faced by the editorial team while planning and organizing the tasks for the proposal. Beyond the language and format, there were other aspects of the initiative that triggered multiple questions. A tendency toward an ecosystem of ubimus venues and activities has emerged as a result of the decentralized and strongly collectivist ways of doing adopted by our community. The financial constraints implied in a project that encompasses practitioners located in low and mid-income countries, the specific demands of supporting practice-led and artistic manifestations and the diversified traits of an international community of practice were factors that shaped the organizational and procedural paths trodden toward a choice of location. We now turn to the actual contents of the volume. After addressing the topics of the anchor article and the accompanying critical commentaries, we will provide an interpretation of how this research may lead to new developments, given a fast-changing landscape of post-2020 creative practices.

1 The impact of DIY and DIT perspectives on ubimus practice

The topic of this volume is centered around Do-it-Yourself (DIY) perspectives, together with the wider idea of Do-it-Together (DIT). These approaches to creative practices and music making have been central to ubimus from the very beginning. While the hardware approach implied by DIY was not part of the earlier research work published by the members of the group, the concept of doing things from scratch with whatever means available and in a collective setting was an important characteristic of early ubimus activities. Much of this is reported in Keller et al (9), leading to experiments in DIY such as the Memories Tree (18), a telling example of the types of artistic actions and interactions promoted by ubimus. The idea of DIY practices as a means of exploring creativity while supporting more sustainable ways of utilizing hardware and software for music has been explored in many ubimus publications (cf. 11) and it has become central to the emergent approaches on ecologies of ubimus.

From this perspective, it is natural that the first volume of j-ubimus focuses on questions of DIY and DIT. The current issue is structured around an anchor article with commentary papers. Brown and Ferguson's "DIY musical instruments: From Handmade Electronic Circuits to Microcontrollers and Digital Fabrication" sets up the context for this volume. This article discusses the digital fabrication side of DIY, looking at the making bespoke devices that produce sound electronically. It considers the practical aspects of the process: 3D printing, custom printed circuit boards (PCBs), among other techniques and how these methods can sustain ubimus activities. The article makes an interesting parallel with another important change in DIY practices which happened in the early years of the century, when the advent of accessible programmability of inexpensive microcontrollers replaced the common practices of fixed circuit development. The article also reflects on the rise of the Maker Culture, considering how the practices of digital fabrication are enabling the efforts within various communities of practice. The conclusions indicate that the ideas explored in the paper may help our field to achieve increased refinement and sophistication, which will enable the development of more complex DIY musical hardware designs.

The featured commentaries appraise and critique the anchor article, providing their own perspectives to key questions raised by Brown and Ferguson. In the first companion article, Timoney puts forward an appraisal of the proposed techniques, examining them from the perspective of a DIY practitioner. In his commentary, he emphasizes central points in relation to ubimus. For example, from a historical perspective, the DIY movement demonstrated a democratization of access to technology impacting how people could apply it as a means to diversify musical expression. Timoney also discusses the digital fabrication process, noting some of the caveats involved, alerting that time consumed making tools should be balanced by time spent exploring their musical possibilities. His argument highlights the dangers of research agenda purely focused on "gadgets" or "new instruments" rather than on supporting meaningful musical experiences.[2]

In his companion article, Kramann discusses an issue associated with a ubimus thread relevant to DIY musical practices: the concept of *comprovisation*[3] within the context of lay musicians (that is, people with little formal or informal experience of music-making). The author makes the point that constructing instruments or interacting with newly designed instruments may not be actually meaningful from a creativity-oriented perspective. Through a series of examples from existing projects, he arrives at a notion that, particularly when engaging lay participants in comprovisation, the presence of a compositional framework, presented via for instance a virtual environment, can furnish more effective support. The author concludes that the incorporation of a compositional theory may be an important addition to some scenarios provided by DIY instrument making, also noting the importance of the social and community-building aspects of ubimus approaches.

As a counterpoint, Merendino's article provides yet another perspective on the digital fabrication of bespoke instruments. He argues that fabrication can enhance DIY practices, bringing these to a higher level. Through a good overview of the area, he makes the point that fabrication can be traced as far back as the Futurists and Russolo's intonarumori. Embracing the Free, Libre, and Open Source Software (FLOSS) culture has benefited the musical communities in ways that could not have been anticipated (cf. 16 on this topic). The article provides case studies to complement the ones presented in the anchor text. These serve to exemplify and amplify the proposed concepts. Finally, the argument against the user-designer dichotomy is made very clearly, as Merendino emphasizes that with the creative practices of music and DIY, we have the emergence of a designer-as-user concept. Highlighting what ubimus practitioners have been proposing, it becomes very hard to draw lines between, for instance, a musician and an instrument maker.

In his insightful commentary, Hofmann shares several ideas on the use of DIY projects for educational activities. He brings in the example of the COSMO project, which aims to build a framework for DIY users as a means to support workshops on instrument design and development. This project has given him hands-on experience of what works and what is more challenging. Hofmann notes it is imperative that activities within the DIY sphere attempt to connect with life outside academic institutional boundaries. He reports on a project that built bridges with an existing community of musicians and makers in Nairobi, demonstrating that DIY ubimus approaches have much to offer beyond the conceptual and geographical borders of eurocentrism.

2 Post-2020 trends and avenues of investigation of second-wave ubimus

This volume focused on emerging perspectives for the expansion of musical hardware from a ubimus DIY perspective. The four critical commentaries and the contents of the anchor article showcase the diversity of techniques available for ubimus practitioners. According to Kramann (this volume), "approaches that introduce languages for manipulating musical structures open the possibility for the user to pursue the symbolic foundation of the respective language, thus the comprovisational activity is decoupled from the tool." Kramann's views can be paired with an emerging trend in ubimus that strives to enable access to music programming to casual participants, whether improvisatory or geared toward asynchronous interaction. This is what ubimus practitioners define as lite coding (22). Kramann's criticisms reflect the preoccupations of second-wave ubimus researchers with the constraints on pliable design imposed by the notion of a fixed instrument. Thus, his criticisms are valid to a certain extent.

If a proposal involves just designing and sharing a material instrument, then it tends to incorporate the genre-oriented restrictions built into instrumentally oriented interaction. Nevertheless, in the cases presented in this volume we are witnessing a different approach. Brown and Ferguson provide a recipe rather than a material instrument. Instead of sharing the outcome, they share the know-how necessary to build the hardware. Therefore, in theory, this proposal is as pliable as a shared algorithm or language. The limitations are linked to the ability of the stakeholders to access the material resources. This is a potential caveat. But the fact that the necessary know-how is already available offers our community a fresh set of research questions that weren't as meaningful or potentially fruitful before the publication of this work.

There is a significant gap between the availability of infrastructure and the development of innovative artistic practices. Sometimes the extant material resources enable changes in musical thinking. Other times, artistic needs trigger technical advances. These misalignments are hardly free of consequences. Artistic practices carry a strong component of social identity. Music, in particular, has been implicated both as a tool of oppression and as a means of resistance (4, 19). Therefore, design choices not only impact our ability to fulfill musical intentions. They also carry an ideological baggage that may either limit or boost our ability to imagine, implement and deploy musical worlds.

Consider, for instance, the computational resources available in the early 1990s as compared to the resources available today. Post-2020 creative endeavors feature challenges that were absent or less conspicuous in pre-internet, pre-mobile and pre-embedded digital music-making. A simplistic take on musical interaction would suggest that "instruments" drive the artistic expansion of the last few decades. This may have been true until the early 1990s. The introduction of connectivity protocols, such as MIDI and the internet protocol, and significant advances in audio synthesis and processing techniques enabled the application of a chamber-oriented music-thinking to computer-based creative activities, thus giving undue emphasis to "realtime" musical interaction.[4] This instrumentally oriented vision of how to make music was later inherited by music genres tailored for specific infrastructure such as networked music performance (15). In spite of ubimus efforts, post-2020 music practices still carry the weight of pre-embedded, pre-mobile, pre-internet and in some cases of pre-computational musical thinking. These views are materialized in the application of legacy resources for knowledge transfer. In fact, an emphasis on transfer rather than sharing is one of the features of acoustic-instrumental thinking. Typical legacy forms of group decision-making include "the orchestra" and "the master-slave" models. Thus, a set of hierarchical approaches strongly criticized by various musicians since the late 1990s (2, 5, 12), resurfaces with adjectives like "intelligent", "smart" or "deep".[5]

Typical legacy resources for musical knowledge transfer include the score and the preset. The former is usually treated as a fixed set of symbolic instructions tailored for a specific device or a set of devices (an instrument or an instrumental ensemble) that when deployed yields a musical product (a piece or an artwork).

[2] Regarding this issue, the ironic term engenhoca (a play of words connoting awkward engineering) has sometimes been applied by ubimus practitioners to device-centric design.

[3] There is an ongoing thread of ubimus artistic endeavors that embrace both compositional and improvisational techniques, while exploring the caveats and opportunities of this fusion. This has led, for instance, to a framework labeled ecomprovisation strongly rooted in ecologically grounded creative practice (cf. 1).

[4] "Real time" was the term historically adopted for any form of music-making that resembled the behavior of acoustic instruments. Current ubimus terminology opts for the more neutral label "synchronous", which stands on an equal footing to "asynchronous" and "quasi synchronous".

A problematic aspect of this restrictive notion of support for musical knowledge transfer is the implied persistence of the material base (an acoustic instrument or its digital emulation) and of the knowledge base (such as common practice notation or its simplified derivatives, e.g. chord progressions).

Given these limitations, to fit the emerging ubimus demands scoring would need to be redesigned as a stakeholder-oriented activity rather than as fixed media. Similarly to how automatic translation may be tied to a personal configuration of local usage, score deployment may be adapted to the profile of each stakeholder. Nevertheless, this human-centric approach to scoring does not solve the problem of sonic production. The procedural instructions may be understood, but if the music-maker does not have access to the material resources needed to render the sonic products then the quality of the outcome may be reduced and the rendition may become useless.

This link of the production chain is under high pressure for standardization. There is a strong tendency to apply pre-computational means, such as emulated acoustic instruments, or to adopt prepackaged solutions that may restrict the range of musical experiences – see for instance the negative social consequences of enforcing Non-Fungible Tokens as a standard format for internet-shared musical resources (13) or consider the constraints imposed by the uncritical repurposing of social networks as conduits for music creation (17).

The preset is another legacy resource widely employed in commercial packages, sometimes in- corporated in exploratory prototypes. The idea of providing ready-to-go and tested combinations of parametric configurations is potentially useful. But it carries the dangers of the black-box mentality (20). Casual or inexperienced participants may tend to stick to just a few choices of presets, yielding results that reproduce functional fixedness. This danger is compounded by a tendency to avoid a more de- tailed understanding of the procedures and their aesthetic consequences, which are seldom addressed by software documentation. A possible strategy to deal with this caveat is ASC. Creative semantic anchoring involves the usage of semantic resources that are tied to the procedural choices at various stages of the creative cycle (21). Their level of specificity is dependent on the subject's profile and the task at hand. Thus, a dosed incorporation of presets in the context of ASC-oriented creative-action metaphors might be an option worth exploring.

To conclude, the topic of this volume is particularly relevant to the ongoing discussions on knowledge sharing in ubimus activities. A key contribution of ubimus for post-2020 creative practice is the expansion and flexibilization of resources to enable collective music making. As mentioned before, musical activities are much more diverse than interacting with an isolated sonic device. Collective music-making involves exchanges of knowledge that may target on-the-fly decision making or that may feature very slow cumulative processes that eventually crystallize as consensual outcomes. Ubimus support mechanisms need to be specific: the former modality deals with volatile resources while the latter employs persistent resources. How to materialize these exchange mechanisms is an ongoing research preoccupation among ubimus designers and practitioners. Brown and Ferguson‘s proposal furnishes an elegant solution that retains the flexibility and replicability of open-source designs while featuring the materiality of deployed hardware.

Evidence-based research has always been a feature of ubimus methods. But some practical limitations have prevented the fast circulation of support strategies. The proposal featured in the anchor article may trigger an expansion of deployments which may boost the replicability of ubimus frameworks. The timely contributions of the critical commentaries included in this volume provide a panoply of perspectives that complement and expand the core proposal. We are confident that the contents of the first volume of the Ubiquitous Music Journal will trigger a productive dialogue with researchers and practitioners interested in a future of music-making without frontiers.

[5] The ideological and practical implications of attempting to recycle musical techniques for post-2020 musical goals are beyond the scope of this editorial. Nevertheless, this is an active avenue of investigations with threads emerging in the last few years, such as ubimus archaeologies and musicologies.

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DIY musical instruments:

From Handmade Electronic Circuits to Microcontrollers and Digital Fabrication

Andrew R. Brown · John Ferguson

Abstract This article explores the use of bespoke digital fabrication for enhancing the making of Do-It-Yourself (DIY) electronic sound devices. With the tools and manufacturing costs now within reach of amateur makers, the production of laser cut, and 3D printed parts and custom PCBs for DIY projects can add stability and reproducibility to a growing number of ubiquitous music projects. This parallels with a shift from the use of non-programmable integrated circuits to programmable microprocessors. We discuss the impact of Maker culture on the custom development of handmade electronic musical instruments, and how incorporating digital fabrication can extend these developments. Several case studies from our own work are discussed and lessons from these for other DIY makers are outlined.

1 Introduction

Traditional notions of musicianship often ignore instrument making, even when describing con- temporary musical practice (2), (15)**,** (9). In particular, it seems that instrument making, and tool making more generally, have been divorced from formal musical practices. Instead, scholars have become focused on composition and performance skills. Rather, as the guitarist Derek Bailey put the idea, “The instrument is not a tool but an ally. It is not only a means to an end, but also a source of material, and technique for the improviser is often an exploitation of the natural resources of the instrument” ((3): 99). We view technologies, techniques and practices of DIY instrument making as part of a network of creativity for musicians and suggest that these can be enhanced by embracing emerging techniques of digital fabrication.

As (10) notes, “DIY audio and sound art practices celebrate the unique visions and practices of the individual artist.” This diversity may arise in a number of musical planes; instrument design, compo- sitional techniques and styles, performance practices, or music distribution processes. This contrasts with many musical traditions that celebrate the reproduction of repertoire and technique and prioritize virtuosity over originality. Creating music with electronics and code involves few predefined sonic constraints and therefore implies “a disposition towards processes, connectivity, and relationships—how things [and people] may or may not interact with each other” (23).

While handmade electronic instrument making has a long history, in recent years the process of using digital fabrication for DIY instruments has become more accessible with free open-source tools and inexpensive production of small runs. These developments bring the process within the reach of more DIY electronic instrument makers, including the authors.

Our motivation for embracing DIY music making are similar to others in the Ubiquitous Music (UbiMus) community; to enable access to music making using affordable and non-complex technologies (24)(8). However, not every technological advance supports these objectives and some, like digital fabrication techniques, take time to develop to the point where they are suitably accessible. This underscores a tension that exists when trying to promote access to music making, that one barrier may simply be replaced by another. This could be the case, for example, when moving from acoustic to electronic instruments, because acoustic instrumental skill requirements are replaced by the need for engineering skills. We feel that the barrier to entry for digital fabrication design and production has reached a point where its value is worth the additional skills’ investment.

Laser Cut components and custom PCBs can be useful for any electronic project and fit neatly into the cyclical design and prototype process. While software-based prototypes are often a starting point for instrument development ((17)), handmade electronic instruments are typically prototyped on a breadboard with components soldered together for use in workshops and performances. The reliability of devices at this stage is quite variable, depending on the engineering skills of the maker. We have found that the use of laser cut parts and custom PCBs has made our DIY instruments more reliable for performance, and construction in maker workshops is easier and faster.

