4.5. Digital, electronic, visual and audio: Digital fabrication and experimentation with musical instruments from do-it-yourself to new business models

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Abstract

Digital fabricators print musical instruments, they explore the ways of creating music in the intersection and beyond of digital and electronic. They also explore how visual and audio meet, either by visualizing music or developing solutions connecting visual expression to music perception and production. Anybody can transgress the blurred borders of creators and consumers of content in the digital arena. I invite taking a glance at the world of digital fabrication to understand the relationship of experimentation from the angle of rapid digital development affecting the music scene and what we perceive as relationship of audio-visual-digital. This paper takes stock of the strands in experimentation with musical instruments and sounds by maker communities and entrepreneurs.

Keywords: digital fabrication, makers, musical instruments, DIY, experimentation.

1. Introduction

Industrial societies in times of scarcity, austerity and even during vast mass production were fabricating things, and finding solutions domestically, manually and in community. This search for accessible ways to solve problems may shift swiftly toward entrepreneurship creating new business models, and survival paths within the local economy. Design in times of scarcity and austerity turns toward self-reliant and self-sufficient forms of production, thus from *industrial* toward *industrious* as put by Bianchini and Maffei (2013), and Maffei, (2014).

Maker communities create scenes of experimentation nested locally in (post)industrial cities, and bring physically together enthusiasts with interdisciplinary background. The pool of knowledge, ideas, and solutions, then is shared globally connecting makers that reveal codes, projects and experience open access. Urban scenes, like fablabs and community spaces for makers host experimentation that raises variety in the landscape of design, food (Faludi, 2016), natural sciences and so forth. If we claim that the underground is the space for experimentation with meanings, forms of expression, and tools of production in relation to the mainstream, thus for finding a counter-definition to one's identity and sharing it with a community, then we might look at the world of fablabs and makers as the underground of design. Design-driven companies prefer in-house closed systems of innovation, or open forms in the permeability-sense of openness (Chesbrough 2003). In case of lack of capacities, companies acquire innovation and design from a well-defined third party: A Knowledge-Intensive Service-Provider in the area of innovation and design, or a partner, e.g. supplier executing the assigned projects based on the core design concepts defined by the company (Faludi, 2015) for well-defined projects and solutions. Meanwhile, designers produced by higher education institutions might find themselves as *frustrated would-be car designers* that design toothpaste tubes instead of cars (Anderson, 2012). Moreover, design-driven industries create meanings for a global language read by the masses, and the high-end consumer. They target emergent and to-be-created markets on a wide geographical scope, thus they prefer a global portfolio of designers (Dell'Era & Verganti, 2010). Desktop

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technologies, however, democratize design rendering it ever more accessible. Given that the channels of distribution, production and design are already gone on-line, and there are viable and emerging business models connected to desktop technologies to serve markets arranged on the internet, the quest of the new industrial revolution is being argued in the overseas context of North-America (Anderson, 2012; Greshenfeld, 2012). Industrial revolutions are induced by and foster at the same time new channels of distribution, market, agents, technology of production, business models; rejuvenate old ones and give birth to new industries. It would stretch the limits of this paper to seek for an answer in broader terms, instead I give an overview of how desktop technologies made us to rethink the design and manufacturing musical instruments. Nonetheless, the main line of argumentation is structured around the connection of the DIY and maker culture, I intentionally grab examples from a wider scope to nest them into the larger discourse of industry dynamics and innovation. Thus, creation of sounds, music and the tools for that are as much of interest, as the new perception of the interplay of audio, visual and digital.

In sum, this paper focuses on instruments constructed in the intersection of digital, audio and visual design, creating new experience of perception of music creation. Specifically, I take examples to give an overview of experimentation with 1) hacking to create sounds, music and interaction, 2) connecting audio, visual and digital experience created with Arduino for educational purposes, 3) additive technologies, thus 3D-printed instruments grabbing cases from makers, makers turning into entrepreneurs, and a high-end architecture company.

2. From DIY to entrepreneurs

The do-it-yourself (DIY) ethic was prevalent for punk's making music, instruments, and so forth, creating the music scene beyond the industry. Dick Hebdige (1979) illustrates the DIY ethic it when talking about the funzine, *Sniffing* Glue the following way (Hebdige, 1979, p.112) "the definitive statement of punk's do-it-yourself philosophy — a diagram showing three finger positions on the neck of a guitar over the caption: 'Here's one chord, here's two more, now form your own band'".

Punks built, and hacked instruments for expressing individuality, and freedom, assembling things roughly, and casually. In times of austerity solutions to everyday needs are more prone to be developed from accessible materials and tools made by the users. The possibility of building instruments stresses accessibility to music, to membership in a collective action for those with poor capabilities. The rough and casual solutions also emphasized the meanings behind the DIY ethic, like working-classness that was shared among punk subcultures (Hebdige, 1979).