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2 Background

Music composers in the 20th century began the turn to everyday objects for music making. Examples include John Cage’s use of paper, screws and other objects for prepared piano works and his use of radios, watering cans and kitchen appliances as sound sources. Since the 1990s the DIY movement in electronic music making has adopted arts and craft approaches to working directly with materials for the making of sound devices and new instruments. These activities have benefitted from a broader push for reducing the costs of small-run electronics, digital manufacturing tools such as laser cutters and 3D printers, and the accessible production of custom PCBs are part of that trend.

There has been a huge growth in the DIY and Maker communities since the 1990s. This reflects the democratization of technologies and the increasing digitization of the music industry. In an academic context, David Tudor’s pioneering work in incorporating instrument making and composition is well recognized (11). The most obvious manifestation of this is the Composers Inside Electronics (CIE) group he started in 1973 and whose ongoing practices are coordinated by John Driscoll.

Networks of hackerspaces and maker communities have arisen around the world. Maker spaces emerged as physical studios and practitioner workshops and have further expanded to include online repositories and forums. Music activities have been part of this growth and include enthusiasts building modular synthesizers, musical robots, microprocessor-based sound generators, and constructing devices from open-source hardware and software tools. With the expansion of online networks and inexpensive microelectronics, “Interest in DIY electronic music has been reinvigorated and rekindled with new agendas, motivations and new resulting communities”. (23)

The history of music is replete with developments in new instruments, but historically that evolution has been quite gradual. The pace of technological development in the past century has accelerated this evolution. Instruments are integral to and an influence on the development of musical practices, which recursively feeds back on the development of musical instruments. A number of histories trace this as technical evolution (19), while others take a more sociological perspective (4) or a musicological approach (25). A central location for the academic study of electronic music’s DIY culture is the community that has formed around the New Interfaces for Musical Expression (NIME) conference. Emerging out of the human-computer interaction communities in the late 1990s the growth of NIME reflects the expansion of similar communities in many fields.

The DIY electronic music scene is in constant flux, and our experience suggest this requires ongoing learning and development. In the words of musicologist Jonathan De Souza, musical instrument technology “is not immutable. Its stabilization requires active maintenance, and though the social actors that reproduce musical instruments and idioms often act in predictable ways, they do not always do so. In other words, instrument and idiom may be transformed as well as preserved” (2017:81). Reinforcing these interactive and evolutionary themes, (20) theory of digital instruments as epistemic tools explores a phenomenology of musical instruments, reinforcing that even in musical contexts designed artefacts (tools) are extensions of human cognition. In digital instruments, he argues, “the distinction often blurs between instrument and composition on the one hand, and performance and composition on the other” (2009: 168). This article emphasizes the evolution of the process through the integration of digital fabrication tools as a way of moving forward the means of ubiquitous musical expression.

The making of DIY instruments has a long history as summarized by (27)**.** The more recent history of DIY electronic music making has been greatly influenced by the publication of the book Handmade Electronic Music ((12). The first and second editions of this book privilege “touch” and tactile immediacy, the main focus is hand-built sound-making circuits and a range of hacking methods that can be used to cannibalize existing circuits for purposes of musical and artistic expression. Overall, the first two editions shun the creative potential of microcontrollers or the personal computer in favor of analogue sensors, integrated circuits, wires, and breadboards. The third edition breaks with the “no computer” agenda of previous editions and includes chapters on Arduino, Raspberry Pi, printing your own circuit boards, etc. While the laptop has been omnipresent at live electronic music events for decades and with its performative potential being expanded by controllerism (16), the rise of microcontroller and single-board computer platforms such as Arduino and Raspberry Pi have been central to enabling electronic music activities since their introduction in the mid 2000s.

The Maker Movement is a do-it-yourself (DIY) culture in which makers, hackers and tinkerers are not satisfied with waiting for others to invent the future but want to do it themselves on their own terms. The practice of Making is described by Breaux as “the process of creating something outside of traditional manufacturing processes” (6:27).

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The accessibility and affordability of new open technologies and the use of digital manufacturing has resulted in The Maker Movement being described as "the new industrial revolution" (1). (10) notes that "Democratization of means—the increased access to technologies since the 1990s—has had a remarkable, positive effect on the development of the broader community of makers," yet despite such claims there is little understanding of which co-operative practices are effective. This project will decipher this, with a particular focus on how new musical practices arise around novel co-operative practices, and how they gain traction to become cultural phenomena. In this article we suggest that techniques of digital fabrication are another step in the long evolution of DIY instrument making and we share our experiences with these tools and reflect on some of the benefits and pitfalls.

3 Custom Boards and Cases

The primary use for digital fabrication processes in our work has been to build custom circuit boards and cases/physical enclosures for our instruments. In this section we describe a range of options for making these with a particular focus on circuit boards, setting the scene for our use of digital fabrication methods for these purposes.

3.1 Breadboards

It is common to prototype electronic circuits on a solderless breadboard. However, these are not very robust for use in critical situations like performing on stage. Interestingly, for a more sturdy alternative, we can go back in time to the etymology of the term 'breadboard' which came from the practice of prototyping radio circuits on bits of wood using nails and screws to hold components and as terminals for connecting wires. Wood-based prototype boards like those shown in Figure 1 have been used for workshops and in education contexts for many years.[1]

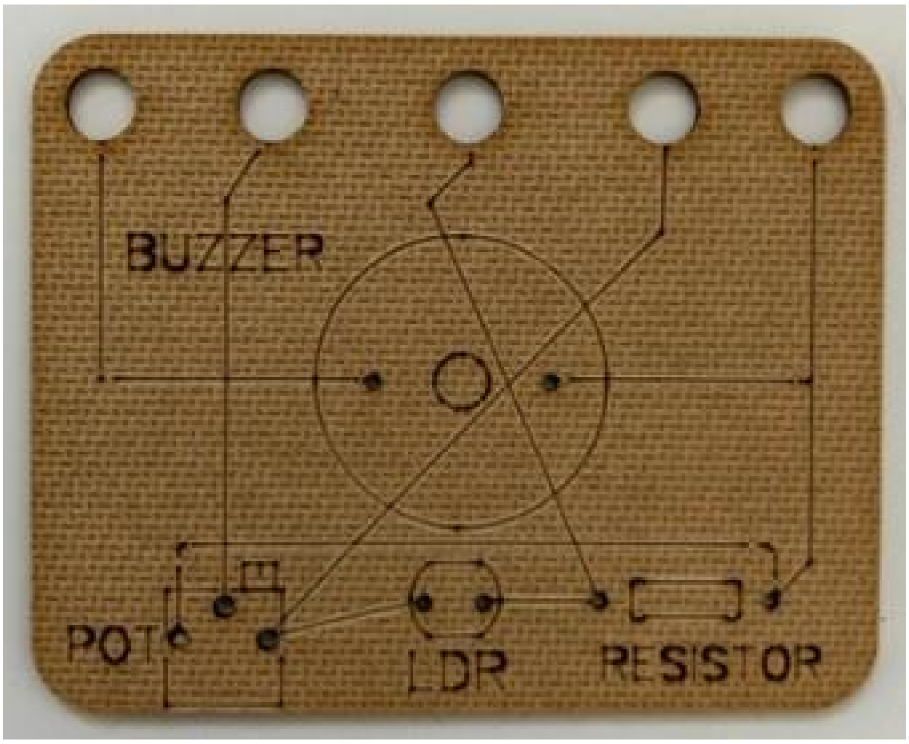
Fig. 1: Wooden breadboard circuits – image source Wikipedia

3.2 Laser cut cases and surfaces

Laser cutters have democratized the production of custom etching and cutouts from lightweight materials including cardboard, plywood, and acrylic sheets. Industrial laser cutting services can also cut sheet metals. Taking inspiration from the wood and nail breadboards, our colleagues Paul Bardini and David Harris created laser cut circuit templates on 2mm wooden board for education use. An example is shown in Figure 2 of a simple light-controlled theremin circuit for attaching via small bolts to a Micro:Bit.

[1] https://en.wikipedia.org/wiki/File:Wooden_Breadboard_Circuits.jpg

Fig. 2: Laser cut printed circuit board cut from 2mm board.



Laser cutters are also useful for creating custom control surfaces and enclosures, as shown in some of the case studies in this article. Designs for simple cases can be generated using sites such as MakeABox[2] while more complex designs can be realized in FreeCAD[3] or Tinkercad[4] and customized in vector graphics software, including Inkscape[5] or Adobe Illustrator. Students of our Electronic Instruments course usually build simple wooden or acrylic enclosures with controls mounted in the top of two parallel panels separated by metal standoffs, all circuitry is contained between the parallel panels. Students are provided with a graphics template of footprints for individual electronic components, each component is grouped for easy manipulation and contains cut-lines (in red) and guide lines (in green). These "tried-and-tested" templates ensure that electronic components always fit the final laser-cut panels and there is sufficient space to allow access for soldering, to ensure the material strength of each panel, and avoid any unforeseen overlaps on the rear of the panel.

Fig. 3: Lasercut instruments made by students of Electronic Instruments (Takondwa Ainsley Shiri, Alex Knight, Oscar Tooms).

Design process: the footprint for each component is duplicated as many times as necessary using whatever vector graphics software the student chooses, these footprints are then arranged in the desired layout and a cut-line is drawn to define the edge of the instrument. As figure 3 shows, many of these projects evolve into quite complex and idiosyncratic instruments with a range of sensors including buttons, linear/circular potentiometers, pressure, infrared/distance, and capacitive touch.

2 http://makeabox.io
3 https://www.freecadweb.org/
4 https://www.tinkercad.com/
5 https://inkscape.org/

3.3 Paper Circuits

Another interesting DIY fabrication method is the use of Paper Circuits such as those by Peter Blasser. In this method, circuit diagrams are printed on paper or cardboard, and the legs of components are pushed through the material and soldered or otherwise connected from below.

Blasser writes that "The paper circuit projects attempt to bring the art of electronics from an impersonal, industrial approach to one which is individual and magical."(5) This approach fits well with the accessibility agenda of UbiMus activities. The reliability and longevity of instruments made with paper circuits is inconsistent.

DIY electronic music tends to focus on live music making using handmade instruments. Often these are noisy or low-fi—partly out of necessity given the materials available—but this has often become a deliberate aesthetic choice. As technologies have improved and costs reduced, the devices made by DIY music makers have expanded in sophistication and musical scope. The access to small-run printed circuit board (PCB) manufacturing is another step in this evolution. Some of Blasser's paper circuit projects have been printed as PCBs. For example, the Rollz-5 drum machine by Meng-Qi.[6]

4 Printed Circuit Boards

The manufacturing of PCBs for electronic music is not new. PCBs were used in the earliest commercial synthesizers from the 1970s and one look at the prevalence of modular synth components, each of which includes a PCB, shows their commercial ubiquity. There is even a strong hobbyist market in the design and distribution of PCBs for music devices on sites such as SynthCube[7] and by organizations such as Dirty Electronics.[8] Like many aspects of technology, the process of printing circuit boards has recently become much more refined and inexpensive, although it is still not trivial. A range of low cost tools and services has made this possible.

4.1 Accessible tools and services

The tools and manufacturing support for PCBs have become more accessible. DIY makers may already be using Fritzing[9] for designing or documenting breadboard electronics, and these projects can be extended to PCB design as well. KiCad[10] is an open source project for designing schematics and circuit boards. It is a bit more complex than Fritzing, but also has more features. The KiCad software was used for the case study examples in this article.

The production of PCBs by hobbyists has been possible in the past, but the etching process involves toxic chemicals and can be messy, if not dangerous. Outsourcing to professional PCB manufacturing opens up the process to many more makers. Having designed the PCB using software tools, these can be exported to Gerber files for sending a professional PCB manufacturing services such as PCBWay[11] (China), OSHPark[12] (USA), AISLER[13] (Germany) and more. A price comparison from various interna- tional manufactures can be accessed at PCB Shopper[14]. Production and shipping typically take a few weeks.

4.2 PCBs for DIY

PCB-based instrument kits, such as the Atari Punk Console by Nava Whiteford[15], have been the basis for community music workshops for some time. These boards have previously been designed and created by relative experts for use in community situations and show the potential for the expanded use of PCBs by amateur engineers, as advocated for in this article.

There are some considerations for utilizing PCBs in a DIY electronic music-making process, compared to their use in commercial settings. Simpler boards will use through-hole components, like those used for breadboards, so the layout enables hand soldering by non-experts. Automated assembly of surface- mounted components is also possible but adds some complexity to the process. Establishing optimal circuit tracks between components can take some time but, fortunately, many design tools include auto-routing or free external tools such as FreeRouting[16] can be very useful for this task.

There are many online resources to assist with undertaking the process of PCB design and manufac- ture. While a full tutorial is well beyond the scope of this article, to give the reader a feel for the process here are the basic steps involved. 1) Prototype the project on a breadboard, 2) Draw a schematic in software. 3) Use the schematic to design a PCB layout. 4) Route connections and establish a ground plane. 5) Export Gerber files. 6) Upload files to a PCB manufacturer and place an order. 7) Solder components onto the delivered PCB 8) Test functionality of final electronic instrument.

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6 https://www.mengqimusic.com/rollz-5-br-

7 https://synthcube.com/cart/synth-diy/pcbs

8 http://www.dirtyelectronics.org/instru.html

5 Exemplar projects

To contextualize DIY electronic instruments and highlight the potential benefit of digital fabrication, we will introduce and discuss some of our own instruments in this section. To set the scene we begin with Analogue Revolutions, an instrument that is completely handmade and features no programable elements, then we move to The Sonic Frisbee, which adopts a PCB but shuns computer code. Next, we look at The Beat Machine, which embraces a PCB, two (Arduino) microcontrollers, and bespoke computer code. Following this, we discuss our lowest-cost instrument to date, the Micro Mono Control, which also embraces a PCB, (Arduino) microcontroller, and bespoke code. Reintroducing some handmade (panel-mount) methods, Box embraces a microcontroller and makes use of a laser cutter for the enclosure while relying on an iPad to run custom code. Finally, we discuss Quadra, which involves minimal hand assembly, and features a custom PCB, (ESP32) microcontroller, bespoke code, and a laser-cut enclosure.

5.1 Analogue Revolutions

Analogue Revolutions (Figure 4) was hand built in 2014 using integrated circuits (ICs) and passive components, there are no programmable (PIC) chips and thus no computer is involved. Analogue Revolutions features two variable step-sequencers arranged in concentric circles. Each sequencer outputs to an individual voltage-controlled oscillator (VCO) and can also be used to rhythmically slice external analogue inputs using vactrols (resistive opto-isolators). Each sequencer is driven by either of two independent clocks, which are dynamically variable in speed but have toggles to choose 1) a range of slow to fast pulses keeping things within the bounds of rhythm and groove, or 2) very fast to audio-rate pulses, which facilitate further timbral possibilities. Sequence lengths are variable in the range of one to eight steps via rotary selector switches. Overall, when clocked at sub-audio rate the VCO produces convincing grooves and has melodic possibilities via the pitch controls for each step and the overall pitch-range control. It is also fun running the clocks at audio rate, which pushes into timbre/frequency modulation territory. Adding in the two distortion circuits (which are deliberately configured quite differently) brings wild/grungy tones and the touch-points add a lot of character.

Fig. 4: Analogue Revolutions

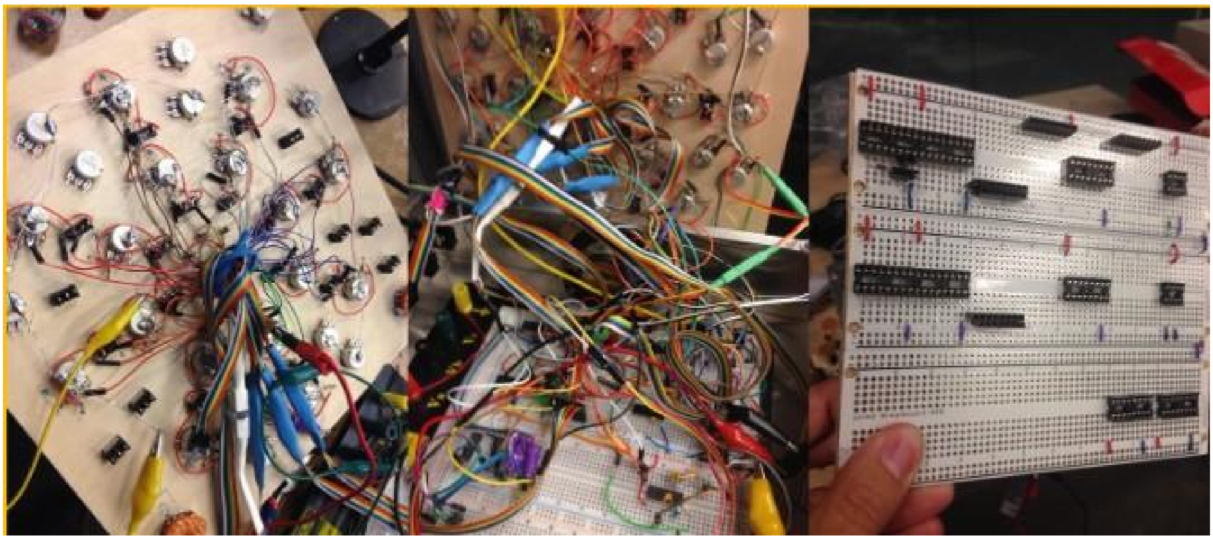
[9] https://fritzing.org/learning/tutorials/designing-pcb/
[10] https://www.kicad.org/
[11] https://www.pcbway.com/
[12] https://oshpark.com/
[13] https://aisler.net/
[14] https://pcbshopper.com/
[15] http://yeovilhackspace.org.uk/2015/11/29/atari-punk-console-kit-now-available/
[16] https://freerouting.org/

Analogue Revolutions utilises:

- Two inputs of a CMOS 40106 Hex Schmitt Trigger Inverter are used to drive the two clocks, each has a switchable capacitor to control the range and a potentiometer for dynamic speed control;
- Two CMOS 4017 decade counters are used to create the variable-step sequencers;
- Two CD4046B Phase-Locked Loops are used for voltage controlled synthesis (these are the infamous chips used to decode touch-tone telephones);
- The 4049 Hex Inverter chip is used with a variety of feedback resistors and capacitors to create distortion effects;
- Two LM386 chips are used to power the two internal speakers.

Once the initial sequencer logic and sound generation potential were decided, the design process for this instrument involved planning a layout, drilling holes in a top panel, wiring the various panel-mount components, then running ribbon cables to a solderless breadboard containing the ICs. Once testing was complete the solderless breadboard was replaced with a solderable breadboard to improve the overall integrity of the instrument, the components were arranged in the same layout on both solderless and solderable board, to ease the transition from one to the other.

Fig. 5: Analogue Revolutions – underside of top plate (left); initial configuration on solderless breadboard (center); final layout of solderable beadboard (right).



In an age dominated by microprocessors, it is perhaps unusual to choose multiple discrete ICs. However, finding sonic and performative potentials in generic mass-produced chips is fun and the all- hardware workflow is rewarding. A computer always has chameleon-like characteristics i.e., functionality can be updated, and behaviour changed. This open-endedness is sometimes great, but there is also a risk with an open-ended project: is it ever really finished? The ongoing temptation to update can get in the way of working with and learning the potential of an instrument. Whereas, at least with discrete IC's and a 100% hand-built workflow, decisions about logic and functionality must be clear from the outset and, once it is all soldered inside an enclosure, the final instrument is difficult to change.

Analogue Revolutions is chosen as the first example in this section because it reminds us that: 1) the initial investment of time and energy in the design of an instrument's functionality is important work. In this case, that's because hardware functionality cannot be easily updated, but we suggest this point is equally true when applied to more open-ended (digital) systems. 2) Building a complex system by hand is a significant investment of time and energy; when undertaking a practical build-process by hand you create a relationship with an instrument and that encourages investment in exploring the creative opportunities offered by the final instrument (performing or making music, rather than continuously "improving" the instrument).

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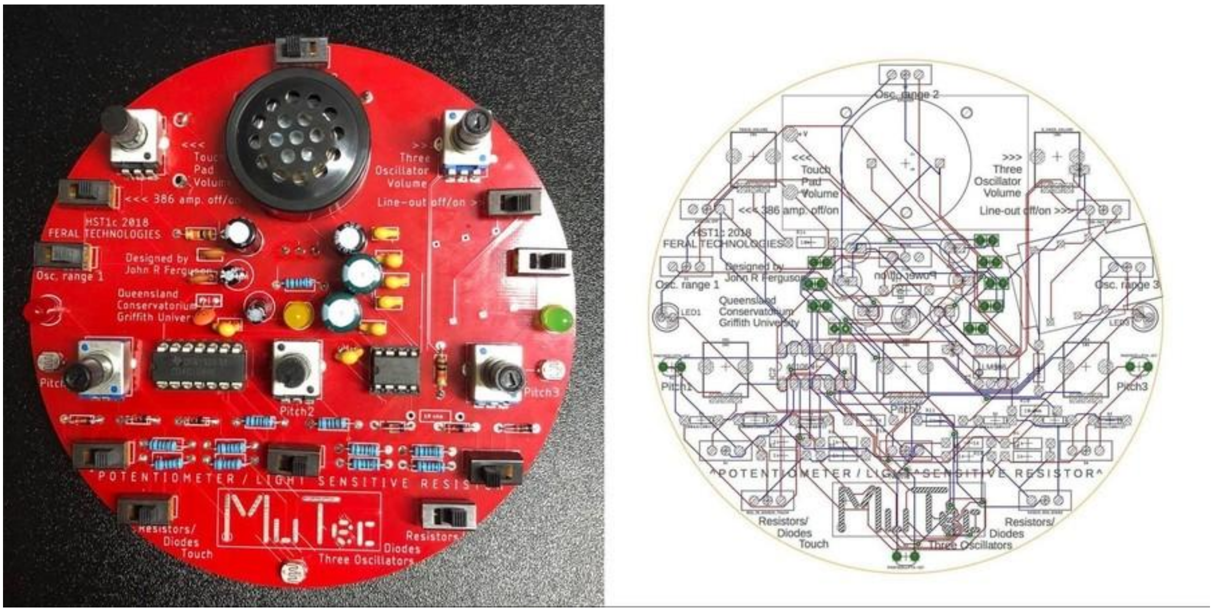
Overall, because handmade electronic instruments like Analogue Revolutions involve significant labor, they become highly celebrated objects that are unlikely to be considered “disposable”. And in-line with Perry Cook’s **(13)** suggestion that “programmability is a curse”, we suggest that handmade electronic instruments with a clear “endpoint” in their practical development may receive more musical attention and experimentation than their (seemingly) more flexible counterparts. That said, the relationship between making instruments and making music warrants further discussion and we’ll return to this in the concluding section. For now, obvious practical drawbacks of completely hand built electronic instruments include the lack of reproducibility due to the time-consuming nature of the build and the complexity of the design; this instrument is just a one-off. It would also be difficult to conceive a community workshop based around making and playing this instrument, because it’s so time-consuming and complicated to build.

5.2 The Sonic Frisbee

Unlike Analogue Revolutions, The Sonic Frisbee shown in Figure 5 was deliberately designed with Maker workshops in mind. It is a six-voice portable and battery-powered synthesizer based around a CMOS 40106 (Hex Schmitt-Trigger) and a LM386 (amplifier) integrated circuit (IC), there is no computer involved. This makes for a very low-cost instrument overall. Three of the synthesizer voices are operated via “resistive-touch” on the MuTec lettering i.e., there is a physical gap in the signal path of each voice and oscillation only occurs when the gap is bridged. This element of the instrument is performed using fingers to touch metal pads so electricity flows across the gap and human flesh becomes part of the circuit. The result is a tactile but unpredictable relationship between human input and sonic output i.e. it is difficult to perform exact pitches but the sonic response to touch is instant. The remaining three voices are either controlled by a light dependent resistor (LDR) or a potentiometer. The pitch range of each voice is switchable high/low, which can lead to dramatic shifts in musical character. LDR/pitch control is laid out horizontally across the board while output of the instrument is divided in half with two separate volume controls: one for the three touch-sensitive voices and the other for the three light/potentiometer voices. The three individual voices that make up each of the two halves of the instrument can either be mixed via diodes or resistors (switchable), this offers further timbral manipulation. Sonic output is switchable between a mono jack socket on the rear and the onboard amplifier/speaker combination. Power is provided by a 9-volt battery that clips into a socket on the rear, this also makes the instrument stable and sets the sit-angle towards the performer when used as a desktop instrument.

Fig. 6: The Sonic Frisbee and its PCB layou



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The design of the Sonic Frisbee was prototyped on a solderless breadboard and the PCB design was done in EAGLE. Both sides of the board are utilized so that the battery and audio socket are hidden beneath the top surface of the instrument. Design priorities include being able to hold the instrument in one hand and the need for a clear and easily performable layout of potentiometers, switches, and LDRs. From a performance perspective, the instrument has two main musical worlds, the first celebrates low-frequency pulse/rhythm (controlled by potentiometers/LDRs), and the second has more focus on generating gestural high-frequency content in response to a performers' touch.

The Sonic Frisbee is designed for use in workshops and other pedagogical situations. While its expressive potential as an electronic musical instrument is rich and its sound world is varied, the instrument is also intended to function as an introduction to soldering and sound making with electronic components. The Sonic Frisbee is distributed in a kit format and is accompanied by a step-by step workshop guide[17]. In a workshop context it is useful to introduce basic electronics theory (Ohms Law and the functionality of passive components) and to show the CMOS 40106 datasheet to indicate how the instrument works. These concepts and practical concerns are straightforward, easy to demonstrate, and can be introduced relatively quickly. For example, a single voice oscillator can be demonstrated with just three components: 1 chip, 1 capacitor, and 1 feedback resistor. The use of a robust PCB design means that all the instrument's logic is pre-routed, which allows beginners to find success relatively easily, because they only need to focus on the most visible and practical matters.

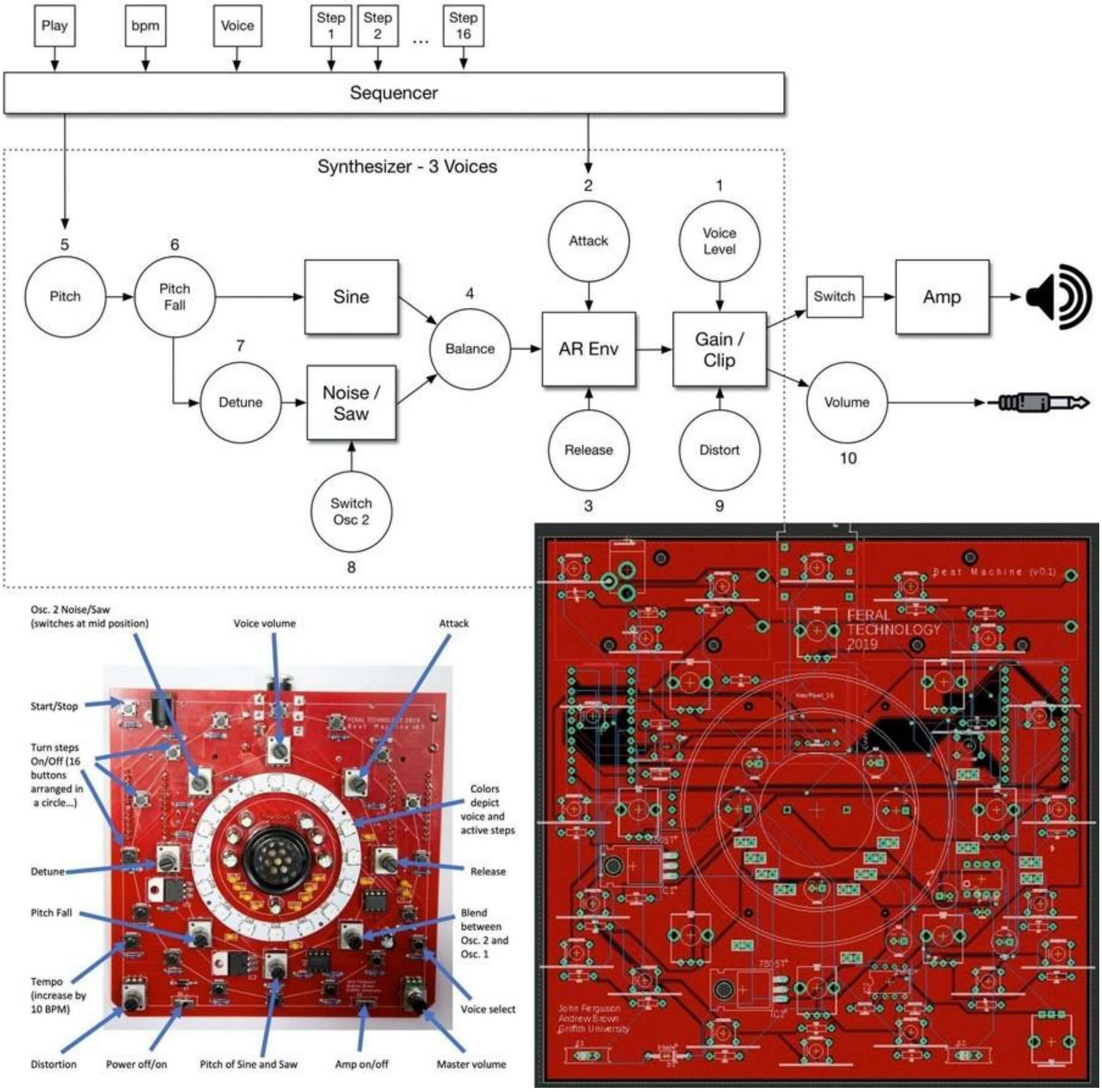
5.3 The Beat Machine

The Beat Machine is a 16-step sequencer and 3 voice synthesizer controlled by 10 potentiometers, 19 buttons, and an accelerometer (7). The controls are connected to two Arduino Pro Micro microcontrollers that communicate via the I2C communications protocol, one microcontroller handles the sequencing and the other functions as a synthesizer using the Mozzi library. There are three layers of control, one for each voice. Low-cost tactile switches are used to enter step-sequences and to access the various layers of control. A ring of programmable LEDs (light emitting diodes) indicates sequence pattern and layer information so the user can see where steps have been programmed to sound and which synthesizer voice these correspond to. The first voice is optimized for a bass drum-like tone (noise source has high frequency rolled off), the second voice is optimized for a high-hat like tone (noise source has low frequencies rolled off), the third voice is full-range and is intended to approximate a snare drum.

Each synthesizer voice is made up of two oscillator elements that can be blended or sounded in isolation using the balance control, the first is a sine waveshape and the second can either be a sawtooth waveshape or a noise source. When using sine and saw these can be detuned by up to an octave and then pitch-fall and the attack/release amplitude controls can be used to sculpt the overall sonic character of each voice. Pitch, volume, and distortion controls are also available, see Figure 7 for an overview.

[17] http://www.johnrobertferguson.com/hst1d-feral-technologies

Fig. 7: The Beat Machine functionality overview, user guide, and PCB design



A two-axis accelerometer on the rear of the beat machine is set such that the Y axis (forward and back) controls the chance of changing the probability of sequence steps, while the X axis (left and right) effects the blend between Osc. 2 and Osc. 1 and can thus be used as a timbral control. A video demonstration of the Beat Machine by students of 2710QCM Electronic Instruments 2021 is available online.

The Beat Machine was prototyped on a large solderless breadboard and PCB design was done in EAGLE. However, the authors have since adopted KiCAD as their preferred software for schematic design and PCB manufacture. The PCB design started with positioning interface components (potentiometers, buttons, LEDs and switches) in the preferred position on the top of the board. Other components (Microprocessor headers, resistors, capacitors, audio and power plugs, etc.) were fitted into available spaces on either side of the board with a preference for as neat and symmetrical a layout as was feasible. Using prototype paper circuits to test the layout and usability of components helped to highlight errors before sending to fabrication.