Meanwhile, makers experiment for the sake of experimentation of accessible design favoring functionality, simplicity, valuing ergonomics, sustainability or easy-to-assemble over exploring the l'art pour l'art of forms and shapes and technology. This later is more in the realm of the discourse of art and design, or art and technology induced by companies creating the spectacle for boosting consumption of (new) technologies and *innovative* products.

Getting back to the DIY objects signaling the value of working-classness (Hebdige 1979), makers can be said to share the image of *techiness*, and values of *being creative*, *entrepreneurial, curious* and *experimental*. I do not argue however, that there is classness being communicated here, as makers come from a global pool of professionals, designers, or creators from any background (or job). Digital fabricators seem to fill in a void of technology and everyday needs not met by mass production, and to explore fields not explored by the industries creating a global playground. However, they do not seem to share a class-consciousness to be expressed by radical means of communication or collective action.

I argue that makers shall not be considered as subculture, in the sense of being attributed as deviant from a shared culture (Hebdige, 1979). Using the notion of scene for explaining the configuration of an identity that can be taken off and put on by entering a music scene as suggested by Bennett and Peterson (2004, p. 3) seems to be more applicable. Digital fabricators often hold nine-to-five jobs or can be home-wives, home-husbands, or freelancers in domains not directly related to their activity as makers. Moreover, they share very different identities. Everyday users enter the scene of makers to live out their creativity or simply to find solutions to emerging needs within a community.

The DIY ethic is often referenced as something more than just being merely soaked into the low-income and no-money reflection of production. It is rather about overcoming the boundaries and limitations of the big labels. DIY serves for the bottom-up arrangement of institutions needed for creating the music scene by producing own T-shirts, (fan)zines, records, tours, etc. Music scenes, thus fed by fans turning into entrepreneurs, or sustained by collectives, etc. are an emerging DIY industry. This active role in scene creation is participatory, inviting members into creation. Self-reliance of the DIY ethic also gave a voice for proclaiming of anti-establishment political statements and of social movement (like the Riot Grrrl movement: Schilt, 2004; Moore & Roberts, 2009).

2.1. Hacking and making

Digital fabricators share the DIY ethic in the technological realm, being connected to hacking: thus creating from something that already exists by turning it into something new. The basis for hacking can be an object, a product of mass-production that might be simply worn-out or something that has lost its meaning in the ever-changing context of fast consumption induced by swift technological change and fetishism (see later). The object goes through the process of "purification" and renewal, as hacking opens for new meanings and functions to be attached. The hacker freed from the encapsulation of function and aesthetics of the mass-produced experiences embrace the empowering and liberating DIY ethic. These objects (old phones, typewriters, or industrial machines) serve as mementos of the speeding circuit of production in the fetishism of technology.

Meanwhile, digital objects (phones, tablets, computers, etc.) have become a prolongation of ourselves, our embodied perception of the world, a body part that is physically not incorporated (yet). Electronic circuits are the mediators between connecting the environment and our digital selves, where Arduino (Genuino from 2016 in Europe) providing the electronic hardware serves as a platform for all experimentation (and numerous examples of entrepreneurships raising).

Audio HackLab is a makers' lab (as cited in FabLab of Turin, Italy) exploring sounds, noises, and sonoric interaction of objects and people, transforming the sounds of our environment into sounds that can be perceived by humans with the help of electronic circuits. Hacking for connecting older machines with the digital, gives these objects rebirth in the world of connectedness. In this domain, Audio HackLab has chosen the *Harsh Noise Generator* once produced (from 2012 to 2014) by HNG Kinetic Laboratories for innovating on, and giving it multiple functions connected to an Arduino circuit. Once the HNG served for literally generating analog noise for constructing sounds and music, with the frequency and density of the noise varied by one button or the other. These were handmade instruments as Kinetic Laboratories, emergent from making things, manufactures hand-made devices for mixing and generating sounds. The description on how to construct a HNG by ourselves is fully published open access on the website of the Kinetic Laboratories, and is not licensed, for anybody can contribute, innovate or even commercialize on it. The choice for hacking the HNG is not arbitrary, as the Harsh Noise Generator as simple as it opens the path for wild experimentation, for e.g. with software producing rhythm and noise, out of which something of a new genre emerged (the Bytebeat software played with Arduino giving birth to *Crowd,* a piece of music):

> the interesting thing is that Crowd, like bytebeat music in general, is a piece of rhythmic and somewhat melodic music with no score, no instruments, and no real oscillators. It's simply a formula that defines a waveform as a function of time, measured here in 1/8000 of a second

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((t<<1)^((t<<1)+(t>>7)&t>>12))|t>>(4-(1^7&(t>>19)))|t>>7
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> (Retrieved from http://canonical.org/~kragen/bytebeat/).