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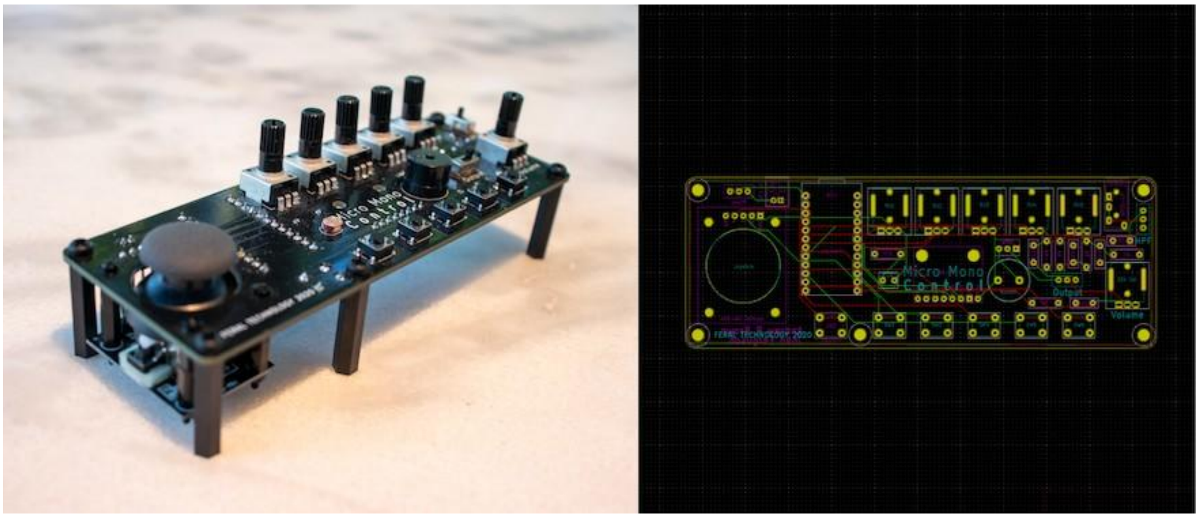
Like Sonic Frisbee, Beat Machine was designed for use in workshops and other pedagogical situations, and is also distributed in a kit format accompanied by a step-by step workshop guide. Again, a robust PCB design means that all of the instrument's logic is pre-routed, which allows beginners to find success. The sequencer-focused agenda of Beat Machine offers a musical experience that is familiar to anyone who has used a commercial drum machine (or software equivalent), there's also substantial control over the musical parameters and overall sound world, as outlined above. Compared to Sonic Frisbee, Beat Machine is much more multilayered, flexible, and musically capable overall. However, this capability comes at a cost: ease of comprehension. The bespoke code running on the microcontrollers is highly complex and, compared to Sonic Frisbee, the underlying principles are difficult to quickly demonstrate in a workshop context.

5.4 The Micro Mono Control

During COVID-19 lockdowns in 2020 some of our music students needed an inexpensive MIDI controller to continue their studies remotely. This prompted the design of the Micro Mono Control (MMC), the components for which cost around $20 USD. The MMC is a MIDI controller with onboard monophonic synthesis capability, shown in Figure 8. It sends continuous control messages from five potentiometers, a light sensitive resistor (LDR), 6-axis accelerometer, and an XY joystick. It includes five buttons that trigger MIDI note messages. The MMC includes a monophonic subtractive synthesizer and arpeggiator modified with the onboard controls or via external MIDI input. Audio level is set by a dedicated potentiometer and output is switchable between an onboard loudspeaker (buzzer) and 3.5mm audio output socket. The MMC is driven by an Arduino Pro Micro microcontroller running the USB-MIDI and Mozzi Audio Synthesis libraries. An example of the low-fi audio output can be accessed online. It can be USB powered or run from batteries.

Fig. 8: The Micro Mono Control and its PCB layout



The design of the MCC was prototyped on a solderless breadboard with programming done in the Arduino IDE. Once the circuit was finalized, the PCB design was done in KiCAD. Interface and speaker components were positioned on the top of the PCB and other components on the bottom. A hole in the PCB allowed the joystick to protrude through. The depth of the joystick, underside components, and battery necessitate standoffs to keep it horizontal on a desktop. The length of the MMC's PCB required a mid-point standoff to keep the PCB stable during button pushes. PCBs have some flex and although the pressure from button presses is not sufficient to damage the PCB, the user experience is enhanced by a more stable device.

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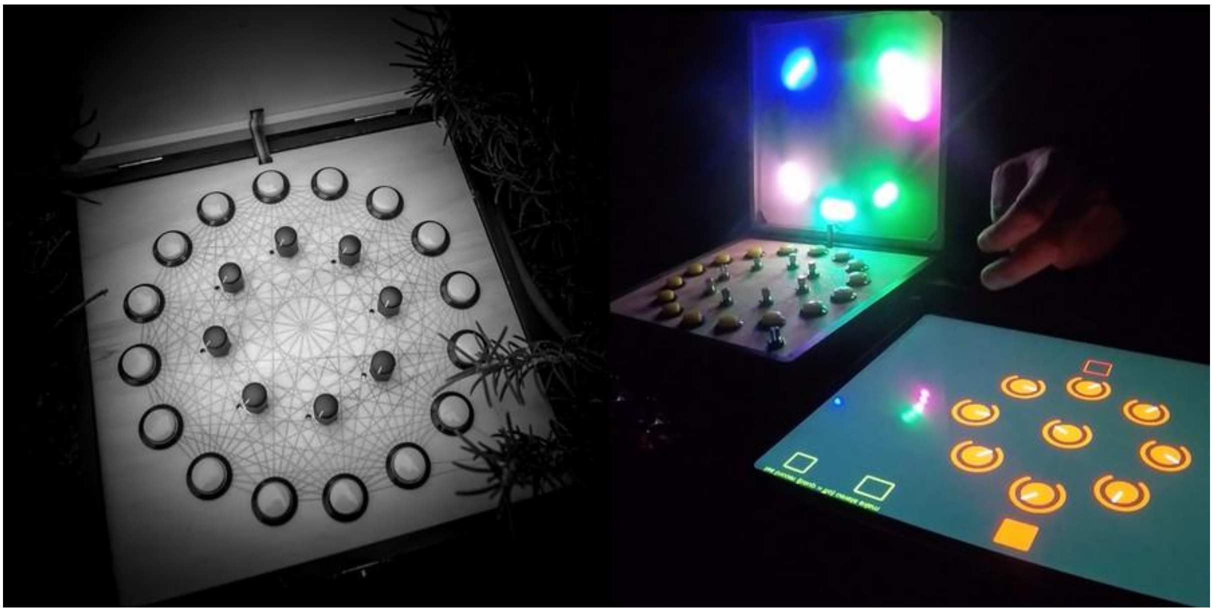
5.5 BOX

The intention with BOX (2019), shown in Figure 9, is to communicate the inner workings of the software and the decisions/gestures of the human performer via 48 LEDs built into the lid of the instrument, which is orientated towards the audience during performance and used for visual feedback by the performer. When closed, BOX has no visible controls on its outside surfaces but hides light and a control interface within. An accelerometer built into the lid acts as overall volume control and provides a link between sound, light, and motion; when BOX is closed no light is visible and sound stops.

Fig. 9: Box: Close up of laser cut detail (left) on stage next to an iPad running associated software (right).



The project highlights the tension between tactile gestures and complex remappings; physicality is celebrated and it explores the creative potential of self-animating systems that are difficult to navigate. There is a clear obsession with circles, loops, and patterns in its layout and the music its produces. The overall goal is to foreground a combination of autonomous and manually operated systems. The software is written in Pure Data and runs on an iPad via Mobile Music Platform, this is controlled by bespoke laser-cut controller programmed via the Arduino IDE for a Teensy LC microcontroller.

The design and build for Box returns to some of the panel mount methods used in Analogue Revolutions, but the top panel is laser cut for convenience and etched with a pattern that visually connects each component with every other component. Electronics are straightforward as all of the logic and sound generation is delegated to the software realm, this negates the need for a breadboard or PCB as all controls are wired directly to the Teensy LC. A ring of 48 LEDs is glued to the inside of the lid and an opal acrylic diffuser sits in front of this with a neatly laser cut whole to accept a small ribbon cable that connects to the LEDs and the accelerometer. Video documentation of Box is available online.[18]

5.6 Quadra

Many of our devices that use digital fabrication have been oriented toward performance, but there is also a role for songwriting tools that are more oriented toward composition. The Quadra (2021) was designed to fit this niche. Its name refers to its four parts: lead, chords, bass, and drums. In this regard, it could be classified as a Groovebox[19] in the spirit of those by Roland, Korg, Akai, Electron, and others. The Quadra includes synthesis engines for each part and a multitrack algorithmic sequencer. It has minimal controls—four pots, eight buttons—and it inherits the 16-step circular LED from the Beat Machine. These are mounted on a custom PCB as show in Figure 10. The Quadra relies heavily on algorithmic compositional processes that generate musical parts as a composition starting point to keep the interface simple and to support inexperienced songwriters in creating their work.

[18] http://www.johnrobertferguson.com/box-box-box/
[19] https://en.wikipedia.org/wiki/Groovebox

Fig. 10: The On Board Quadra, with standoffs (left) and with a laser cut case (right).

To support the polyphony required by four musical parts on the Quadra a more powerful microcon- troller than the Arduino Pro Micro used in previous projects was required, yet maintaining a low cost remained an important accessibility requirement. The ESP32 microprocessor was selected as meeting a good price-performance ratio. An ESP32 board with a built-in rechargeable battery was selected to support portability. This is soldered underneath the PCB with header pins located either side of the central button matrix. The ESP32 is often used for its WIFI and Bluetooth capabilities, but neither is utilized in the Quadra. Audio output is via a mini-jack headphone socket on a digital to analog converter (ADC) board that supports the I2S digital audio codec. This is mounted under the PCB along with amplifier boards that drive small stereo loudspeakers. Video documentation of the Quadra is available online.[20]

The Quadra continues our tradition of real-time audio synthesis for your instruments, but a change in microprocessor for our projects prompted a change in software audio library. Our previous projects often used the Mozzi library for Arduino-based projects, and we occasionally used Teensy and its MIDI and audio libraries. At time, when focusing on controller devices, these were typically connected to computing devices running Pure Data software patches. For the Quadra project we developed a new open source audio synthesis library called M16[21]. This was modelled on the Mozzi library but enables higher resolution audio and exploits the duel core capabilities of the ESP32's processor.

Design of the PCB for the Quadra followed similar processes outlined for previous boards. The PCB included corner holes for either standoffs or for connection to a laser cut case as shown in Figure 10. The case provides a more resolved appearance and can be decorated by users to personalize the device reinforcing the connection to it and encourages care for it.

6 Reflections on the exemplar projects

The design of digitally fabricated circuit boards for an instrument is a task that requires and builds upon a solid background in breadboard prototyping. Although software applications such as Inkscape and KiCAD include useful default settings, and KiCad has tools to check the validity of circuits, the digital design process can be somewhat abstract and is best grounded is an understanding of breadboard and paper circuit prototyping activities.

The assembly of laser cut parts requires some minor woodworking skills and PCBs require that makers solder components to the boards. Often sanding, painting, screwing or soldering are already a part of DIY electronic music processes, but for those who may have only used solderless breadboard, the circuit design processes and the addition of new assembly skills may present an additional hurdle and/or learning opportunity. Fortunately, end users at UbiMus workshops need only assemble (some) components when PCBs and case components are pre-prepared, therefor it is only instrument designers that need to engage with the full design and manufacture processes of digital fabrication.

While one aspect of the maker culture is to embrace the affordances of new technologies, there is also an undercurrent of technological critique in the DIY movement. For some, the use of digital manufacturing may be seen as giving in to the professional and commercial world of technology, and they may prefer the deliberate messiness of roughly soldered components on recycled materials. Others may find solace in unruly

[20] https://www.explodingart.com/arb/2022/03/01/on-board-quadra/

[21] https://github.com/algomusic/M16

PCB designs like those of Gijs Gieskes[22] that shun a neat and clean modernist aesthetic. There is also the consideration of resource usage in the PCB manufacture and shipping to take into account (21), although this may be somewhat offset by the increased longevity of devices more robustly made using digital fabrication processes.

For us, the sense of empowerment to make what we imagine while not being restricted by other's instrumental visions elevates our musical practice to new heights. The cost of that is the development of new maker skills and having to divide our time between device making and music making. Returning to previously initiated discussion on the relationship between making instruments and making music, it is useful at this point to quote Brian Crabtree, who is one half of Monome[23], a company that embodies many of the DIY and Maker ideas that are at the foreground of discussion in this paper, and whose grid controllers have become a shining exemplar of what's possible with open-ended community-supported hardware.

I've tended to create patches in Max/MSP that do everything I want, which is a drawback in some ways because there's always something new one might want. Instead of actually making music, you go program a bit longer, until eventually you're more obsessed with making tools than using tools. What matters is acknowledging that this is not a bad thing—Max Matthews and Miller Puckette as testament (14).

We sometime wonder if we have become more obsessed with making tools than making music. Having a workshop of 20 people all complete a Sonic Frisbee in one day and perform music with it in an ad hoc ensemble is a different way of making music than simply building an instrument that one performs oneself. Building an instrument to meet the needs of one person is cathartic, and perhaps that's an end point in and of itself. As we look beyond "one-off" bespoke instruments and explore the possibilities offered by digital fabrication where multiple instruments can go out into the world to be used in different ways, designing, and making are not an endpoint, but more of an opportunity for open-ended interaction with other musicians. However, we are unsure if we are blindly appropriating the tools of mass production, or if are we simply taking advantage of their increasing decentralization. Further questions that emerge for us when reflecting on these projects include: Is Digital Fabrication still DIY? Is mass production becoming decentralized or more centralized? Is a danger of accessible digital fabrication that we will producing many things that aren't worth making? How do we avoid the cycle of endless iteration that rapid prototyping allows? When embracing digital fabrication, how can the ethics of the handmade and the intimate experience of working with materials remain at the foreground? And will these techniques negatively reinforce disposable relationships with our materials?

7 Conclusion and future work

This article has outlined a case for the addition of small-run digital fabrication as a viable addition to existing DIY electronic music-making activities for use in UbiMus contexts. Just like the DIY move from non-programmable to programmable chips, the change from breadboard construction to laser cutting and custom PCBs seems like a next-step for those looking to expand their DIY instrument-making methods. 3D printing has similar potential and is used by a growing number of electronic instrument makers (18), (28), but is yet to be employed by the authors, which is why it is not featured as highly in this article.

The example projects show some of the potential use of small-run digital fabrication processes, and various approaches to sound generation and control are documented (discrete electronic components, versus microcontrollers and code). These examples were created by reasonably skilled individuals who were new to Laser Cutting and PCB design processes at the time. We suggest there is scope for such digital fabrication processes to be incorporated into bespoke instrument building processes, especially where outcomes require multiple devices as employed in workshop-based activities and Do-It-Together (DIT) approaches to DIY advocated by (26) and (22) and already embedded in many UbiMus activities.

The next stage for our projects is to consider 3D printer parts, using digitally controlled routers for 3D woodwork, and have surface mounted components added to PCB boards during production. These techniques would allow us to fit more complex designs in a more compact space, further reducing materials usage and more flexible instrument possibilities. But before then, we look forward to finding more time to make music with the instruments we have already created.

[22] https://www.gieskes.nl/

[23] https://monome.org/

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A Commentary on DIY musical instruments:

From Handmade Electronic Circuits to Microcontrollers and Digital Fabrication

Joseph Timoney

Abstract This article offers a commentary on the anchor article of this issue and provides a context for the discussion of the use of Do-It-Yourself (DIY) technologies, methods, and techniques. We start by a general appraisal of the article, following this with some thoughts and reflections on the process of making instruments and how these may enable ubimus practices.

Keywords Handmade musical instruments, Digital fabrication processes, DIY projects

1 Introduction

This is a very interesting work on the creation of handmade musical instruments. The ideas are illustrated with a number of case studies. What has led to this work is the increasing ease of availability of machinery for producing laser cut and 3D printed parts, along with web-based facilities for the economical fabrication of custom PCBs for DIY projects. The paper discusses some of the history, followed by descriptions of six example instruments that highlight different aspects. It then uses its experience to derive a few observations on what has been learned and what might be the most promising direction for the future steps. The layout of the paper is very logical and the material is very informative. Anyone interested in the field of DIY instruments will find much to pick up. As an area there is little published material so any opportunity to read and absorb more is very welcome. Pioneers such as this research group suggest that the harnessing of new technologies and with some efforts can lead to the creation of new digital instruments that fit well within the remit of UbiMus. There are still obstacles but they are diminishing year-on-year. In the ideal world, anyone with some technical appreciation, manual skills and either hardware or software skills, or both, could bring their imagination to making digital instruments that could appeal to everyone. It is a noble wish and certainly this paper promotes the belief. The next paragraphs are a synopsis followed by a set of short observations from the work. The text very much speaks for itself as everything is presented with clarity, and they ooze experience.

2 DIY and Democratization of Technology

Although the idea of DIY electronic instruments have been available for well over 50 years, e.g. David Tudor's ground-breaking activities in the 1970s, the difference now is that since the 1990s everything is becoming so much more accessible. This reflects broader changes that have been happening in the electronics industry and the democratization of technology. The underlying philosophy for the paper is that the instrument, and the technology that created it, is united with the musician in the creation process. Particularly when people are making music with the instruments they created themselves they are expressing their originality before even playing a note. Additionally, the artistic intention then is amplified by the unique nature of the instrument which is very different from the traditional approach. Also, the use of code over notation is another shift in emphasis.

Can the current situation then mean that such DIY instruments can be considered as a suitable candidate to join the family of ubiquitous musical devices? This is not fully the case yet, there are skills that must be mastered, and these are technical more than musical. However, with every emerging innovation these are becoming easier to learn so for a musician it is worthwhile to acquire them. The rise of the Maker communities with their Hackerspaces offers a place where people can meet and practice these skills together as well as developing new ideas. The NIME conference is the meeting place for the academics interested in theorising and prototyping for the field.

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3 Digital Fabrication Processes

The intended application of digital fabrication processes discussed in this paper has been to build custom circuit boards and cases/physical enclosures for their instruments. The two most important facilitators for this are laser cut parts and custom PCBs. Laser cutters have very much democratized the production of custom etching and cutouts from lightweight materials including cardboard, plywood, and acrylic sheets. They are useful for creating custom control surfaces and enclosures. The simplest instruments can be formed using parallel panels separated by metal standoffs. Another facilitator is Paper Circuits, where circuit diagrams are printed on paper or cardboard, and the legs of components are pushed through the material and soldered or otherwise connected from below. However, the UbiMus appeal of instruments built from Paper Circuits is tempered by the fact that their reliability and longevity is inconsistent. Thus, small-run custom printed circuit board (PCB) manufacturing is a better choice overall, and the cost is continually decreasing. Additionally, the PCB design software tools have become more accessible. Two popular choices are Fritzing and KiCad. Lastly, the introduction of single-board computer platforms such as Arduino and Raspberry Pi have been critical facilitators for electronic music since the mid-2000s.

1) The basic steps identified to make a digital instrument are thus:
2) Prototype the project on a breadboard;
3) Draw a schematic in software;
4) Use the schematic to design a PCB layout;
5) Route connections and establish a ground plane;
6) Export Gerber files;
7) Upload files to a PCB manufacturer and place an order;
8) Solder components onto the delivered PCB;
9) Test functionality of final electronic instrument.

In the paper, six example projects are presented to show the application of these ideas. The names of the instruments are Analogue Revolutions, the Sonic Frisbee, the Beat Machine, the Micro Mono Control, Box, and Quadra, which involves minimal hand assembly, and features a custom PCB, (ESP32) microcontroller, bespoke code, and a laser-cut enclosure.:

4 Conclusion

In conclusion, the article does provide some very practical ideas for DIY applications within the ubimus context, particularly from the perspective of the various case studies. Observations from these projects include:

Iteration and mistakes are inevitable and need to be considered part of the design process. Be prepared for reprinting.

The assembly of laser cut parts requires some minor woodworking skills and PCBs require that makers solder components to the boards. The circuit design processes, and the addition of new assembly skills may present an additional hurdle and/or learning opportunity.

Care has to be taken to balance the time spent in making tools and making music.The next step is to consider 3D printer parts, using digitally controlled routers for 3D woodwork, and have surface mounted components added to PCB boards during production. These techniques would allow more complex designs in a more compact space.

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DIWhy and How:

Commentary on “DIY musical instruments” by Brown and Ferguson

Alex Hofmann

Abstract. Based on the anchor article “DIY musical instruments: From Handmade Electronic Circuits to Microcontrollers and Digital Fabrication” by Brown and Ferguson (2024), this commentary discusses why their presented Open Source hardware and software instruments are relevant, as well as how their Digital Fabrication approach may help to reach new communities, including those outside academia.

1 Introduction

Starting from simple circuits (3) to complex stand-alone microprocessor-based instruments (6), the do-it-yourself (DIY) musical instrument communities such as Ubiquitous Music (UbiMus), New Interfaces for Musical Expression (NIME), and LinuxAudio have greatly benefited from the technical developments of smaller, faster, and more accurate tools that were invented over the past two decades. At the same time, the design and the making of electronic instruments became an important part of the artistic practice, leaving behind the traditional roles of instrument maker, composer, and performer as separate units that we mostly see with acoustic instruments. Electronic musicians often blur these roles and are considering multiple aspects when designing and building their tools for musical expression (1) . Thus, we saw a boom of unique, performance dedicated, new instruments (Jensenius, 2016) , however, a number of those were only prototypical designs that barely survived the year that they were presented as a conference demo.

Taking these developments into account, (2) propose to take advantage of today’s Digital Fabrication methods, such as manufacturing printed circuit boards (PCBs) and laser cutting (or 3D printing) of enclosures, for more stable and reproducible DIY instruments. They showcase an impressive collection of DIY projects, with different skill levels and time required to build these instruments. By using a Digital Fabrication approach, their DIY projects can be built within a shorter and foreseeable timeline to be used as pedagogical tools in University courses and during other workshops. Furthermore, this approach leaves time for the participants to also perform with their new instruments in the group and to build their musical networks.

Whereas the Digital Fabrication approach on one hand, provides improved planability of resources, better time management during the workshops, as well as more time for music making, it, on the other hand, raises the question of how much of the creative aspect of DIY instrument making is left? When does it become instrument assembly, and why let musicians solder components to PCBs and have them assemble their electronic instruments, if robots could do it?

2 Designing Frameworks for DIY Instrument Workshop

When preparing workshops and courses it is a challenge to decide how much time is dedicated to which step and why. Who are the participants and what are their expectations? Where lay the creative moments for the participants? Are these during the stage of designing an instrument, during the assembling of the components, while plugging in the power, or is it the moment when they can start playing their new instrument? How much detail needs to be prepared and how much freedom can we give in a workshop-based setting, considering the time constraints? Such trade-offs have to be made on many levels during the preparation of workshops and courses. By using integrated circuits, hardware- or software frameworks to speed up the building process, we always have to leave design decisions to the creators of these frameworks. Brown and Ferguson (2) offer such frameworks with varying levels of complexity for building electronic instruments. From Analogue Revolutions, a non-programmable analog hardware synth, to the complex designs of BOX and Quadra that use programmable microchips, many of their instruments share certain design decisions (circular position of components, step sequencers) that are very distinctive of the creators’ style.

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In my experience, building such complex instruments within a workshop or course is impossible without careful planning and preparation, as well as the use of pre-fabricated parts. During our Csound on Stage Musical Operator (COSMO) project (4), we ran a series of 2-day maker workshops, where participants were building custom FX stomp boxes, based on the RaspberryPi (RPi) running Csound. For our first workshops in 2013 we had to design a custom PCB (with iterations over the following years) to be able to connect analogue controller inputs to the RPi and the question of whether to provide a dedicated PCB with the entire front panel layout of control knobs and buttons was also discussed. Luckily, we did not have one for the first workshop, and we quickly noticed that participants highly enjoyed the process of designing the front panel layout of their devices. Although providing a front panel PCB would have sped up the workshop significantly, as the components would only have to be soldered to the PCB, we then let this intentionally open throughout the project.[1] We even went a step further and provided different buttons and knob cap designs, as we observed how this fueled creativity in both, front panel and instrument function design (5). In 2018, we switched from the RPi to using the Bela Platform (McPherson, 2016) as the core microprocessing board. This provided better audio quality (especially in terms of latency) and freed us from producing custom PCBs, as Bela provides the dedicated I/O interface for both audio and controls in one core unit.

A drawback of this decision was that it slightly raised the material costs for our workshop participants, especially for those who already had RPis and USB-audio interfaces, and were re-using those spare parts in their COSMO projects. The Bela price tag may be a reason why other low-cost platforms such as the Teenzy, Arduino Pro, and recently the ESP32, are still very interesting for DIY beginners as well as for entry level workshops. However, with the core feature of ultra-low latency, Bela became a relevant platform for our COSMO project and for many other DIY projects. In this regard, the Bela project is remarkable as it seems to provide enough of a basis to quickly get started with building DIY musical instruments, whereas it leaves enough room for a large variety of very different designs, as can be seen on the Bela blog-website.

For the Digital Fabrication approach by Brown and Ferguson (2), many instrument design decisions had to be made by the instrument designers, to pre-produce the front panel PCBs and enclosures, so that the instruments can be assembled within a short and foreseeable timespan. This allows participants to build their instrument and immediately perform with it. Making music with the participants is of such importance, that Brown and Ferguson removed the instrument design phase intentionally and are even asking themselves: “Is Digital Fabrication still DIY?” Which resonates with my question if instrument assembly is still a creative process? Certainly not to the same extent as instrument design, however Brown and Ferguson(2) are proposing an approach that shifts the creative action towards the musical exploration and the community music making with self made Open Source tools. They thereby provide the “..opportunity for open-ended [musical] interaction with other musicians”, an idea that might attract communities with a primarily strong music background.

3 DIY Communities Outside Academia

The idea of Brown and Ferguson’s (2) instrument Quadra, starting from a groovebox design, may also be appealing for beat makers, electronic music producers, DJs, and other musicians who enter the domain of DIY electronic instruments from a popular music background. Furthermore, the Open Source Software (OSS) of their DIY projects is important, as it allows participants to later modify and extend the functionality of their instruments themselves.

Many artists with a popular music background work with proprietary digital audio workstations (DAWs) like Ableton Live, NI-Maschine, Fruity Loops or with so-called groove box devices produced by larger companies such as Roland, Korg, Electron, AKAI and so on. In the beat maker communities, customisations of their instruments are often related to designing a unique front panel sticker and by exchanging the black standard knob cabs with colourful or shiny ones (eg. see for the Roland SP-404[2] or AKAI MPC [3] devices). No question that this can also be done on top of the design of Quadra. However, looking at the backbone of Quadra, the developed M16 OSS sound processing library [4] for the low-cost (less than 10$) ESP32 micro-processor, may be key to bringing DIY instrument making to entirely new communities.

Brown and Ferguson (2024) describe how not being restricted by other’s instrumental visions is giving them “the sense of empowerment to make what [they] imagine”. A major potential of their

1 https://cosmoproject.github.io/docs/
2 https://articles.roland.com/skin-deep-art-of-the-sp-404-overlay-and-beyond
3 https://hiphopmakers.com/70-must-see-custom-mpc-designs

work resides in the fact that they pass on their knowledge and thereby empower others. Taking into account the specific consideration in Brown and Ferguson's (202x) design, to be low cost, with some of their instruments' total material costs being less than 20$ (Micro Mono Control), this opens a door to communities where budgets are crucial, such as music schools, especially in regions outside Australia, North America, and Europe.

In February 2023, Bernt I. Wærstad and I gave a live-electronics Csound/Cabbage workshop at the Santuri Electronic Music Academy (SEMA) in Nairobi, with the majority of participants being electronic music producers with skills in proprietary DAWs. For us, a key take-away from this workshop was that the DIY and Open Source Software (OSS) approach had not reached this electronic music community, although their interest in instrument making is very strong. Taking into account that the average income in this area is much lower than in Europe, Australia or North America, buying proprietary music software is a significant investment. OSS and DIY might provide a cost-effective alternative, which at the same time, through its openness, allows music students to understand the inner workings, and may even allow for culture specific music software adaptations by the artists themself.

Many acoustic instruments have obvious cultural references that are not immediately apparent in electronic music tools. Nonetheless, in many music software programs Western biases exist, which are recently more thoroughly discussed (Faber, 2021; Pardue & Bin, 2022). The approach of Brown and Ferguson (2) with their low cost (ESP32), Open Source Software (M16), beat maker-oriented, groove box designs may attract new communities and encourage their artists to hack and modify these devices for their musical applications. By acquiring the underlying DIY maker skills, this approach may empower them, in the long run, to design and build their very personal, electronic music tools.

4 Conclusion

Brown and Ferguson (2) show how to facilitate Digital Fabrication to make DIY instrument making faster, more reliable, and thereby more approachable, also for new communities, especially those with a strong background in music making with less technical experience. Coming back to my question, why let musicians assemble electronic instruments in the first place? Providing blueprint designs for building musical instruments has pedagogical benefits. For DIY novices, these designs can serve as a tool to learn how to solder, understand basic electronics, while also experiencing the satisfaction of successfully building an instrument that can be used to make music. Moreover, by sharing the knowledge and opening the underlying hard- and software designs, Brown and Ferguson (2) allow others to study, adapt, modify, hack and personalise these instruments and let them thereby gain DIY maker skills. This has the potential to give more musicians the described "sense of empowerment to make what [they] imagine while not being restricted by other's instrumental visions" and thereby hopefully also elevates many more musicians' musical practices to their individual new heights.

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[4] https://hiphopmakers.com/70-must-see-custom-mpc-designs

Eröffnung von Comprovization für Laien

Ein Erfahrungsbericht

Guido Kramann

Abstract Es geht in diesem Artikel um die spezielle Problematik im Bereich Ubiquitous Music, Comprovization für Laien zu öffnen. Stellt man Vergleiche verschiedener Herangehensweisen unter dieser Zielsetzung an, scheint das umso besser zu funktionieren, je stärker virtualisiert ein Ansatz ist. Mittels elektronischer Selbstbau-Instrumente, ist es schwer zu bewerkstelligen, dem Benutzer musikalische Fertigkeiten zu vermitteln: Beim Zusammenbau solcher Instrumente erschließt sich kaum musikalisches Wissen und eine auf dem besagten Instrument intuitiv erarbeitete Fertigkeit, bleibt an genau dieses Instrument gekoppelt. Ansätze hingegen, bei denen Sprachen zur Manipulation musikalischer Strukturen eingeführt werden, eröffnen dem Benutzer über den intuitiven Zugang hinaus die Möglichkeit, der symbolischen Gründung der jeweiligen Sprache nachzugehen und so zu einem vom Werkzeug entkoppelten Verständnis für Comprovization zu gelangen.

Abstract This article is about the special problem in the field of ubiquitous music to open up comprovization for laypeople. Comparing different approaches under this objective, the more virtualized an approach is, the better it seems to work. By means of electronic self-assembly instruments, it is difficult to impart musical skills to the user: Assembling such instruments hardly reveals any musical knowledge, and a skill intuitively acquired on such instrument remains coupled to that very instrument. Approaches that introduce languages for manipulating musical structures, on the other hand, open up the possibility for the user to pursue the symbolic foundation of the respective language beyond intuitive access and thus arrive at an understanding of comprovization that is decoupled from the tool.

1 Beschreibung einiger Versuche dazu, eine breitere Öffentlichkeit in musikalische Performances einzubeziehen

Die nachfolgend beschriebenen Szenarien haben gemeinsam, dass in allen Fällen angestrebt wurde, ein Setting zu entwickeln, bei dem es möglich sein würde, Laien in eine musikalische Performance zu involvieren. Es wird deutlich werden, dass die Nach- haltigkeit, in der das gelingt, sich von mal zu mal in der chronologischen Abfolge der Szenarien steigert. Gleichzeitig verlagert sich der Wirkungsort des jeweiligen Settings von mal zu mal immer weiter weg von einem realen Schauplatz, der mit Elektronischen Klangerzeugern bespielt wird, hin zu einem virtuellen, der mit Software gestaltet wird. Mögliche kausale Zusammenhänge und die sich daraus jeweils ergebenden Konsequenzen, werden im Anschluss daran diskutiert.

1.1 Szenario #1 aus dem Jahr 2012: Licht-Klang-Kugeln zum selber bauen

Zum zwanzigjährigen Bestehen meiner Hochschule habe ich eine Licht-Klang-Kugel entwickelt (Figure 1), Audiodatei: www.kramann.info/20_jahre/klangkugelduett.mp3. Die Bauanleitung wurde veröffentlicht, mit dem Ziel, dass möglichst viele Interessierte sich daran beteiligen, ein Exemplar zu bauen, siehe www.kramann.info/20_jahre. Indem diese Kugeln in Bäume gehangen werden sollten, sollte ein interessantes abendliches Licht und Klang-Spektakel die Besucher*Innen des Campus bezaubern. Lötkenntnisse, die Fähigkeit, einen Schaltplan zu lesen, und handwerkliche Fertigkeiten beim Zusammenbau der Kugeln waren erforderlich, um ein solches Objekt herstellen zu können. Am Ende existierten drei von mir hergestellte Exemplare und je eines von drei besonders interessierten Studierenden, die bereits Lehrveranstaltungen in den Bereichen Mikrocontrollertechnik und Informatik besucht hatten und im Rahmen einer von mir gegebenen Lehrveranstaltung "Licht-Klang-Installation" sogar ein eigenes Gesamtkonzept mit der Licht-Klang-Kugel entwickelt hatten. Laien von außerhalb der Hochschule konnte ich nicht fürs Projekt interessieren. Die Installation wurde am Ende niemals der Öffentlichkeit zugänglich gemacht, insbesondere weil die Menge fertiggestellter Licht-Klang-Kugeln so gering war.

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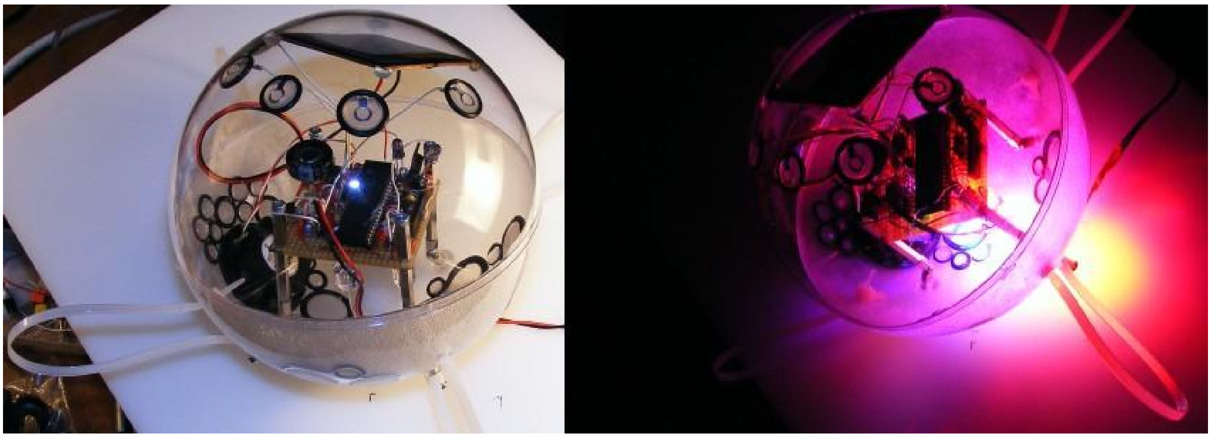
Fig. 1: DIY Licht-Klang-Kugeln zum 20 jährigen Bestehen der Technischen Hochschule Brandenburg im Jahr 2012



1.2 Szenario #2 aus dem Jahr 2015: Interaktive Klangskulpturen aus Beton

Eine Mikrocontroller basierte interaktive Anwendung wurde realisiert, um sie in Masken aus Beton zu verwenden, (Figure 2). Letztere wurden im Sommer 2015 auf dem Campus der Technischen Hochschule Brandenburg aufgestellt. Sie reagierten auf Geräusche und Pfiffe von Passanten in der Nähe und aufeinander, indem sie passend dazu eigene Klänge in Echtzeit komponierten und wiedergaben, siehe https://youtu.be/rTYhLyQXUyw. Bewusst wurde hier auf eine aktive Beteiligung Dritter bei der Herstellung verzichtet. Lediglich die Bereitschaft, mit der Installation zu interagieren, war Teil des künstlerischen Konzepts. Jede der Skulpturen hatte ein eigenes spezielles Interaktionskonzept, wobei zwei der fünf Installationen von Studierenden aus dem Masterstudiengang Digitale Medien entwickelt wurden. Über einen Zeitraum von zwei Wochen hinweg, wurden die Skulpturen täglich morgens mit einer Sackkarre auf eine Wiese vor die Mensa gestellt und abends wieder zurück in einen Vorraum des Informatikgebäudes gebracht. Durch die exponierte Lage, an denen die Slulpturen präsentiert wurden, ergab es sich innerhalb dieses Zeitraumes tatäglich, dass wenigstens eine handvoll der 700 Studierenden der Hochschule in Interaktion mit den Skulpturen traten.

Fig. 2: “Tönende Masken” auf dem Campus der Technischen Hochschule Brandenburg im Jahr 2015.

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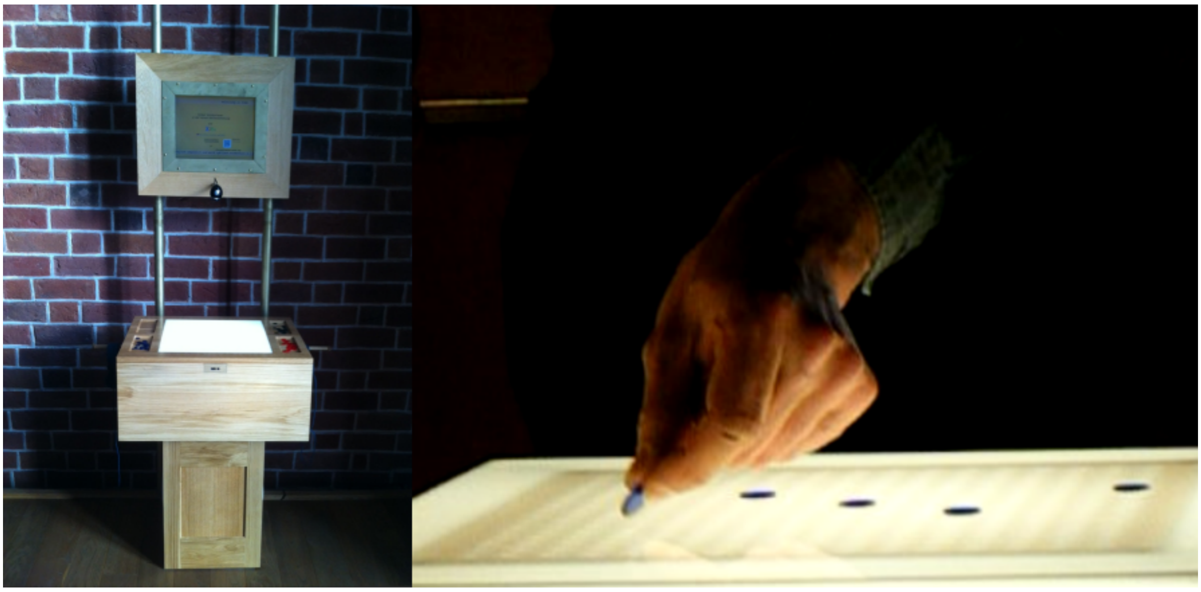
1.3 Szenario #3 aus dem Jahr 2016: Komponierstation “KIBA”

Für die Internationale Bachausstellung in Frankfurt an der Oder in Deutschland “C. P. E. Bach - Leben, Werk und Nachwirken” wurde eine Komponierstation ”KIBA” entwickelt (Figure 3). Bei KIBA können durch Anordnung farbiger Chips auf einem rechteckigen Leuchttisch in Echtzeit musikalische Phrasen gebildet werden. Diese Phrasen wurden von dem System dann in Beziehung zu Originalwerken von Carl Philipp Emanuel Bach gebracht und eine Gesamtkomposition gebildet und gespielt. Technisch Einsatz kam ein Industrie PC und eine daran angeschlossene USB-Kamera. Die agile Haptik der Benutzerschnittstelle, bei sehr leicht und schnell Chips neu gesetzt, verschoben und “weg gewischt” werden können, wurde im Nachgang auch mit einigem Erfolg auf der Konferenz CMMR2015 in Plymouth vorgestellt, siehe auch https://youtu.be/3WLbsNjVU. Bei dieser Präsentation wurden keine Fragmente der Kompositionen C.P.E. Bachs ergänzt, sondern man hörte nur die Phrasen, die man auch auf dem Leuchttisch sah. Von dieser Variante existiert auch eine Android-App, bei der Spielchips aber nicht echt sind, sondern als verschiebliche grafische Elemente umgesetzt wurden: https://play.google.com/store/apps/details?id= processing.test.kiba&pli=1.

Im Gegensatz zu den vorangehenden Konzepten zeichnet sich KIBA durch eine extreme Transparenz aus. Ein Benutzer von KIBA bekommt vermittelt, dass er die Comprovization vollständig durchschaut und kontrolliert.

Frankfurt an der Oder.ig. 3: “KIBA” (Kirnberger - Individuell - Bach) – Komponierstation für die Internationale Bachausstellung in



1.4 Szenario #4 ab dem Jahr 2019: Generative Sprache AOG “Arithmetic Operation Grammar”

Bei einem TEDx Event im Dezember 2019 an der Technischen Hochschule Brandenburg wurde von mir der Vortrag “Komponieren für alle” gehalten. Im Anschluss wurden an Teile des Publikums Tablet- Computer verteilt auf denen in einem Programm formelhafte Ausdrücke simuliert werden konnten, die über W-LAN auf einen zentralen Computer zusammengeführt und dort gemeinsam mit einem Projektor visualisiert und in Musik umgesetzt wurden (Figure 4). Die hier verwendete generative, formelhafte Sprache konnte zuvor innerhalb des Vortrags wenigstens rudimentär eingeführt werden. Die beteiligten Personen konnten auf der Projektion ihre Formelausdrücke mit denen der an- deren Beteiligten vergleichen. Jede Formelzeile in der Projektion entsprach der Eingabe einer Person und wurde auch mit einem sich klanglich von den anderen abhebenden virtuellen Musikinstrument gekoppelt, see https://youtu.be/MPjBExFyDHM.

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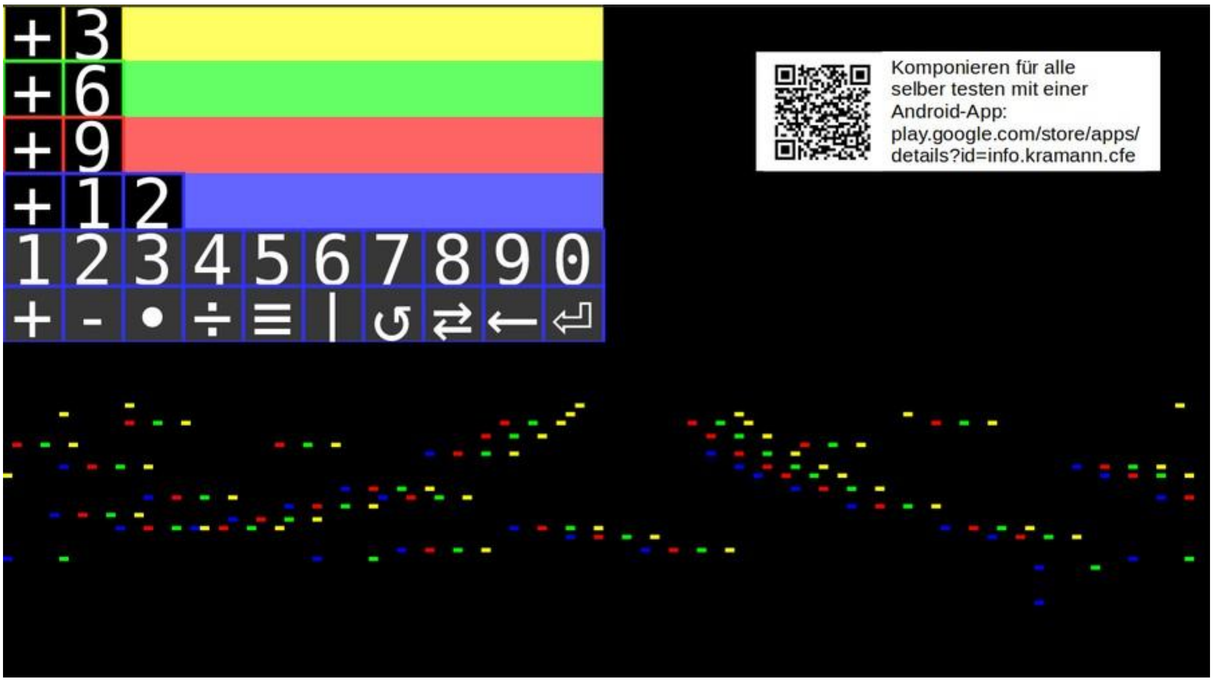
Fig. 4: Editor zur Eingabe formelhafter Ausdrücke der generativen Sprache AOG auf einem Tablet-Computer



2 Diskussion

Die Beurteilung der vorangehend beschriebenen Szenarien erfolgt in der nun anschließenden Diskus- sion stets in Hinblick darauf, Comprovization für Laien zu eröffnen. So ist es bei diesem Ziel plausibel, tiefer gehendes Wissen über die Wirkzusammenhänge zwischen einer Mensch-Maschine-Interaktion und einer daraus generierten Musik bei den Beteiligten zu verankern. Dieses Ziel kann man natürlich nicht verabsolutieren. Bei einer musikalisch-kürformance im klassischen Sinne ist eine solche Offenlegung der Zusammenhänge unüblich. Die Intentionen klassischer musikalischkünstlerischer Performances zeichnen sich typischerweise gerade dadurch aus, dass sie außerhalb dieses Zusammenhangs liegen, beispielsweise aktuell oft bei politischen und gesellschaftlichen Themen wie Klimaschutz, Gleichberechtigung, oder Problemen mit menschlicher Gewalt. Jedoch weisen Aktivitäten im Bereich Ubiquitous Music über den Bereich des professionellen Kunstbetriebes hinaus. Comprovization für Laien zu öffnen, ergibt sich theoretisch einfach aus dem Geist der Sache von Ubiquitous Music und sollte auch in praktische Konsequenzen heinein weiter getrieben werden.

Die vorangehend beschriebenen Szenarien werden hier somit gezielt unter dem Gesichtspunkt Comprovization für Laien zu eröffnen, beurteilt, da dies von besonderer Relevanz für Ubiquitous Music ist. Unter diesem Gesichtspunkt erscheint alles, was nicht unmittelbar mit der Vermittlung einer musikalischen Praxis zu tun hat, ja vielleicht nicht einmal überhaupt einen Bezug zu Musik hat als überflüssiges Beiwerk und oft gleichzeitig als zusätzliche Hürde, die es zu nehmen gilt. Darunter fallen insbesondere die bei Szenario #1 erforderlichen Fertigkeiten, Elektronikschaltungen verstehen und aufbauen zu können, sowie eine Entwicklungsumgebung für einen Mikrocontroller zu installieren, um mindestens ein Programm auf den verwendeten Chip flashen zu können. Wer immer sich auf dieses künstlerische Projekt eingelassen hat, sich also an dem Bau von Licht-Klang-Kugeln beteiligt hat, ist aller Wahrscheinlichkeit nie an den Punkt gelangt, sich mit den in das System integrierten musikalischen Strukturen und Gesetzmäßigkeiten auseinanderzusetzen, weil man alle Hände voll zu tun hat, das System überhaupt aufzubauen und dann erfolgreich zu testen.

Szenario #2 entlastet die beteiligten Person davon, selber das System mit aufzubauen und eröffnet so mehr Raum dazu Erfahrungen in der Interaktion mit dem System zu sammeln. Die beteiligten Personen gerieren hier aber zu reinen Rezipienten. Sie werden zwar durch die Interaktion mit den Betonskulpturen aktiv mit einbezogen, aber dabei nicht wirklich ernst genommen: Sie werden zu Teilen eines Spiels dessen Regeln nur die Künstlerpersönlichkeit kennt, die das Gesamtkonzept ersonnen hat. Ein allgemeiner Trend geht dahin, dass der Komponist nicht mehr der Schöpfer einer musikalischen Struktur ist, sondern den Rahmen bestimmt, in dem sich eine interaktive künstlerische Performance dann abspielt (9).

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Erst in Szenario #3 ändert sich das Verhältnis der beteiligten Personen zu der Sache grundlegend. Statt unmündige Rezipienten in einem künstlerischen Setting rücken die Nutzer des Systems hier wirklich in den Fokus. Durch den leicht zu durchschauenden Zusammenhang der auf dem Leuchttisch gebildeten Muster zu den hörbaren repetitiven Phrasen, eröffnet sich den Benutzern erst ein eigener gestalterischer Horizont, der eigenen Zielen folgen kann, die nicht vom Entwickler des Systems intendiert sein müssen.

Zu Szenario #4: Seit dem Jahr 2019 liegt der Fokus meiner Arbeit ganz be- wusst darauf, Laien Theorien zum Komponieren bereit zu stellen. Seitdem orientieren sich Veröffentlichungen generativer Systeme für Musik an dieser klaren Zielsetzung. Konkret bedeutet das, dass jede Mensch-Maschine- Interaktion mit einer Software oder einem Gerät für Comprovization immer die Anforderung mit sich bringt, ihren Bezug zu der mit dem System generierten Musik transparent machen zu müssen.

Zu Szenario #4: Seit dem Jahr 2019 liegt der Fokus meiner Arbeit ganz bewusst darauf, Laien Theorien zum Komponieren bereit zu stellen. Seitdem orientieren sich Veröffentlichungen generativer Systeme für Musik an dieser klaren Zielsetzung. Konkret bedeutet das, dass jede Mensch-Maschine- Interaktion mit einer Software oder einem Gerät für Comprovization immer die Anforderung mit sich bringt, ihren Bezug zu der mit dem System generierten Musik transparent machen zu müssen. Mehr noch, bemisst sich geradezu der Wert einer Mensch-Maschine-Interaktion unmittelbar daran, wie eng ihr Zusammenhang mit der generierten Musik ist. Dies steht leider in unmittelbarem Widerspruch zum notwendigen Erklärungsbedarf bei der Interaktionsart für sich genommen: Werden ein Schachspiel (https://youtu.be/RXwY4FcAT3Q), ein Malprogramm (https://youtu.be/msMj14Xopdc), Bewegungssensoren eines Smartphones (https://youtu.be/JW3B33c6IEE), oder ein Hirnwellensensor (https://youtu.be/e2J 0njqDLOo) mit einem Musikgenerator gekoppelt, so muss zur Interaktion kaum etwas erklärt werden, wohingegen sich aber dem Benutzer der Zusammenhang zur Musik nur sehr vage, intuitiv über das musikalische Nachhaltiger, präziser und prinzipiell sogar entkoppelbar von jedweder Soft-oder Hardware, gelingt die Vermittlung einer Kompositionstechnik u¨ber die Vermittlung einer generativen Sprache. Die Sprachregeln orientieren sich im Idealfall an eine konkrete musikästhetische Haltung und begrenzen das in der Sprache Darstellbare auf aus dieser Perspektive heraus musikalisch Sinnvolles. Im Idealfall ist eine solche Sprache einfacher zu lernen, als klassische Musiktheorie und Kompositionstechnik und stellt hierzu auch eine echte Alternative dar. Die generative Sprache AOG "Arithmetic Operation Grammar" und ihre Derivate sind in dem Bestreben entstanden, diesen Zielen möglichst nahe zu kommen.

Hierzu sei ergänzend angemerkt, dass Code, der Musik generiert, als Konkretisierung einer bes- timmten Vorstellung dessen angesehen werden, was als Musik gelten kann. Diese konzeptionelle Vorstel- lung begründet sich bei "Arithmetic Operation Grammar" (AOG) darin, dass die Verteilung kleiner Primfaktoren (2,3,5,7) in der Folge der natürlichen Zahlen bereits als musikalisch sinnvoll organ- isiert angesehen wird und originäre musikalische Kompositionen durch Transformationen dieser Folge gewonnen werden können (5). Mit der zeilenweise von oben nach unten interpretierten Skriptspreche AOGscript lassen sich solche Transformationen sehr leicht beschreiben (6). Ohne auf die Sprachsyntax in diesem Zusammenhang näher einzugehen, sei hier mit Listing 1 ein Code-Beispiel zu AOGscript angeführt und die korrespondierende Audiodatei: www.kramann.info/fantasia.mp3.

Listing 1. Fantasia for Clarinet and Piano

```
' / 3 2%11+14
' / 7 2%11*4+12
' + 2 ?%[ 1 ] >( ' / 8 % 3 )
' + 3 ?
'* 2 ?
' + 8 ?%[ 1 ] >( ' / 14 % 3 )
' + 12 ?%[ 1 ] >( ' / 16 % 3 ) § [ 2 ] / (
[ 3 ] 2@( [ 1 ]%2 + 2 ) )?
[ 2 ] / ( [ 4 ] @( [ 2 ]%2 + 3 ) )? §§
[ 2 ] / ( [ 5 ] 4 ( [ 1 ] %3 + 2 ) )? [ 2 ] / ( [ 6 ] @2 ) ? §§
[ 2 ] / ( [ 7 ] 2 2 ) ?
1 ( ' / 18%[ 1 ]% 3 $)
{ 0 , 1 }
{ 68}
{ 0 , [ 8 ] , 1 3 2 , 5 6 , 6 0 , 1 0 8 }
{ 1 , [ 9 ] , 1 5 4 , 5 6 , 4 8 , 1 0 8 }
{ 2 , [ 1 0 ] , 1 7 6 , 5 6 , 3 6 , 1 0 8 }
{ 3 , [ 1 1 ] , 2 3 1 , 5 6 , 4 8 , 1 0 8 }
{ 4 , [ 1 2 ] , 3 7 4 , 5 6 , 6 0 , 1 0 8 }
{ 0 , [ 1 3 ] , 0 , 5 2 , 8 8 }
```

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3 Fazit

In Ubiquitous Music gibt es eine langjährige Praxis dazu, die für das Komponieren und Musizieren notwendigen Fertigkeiten in Werkzeugen zu inkorporieren, durch deren Gebrauch dann auch Laien die Möglichkeit eröffnet wird, Musik zu produzieren. Die Werkzeuge werden typischerweise in Sprachen wie Csound, Pure Data, oder Faust erstellt (7). Das sich daraus ergebende Werkzeug, oder virtuelle Musikinstrument kann dann in Live-Performances eingesetzt werden, oder kann die Grundlage von Laien für ihre alltägliche kompositorische Praxis “Little C” dienen (4).

So kann ein Werkzeug, oder virtuelles Musikinstrument in dem oben beschriebenen Sinne so gestaltet sein, dass beinahe jede beliebige Art es zu handhaben, jeweils stets etwas hervorbringt, das Musik zu nennen bei einer Vielzahl an Menschen Zustimmung hervorrufen wird. Um zu verstehen, was hier gemeint ist, kann man sich auch die akustis- chen Vorgänger solcher Musikinstrumente vor Augen führen, wie die Orffschen Instrumenten, Pandrums, Kalimben und Ähnliches. Bei diesen Instrumenten wird die Gewähr, dass “Schönes” herauskommt, wenn man sie benutzt durch eine starke Beschränkung der Spielmöglichkeiten erkauft.

Der Einsatz von Elektronik und Software eröffnet nun die Möglichkeit zur Herstellung von sich ähnlich “gutmütig” in der Handhabung verhaltenden (teilweise virtuellen) Musikinstrumenten, die aber nicht mehr, oder zumindest in geringerem Maße auf eine Beschränkung der Spielmöglichkeiten angewiesen sind, um dies zu erreichen.

Dies geschieht dort aber zu dem Preis, dass ihr Verhalten nicht mehr in einfacher und eindeutiger Art und Weise von deren Handhabung abhängt, sondern beispielsweise adaptiv, ergänzend und/oder intelligent ist. (1)

Das unmittelbare klangliche Feedback bei einer fortgesetzten Verwendung, gereicht in einem solchen Fall oft dazu, ein intuitives Verständnis für eine adäquate Handhabung eines solchen Musikinstrumentes zu entwickeln, siehe beispielsweise (2). Im Gegensatz zu einer Inkorporation physikalischer Eigenheiten und Handhabungstechniken bei akustischen Instrumenten, findet bei virtuellen Instrumenten in stärk- erem Maße eine (vor-symbolische) Inkorporation von Musiktheorie und kompositorischen Ideen statt (8).

Wenn ein solches Musikinstrument in Form eines DIY-Projektes zur Verfügung gestellt wird, dann kann eventuell auch vermittelst der bei einem Selbstbau notwendigen intensiven Auseinandersetzung mit der inneren Beschaffenheit des Musikinstruments sich zumindest das theoretische Wissen für dessen adäquate Handhabung beim zukünftigen Benutzer einstellen.

In welchem Zusammenhang aber steht zu einer vor-symbolischen Inkorporation von Musiktheorie und kompositorischen Ideen das Erlernen Symbol basierter algorithmischer generativer Methoden für die Musikproduktion, wie sie exemplarisch in einer generativen Sprache wie AOG oder AOGscript vorliegt?

Wenn es gelingt, adaptives, ergänzendes und/oder intelligentes Verhalten als Algorithmus oder in der Abstraktionsstufe höher gehend als Codezeilen in einer Skriptsprache zu formulieren, dann hat man dem Anwender eine Sprache in die Hand gegeben, die ihm die Handlungsmöglichkeiten mit dem Instrument unmittelbar auf einen Schlag vor Augen führen kann. Dies ist der Fall, weil der ausformulierte Algorithmus und noch in stärkerem Maße das vorliegende spezielle Skript über sich selbst hinaus auf all die Varianten, und Alternativen, die an ihrer Stelle auch möglicherweise waren, verweist. Während ein vor einem liegendes Musikinstrument nur das ist, was es eben ist, so sind Algorithmen und Skripte nicht nur symbolische Repräsentationen eines besonderen Aspektes des Instrumentes, oder einer Komposition, sondern hier hat bereits jemand die spezielle Ausprägung allein durch Gebrauch der Sprache in einen größeren Kontext gebracht und vermittelt so eine Mannigfaltigkeit an Handlungsmöglichkeiten, die erst den Benutzer befähigt selber und eigenständig Comprovization zu betreiben, oder selber adaptive, ergänzende und/oder intelligente Musikinstrumente zu entwickeln. Eine gewisse Stützung erfährt diese These durch die in der Symbol-Gründungs-Theorie bereits experimentell belegte These des Kumulativen Lernens. Danach kann eine neuartige Situation, in der ein Symbol auftaucht dazu dienen, sich ein alternatives auch gültiges aber bislang unbekanntes Netzwerk von Bedeutungszusammenhängen zu erschließen, um dann resultierend daraus eine Lösung für ein bislang noch nicht bewältigtes Problem zu finden:

> *In real life, symbol grounding has a dynamic or contextual aspect to it. Heidegger refers to this as as-ness (Soheit) of language. In other words, language enables us to see the world (or the context) in a new way. Suppose Alice says to Bob, I need a hammer. Bob, seeing no hammers around, hands her a rock. This is clearly a successful case of communication, even though the word hammer was grounded to a rock by Bob. (10)*

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4 Soziale Aspekte bei DIY

Was bei den bisherigen Uberlegungen unberücksichtigt blieb, ist die Festigung des sozialen Zusammenhalts einer Gemeinschaft durch das Arbeiten an einem gemeinsamen Ziel. Dabei tragen typischerweise viele unterschiedliche notwendige Verrichtungen dazu bei, dieses Ziel zu erreichen, ohne dass diese Verrichtungen für sich genommen viel mit dem Ziel zu tun haben müssen. Eine kaputte Kirchenbank zu reparieren, ist keine religiöse Handlung. Eine elektronische Schaltung gemäß Szenario #1 aufzubauen hat nichts mit Musik zu tun, trägt aber in diesem Fall entscheidend zum Gelingen einer musikalischen Performance bei und kann im Zuge dessen bei den beteiligten Personen ein starkes Gefühl der Verbun- denheit mit der Sache hervorrufen. Und schaut man auf die kulturellen Zentren der Welt, so findet man dort immer ein eng verzahntes Zusammenspiel vieler Verrichtungen vor, sei es beim Betrieb einer Oper, oder bei der lebendigen Bewahrung der Herstellung und der Spielpraxis beim Alphorn (3). Und schließlich tragen sich soziale Netzwerke wie die Maker Fair, oder das Symposium für Ubiquitous Music auch gegenseitig, indem sie zur Verbreitung von Kenntnissen aus dem jeweils anderen Bereich beitragen.

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DIY Musical Instruments and Communities:

From Handmade Electronic Circuits to Microcontrollers and Digital Fabrication

Nicolo Merendino

Abstract *This article explores the use of bespoke digital fabrication for enhancing the making of Do-It-Yourself (DIY) electronic sound devices. With the tools and manufacturing costs now within reach of amateur makers, the production of laser cut, and 3D printed parts and custom PCBs for DIY projects can add stability and reproducibility to a growing number of ubiquitous music projects. This parallels with a shift from the use of non-programmable integrated circuits to programmable microprocessors. We discuss the impact of Maker culture on the custom development of handmade electronic musical instruments, and how incorporating digital fabrication can extend these developments. Two case studies from our own work are discussed and lessons are outlined.*

Resumo. Este artigo explora o uso da fabricação digital para sustentar a fabricação de dispositivos de som eletrônico do tipo Do-It-Yourself (DIY). Com as ferramentas e os custos de fabricação agora acessível por fabricantes amadores, a produção de corte a laser e peças impressas em 3D e PCBs personalizadas para projetos DIY podem adicionar estabilidade e reprodutibilidade a um número crescente de projetos de ubiquitous music. Isso é paralelo a uma mudança do uso de circuitos integrados não programáveis para microprocessadores programáveis. Discutimos o impacto da cultura Maker no desenvolvimento de instrumentos musicais eletrônicos DIY e como a incorporação da fabricação digital pode estender esses desenvolvimentos. Dois estudos de caso de nosso próprio trabalho são discutidos e as lições são delineadas.

Keywords digital manufacturing, DIY, musical instrument

1 Introduction

As pointed out in the anchor paper of this special issue, custom circuits and Do-It-Yourself technology has increasingly gained importance in the electronic music community. In this paper, we complement the anchor paper by providing a reflection on the ecology of making based on two case studies developed by the first author.

Before deepening our essay in the case study, we would like to commence with a short overview of the evolution of making in the musical discourse. Indeed, throughout the entire development of electronic music history, composers have developed some making and hacking practices. This tendency actually predates the electronic music era; examples like Russolo's Intonarumori (1913), or early examples of prepared piano like Saties's Le Piège de Méduse (1913) and Maurice Delage's Ragamalika (1914) already pointed out more than one century ago the interest that musician have in building their own instruments. With the technical advancement and the introduction of electronic technologies, this tendency greatly expanded. For instance in 1958, german composer Karlheinz Sockhausen built a rotating speaker to create a spinning sound effect (16). American composer Alvin Lucier, while discussing the piece Hornpipe (1967) by Gordon Mumma, wrote that "the scores were inherent to the circuits" (22).

With the development of computational technology and digital fabrication techniques this trend thrived reaching the point of being a worldwide spread practice with countells artists, makers and musi- cians collaborating to develop new musical interactive devices. Terms like Digital Musical Instruments (DMI) and New Interfaces for Musical Expression (NIME)[1] are now widely adopted in both artist and academic communities. Additionally the ideas of Digital Lutherie (17) or NIME crafting (1) have emerged, and were investigated as an important part of contemporary musicking activities.

Masu and Morreale (25) highlighted the entanglement between such practices and the hacking or DIY culture and argued in favor of embracing a Free Software/Open Culture approach in teaching electronic music. According to the authors the explicit use of free software in the classroom can promote "collaborative and sharing attitudes toward computer music practice" as well as "developing critical thinking concerning the complex relationship between technological and musical choices and developing the musically meaningful use of technology".

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In line with this perspective, in this paper we reflect upon strategies that can be pursued in order to fully embrace a comunital vision. With the skyrocketing spreading of DIY laboratories and FabLabs around the world, indeed, it is possible to conceive, design, and develop new musical interfaces and in such a way to contribute to a worldwide community, while also addressing individual needs of a specific case. We will highlight here how open culture can play a pivotal role in fully racing this potential. This perspective is in line with the analysis of the development of the community of musicians/makers that developed around the Bela Platform, which is also an open hardware project (28). This idea is aligned with the vision of DIY citizens:

> "*We suggest that these emergent communities of 'critical makers' and political protestors that organize on- and offline are aptly described as 'DIY citizens.'* " (31)

While music technologies and composers do not necessarily develop an explicit agenda, they can actively contribute to an approach to technology that supports commoning practices - on commoning practices see (8) - rather than a passive relation with technology which would facilitate exploitative dynamics (15). Such an approach is also in line with the Design Justice perspective, as it facilitates the development of specific projects tailored to the individual needs of specific persons or groups.

> "*In fact, design justice as a framework is meant to do the opposite: to act not as a funnel that we use to limit ourselves to a minimal set of supposedly design choices, but rather as a prism through which to generate a far wider rainbow of possible choices, each better tailored to reflect the needs of a specific group of people.*" (11)

At the same time, sharing the results of a project using open hardware and Free Software facilitates the possibility of sharing such results with a broader community of makers and musicians (30).

The Ubiquitous Music community has actively explored do-it-yourself (DIY) practices. In the paper titled 'Prototyping of Ubiquitous Music Ecosystems' (21), a range of studies are presented that utilize open-source systems to develop prototypes. These prototypes serve as experimental platforms for testing innovative ideas in the field of ubiquitous music. In a more recent development, the discourse within the community has expanded to include physical prototypes; Andrew R. Brown and John Ferguson have investigated the application of technologies like 3D printing and custom fabrication techniques in the anchor paper of this journal.

2 Case Studies

In this section, we will provide two examples based on the practice of the first author of this commentary in which we highlight specific design strategies meant to support a making practice that favors sharing.

The DCM (Dispositivo Cinetico MIDI - Italian for MIDI CInetic Device) is an experimental MIDI controller that was ideated with the aim of going beyond the 'classic' paradigm of a standard piano keyboard complemented with buttons and knobs. (26)

The DCM aims to incorporate the artist movement in the control paradigms, thus enhancing the connection between musicians movements and body and the sounds. By combining motion sensors with buttons for each note the system guarantees a wide and deep range of options in terms of stage mobility and performance expression. In this way the DCM provides artists with an interface that is both intuitive to operate and capable of creating complex interactions. There are two possible interactions with the controller that are facilitated by two different technologies: 12 buttons that can trigger MIDI notes, and a gyroscope that turns the position of the device into MIDI signals. By orienting the device, artists are granted the possibility to apply sound effects to the note played by pressing the buttons, creating a strong bond between the performer's gestures and the sounds produced, additionally 4 LEDs visual feedback about the device orientation. The DCM is equipped with a MIDI socket and of a mini USB port that can be used to upload custom code to remap the device (Figure 1).

[1] NIME is also an international conference that aims to "gather researchers and musicians from all over the world to share their knowledge and late-breaking work on new musical interface design." https://www.nime.org

2.1 DCM

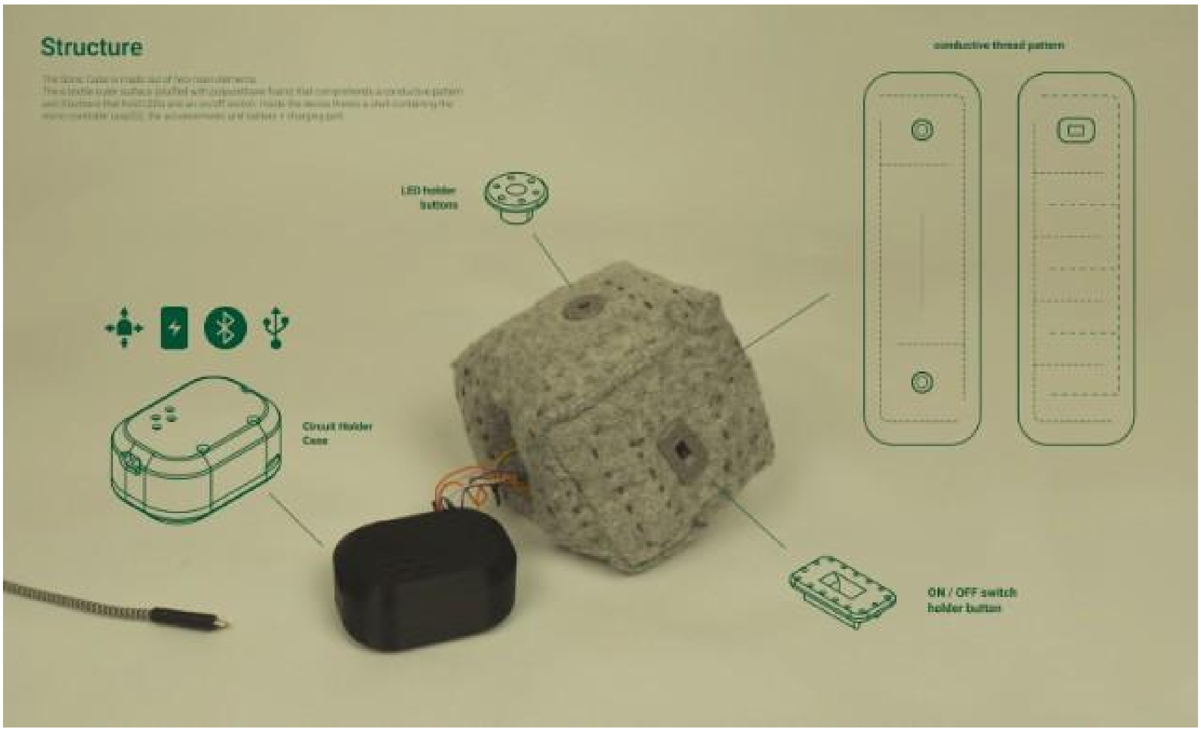
Fig. 1: Overview of the DCM

Being based on open hardware and open software, any artist can disassemble the instrument and re-code the program to customize sensor calibration and other specifics. In fact, in our website we encourage artists to personalize the DCM by shipping it with assembly instructions. The repository with the hardware and the source code can be found here. It is 100% developed with open source software. In this project we tested an open source CAD workflow for experimental music and media arts that combines and integrates KiCAD, FreeCAD, Inkscape. By developing this project we reached the conclusion that Open source CAD software has reached a state of maturity that enables makers, researchers and artists to 'embrace this long term sustainable and cost-effective option to produce hardware for their work'(27).

2.2 Sonic Cubes

The second case we analyze is the redesign of the Sonic Cubes, an IoT device developed which would allow a person to interact with sounds in a playful and engaging way. The device is a padded fabric cube that can send MIDI notes. The outer shell of the device is made out of felt, and it's embroidered with a pattern of conductive thread that works as a capacitive sensor that allows the device to sense when the user it's holding it. Inside the device there's an accelerometer that can detect the movements of the cube. Each cube is also equipped with a set of 2 LEDs that provide visual feedback. Finally, an esp32 micro controller that processes the provided by the sensors and sends it to a computer through a BLE connection sits at the core of each device (Figure 2).

Fig. 2:. Overview of the Sonic Cube



Particularly relevant for the reflection we are developing here is the focus on longevity of the instrument. Indeed, longevity of the device is pivotal to maximize its sustainability - on the matter see for instance Carlsson (9) and Chapman (10) - thus maximizing its shareability within communities. For this reason, we devised a number of strategies to facilitate active repair, and custom modifications. In particular we articulate our reflection by considering the designer as the user of the future. To this end we adopted open source software using the workflow consolidated with the design of the DCM and used open standard to facilitate interoperability of the device. In addition we produced extensive documentation and manuals, allowing a user to easily re-designing, change, and appropriate the instrument. We also carefully consider the process of producing or finding spare parts. And for this reason we designed all the physical components of the interface so that it can be remade using only a laser cut following the instruction on the repository (thus only one machinery is needed). Additionally we relied on well documented and used PCB components, such as ESP 32, as this device has an active community and the chance of discontinuity are very low at the moment. The possibility of repairing the instrument is also exposed aesthetically, as the material is felt and aesthetically it suggests that it can be easily fixed or repaired - the idea of embedding instances that suggests reparability was also previously discussed in relation to circuit bending (12).

3 Rejecting the User-Designer Dichotomy

In both projects, the instrument is both easy to repair, open, and complemented with documentation. This focus on repairing, reusing, misusing, and hacking implies circular relationship between user and developer, which aim to create a mutually beneficial engagement, and blur the clear cut distinction between the user and developer - a vision that is well known in FLOSS communities (30), and scholars have debated how open source software facilitate to adapt a project to future needs (4). In a commentary on that project on DMI design (26) we labeled this approach as ’Designer as User’ of the future, and suggested that when designing an interface, the designer should empathize with its user and provide all the means to hack and/or redesign a certain design product. This vision is also aligned with an overall critique on the term ’user’ in HCI (3) and NIME (33). Indeed the term has been criticized to present an oversimplified vision of a person. This approach is in line with recent European actions such as the Indice de réparabilité (french for reparation index) - introduced in France in 2021.[2] Additionally it can promote the development of stronger communities bound by sharing attitudes and commoning practices.

4 An Ecology of Hardware and Software for DIY Musical Instruments

In this short commentary we advocate for the use of several strategies mutated from Open Hardware and Free Software culture in order to fulfill the great potential that the DIY movement has to promote a sustainable and just development of musical tools that can contribute to the broad community of makers, musicians, and researchers. In this final section we articulate how an ecological vision on digital instrument design is crucial to effectively implement it, considering the DIY Musical Instruments, the software and the machines used to design and build them as an ecology of artifact.

The term ecology is not novel in the music technology debate. For instance, Gurevich and Treviño (13) proposed the idea of an ecology of musical creation (14) proposed the term performance ecosystem to look at the interactions among performers, instruments, and environment. In relation to ubiquitous music the ideal of ecology is used to look at properties of musical activities and the design strategies related to distributed decision making (19). In their reflection the authors claim that human agents and material resources are connected through relational properties. Such a conception, in the view of the authors, has the potential to support exploring the creative potential of the Internet of Musical Things (IoMusT). The IoMusT itself encompasses manifold ecosystems (35). The idea of ecology has been recently widely explored in relation to ubiquitous music including multimedia design, education, and everyday objects (20).

In proposing our reflection we rely on the idea of artifact ecology, a concept that was introduced in the Human Computer Interaction (HCI) debate by Jung et al, who proposed as a theoretical lens to look at the 'set of all physical artifacts with some level of interactivity enabled by digital technology that a person owns, has access to, and Uses' (18). This concept has been steadily used in HCI, and Bødker argued that artifact ecologies is a concept that can 'help us focus on multitudes of artifacts that users bring together when carrying out particular activities.' (6). In the initial proposal by Jung, Artifact Ecologies accounted for only digital artifacts, however, this vision has been subsequently extended, and artifact ecologies have been used to study digital and non digital artifact in combinations (e.g. (32)), and tu investigate both individual usage of compounds of artifacts (e.g., (7)), or social interaction in groups using sets of artifacts (e.g., (5). In music performance the idea of artifact ecology has been used to study the multitude of objects and persons that collaborate toward the creation of a specific music (e.g., (24)) or dance performances (e.g., (23)), or everyday practices of guitarists (e.g., (2)). In our reflection we will consider the artificial ecology of a Digital Fabrication process, scoping from the designed system, to the community and to the societal context in which the community operates.

4.1 Open Source: Design for a Community

The software used to design systems are an important part of the artifact ecologies. In the first case (the DCM), we explored a workflow combining three Free Software for 3D modeling and digital fabrication (KiCAD, FreeCAD, Inkscape). The main advantage of the adoption of these software emerges if we consider the long term usage of the designed musical systems. If the systems are complemented with proper documentation, fixing, repairing would be relatively easy. However, in a community of musicians who are also makers, simply fixing might not be enough to maximize the usefulness of a specific DMI nor to promote its longevity. Indeed, musicians might want to change it, customizing it to their specific needs. In this case, if the project is realized using Free Software anyone will be able to open them using any OS, without the need to pay any license for it. Thus customizing, hacking or redesigning the system would be easier for the entire community of musical instrument makers and not only for the original designer/maker.

4.2 Open Hardware: Community of Communities

The hardware of the system (DMI, NIME, ect.), is probably the central part of our artifact ecology. To maximize the longevity and the repeatability of the systems is important to use open standards and documentation, this point is deeply connected with the choice of using Free Software tools for designing them and documenting them, and we already discussed it above. In addition, we want to highlight the importance of using Open Standard and well supported hardware. Using USB, Jack, as connectors facilitates interoperability, most likely does not require additional cables, or connectors. Additionally, using hardware widely adopted by communities of makers outside the music community of makers (i.e., ESP 32) makes it easier to find spare parts in the future, and creates strangers' bonds between the instruments, the music maker community and other makers communities. This aspect of the research presented complement and intersects with the work presented in the Ubimus Ecologies book, we can mention in particular chapters of the book entitled "DIY

[2] https://www.ecologie.gouv.fr/indice-reparabilite

electronics for ubiquitous music ecosystems" and "A brief report from the land of DIY", where the authors examinate respectively the relationship between the history of electronic musical instruments and DIY hardware (34) and the experience of the Bitraf community, where do-it-yourself practices are central at different level of the community's life. (29)

4.3 The Maker Machineries: Communities in their Social Contexts

We argue that it is important to consider also the machinery used to make a certain DMI as belonging to its artifact ecology. To maximize its reparability, indeed, it is important that the tools needed to fix it are easily available. For instance in the case of Sonic Cubes, we opted for using only laser cut felt, avoiding 3D print. Considering the evolution of Makerspaces and FabLab is crucial for ensuring that a certain project can really contribute to a broader community, which does not exist in isolation, but is always determined by social context and physical limitations.

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