Bytebeat due to its simplicity allows for many contributions and variations in constructing *bytebeat music* (follow the above source for more information) with formulas.

Figure 1: Harsh Noise Generator.
Source: Retrieved from http://kinetiklaboratories.blogspot.hu/p/harsh-noise-generator.html

The DIY of hacking, and constructing is well supported by simple elements like electronic circuits, printed elements, downloadable files and software. Emerging products of experimentation turn their creators into entrepreneurs, and those providing the elements and circuits for these products, easily turn into platforms. Forerunners like Google, Etsy, or Youtube successfully created platforms inviting communities to innovate and build their businesses on. In the long run platform-leaders are capable of controlling the industry by opening up entry points for innovation and for other businesses through standards defined by the platform leader (Gawer & Cusumano 2008; Baldwin & Woodard, 2009). In the world of internet of things and robotics, spare parts, circuits and other elements serve for constructing solutions, where Arduino is a platform for makers and entrepreneurs providing floor both for experimentation, play, and emerging business. The case of Music Ink illustrates how a project that redefines the concept of music making based on an Arduino electronic circuit, is on the way on turning into an exciting product.

2.2. Connecting sound, touch and visual experience

Music Ink reconceptualizes in a tender way how sound production, or an orchestra can be experienced and taught to children. Music Ink[2] is one of the most exciting projects on the basis of an Arduino board, by Riccardo Vendramin and Gilda Negrini. It connects audio and visual and digital experience tapping into the heart of how we understand interaction with a musical instrument. Kids paint the instruments with electronically conductive ink the way they imagine them, then the drawings are connected to the electronic circuit for producing sound: and converted into melodies played. This digital and painted orchestra does more than just visualizing music: by drawing in any desired shape, sounds are disconnected from the traditional perception of an instrument (here is a video on how it can be used in class: https://vimeo.com/59478964).

Music Ink is to be available soon as a product, it has an app for converting the sounds made into music, moreover, it also invites for further exploration on its functions.

Makers turn into small entrepreneurs at a glance, selling their products on choice: thus products can be 1) purchased the way they are, 2) given the option to be constructed DIY with open access files with all the possibility to play with the design, 3) be purchased on e-markets with the option to be personalized.

[2] http://musicink.co/

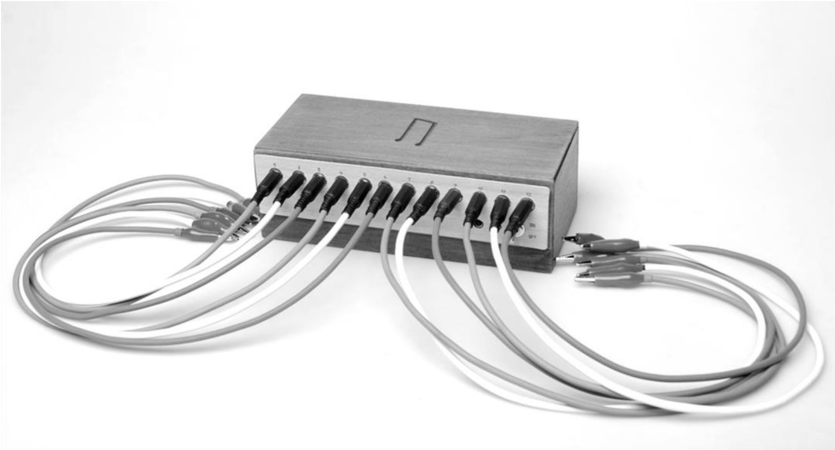

Figure 2: Music Ink.
Source: Retrieved from musicink.co.

I find it important to distinguish *customization* from *personalization* in the context of brands wildly providing (now even turning annoying) option of *customization* to widen the market, where modularized products are fine-tuned by mix and match of the elements by the consumers. Thus, the very stage of making the product more appealing is given in the hands of the consumer, while the elements are mass-designed and mass-produced. Customized products are often launched and communicated as products of co-creation (Chesbrough, 2011), however there is no element of "togetherness" or creation in the process of assembling from pre-designed elements of a well-defined architecture of a mass product. *Personalization* on the other hand adds the note of creation or giving that personal final touch to the design, which is then produced (printed) individually coming down right from the desktop. Personalization is also said to create a "market for one" (Anderson, 2012), while the tools allowing for personalized design and production are available on a wider market. The DIY-ethic of the downloadable solutions, and simple, modular and adjustable design of open access empowers the users to personalize their creations. Desktop technologies create a scene for playing with shapes and prints converted into files and then printed objects, as musical instruments for example.

3. Modularity, musical instruments and printing

Creating instruments merges traditional design and new technology. On the one hand, they are created to match long-lived standards to meet requirements of sound, tones, touch, and spare parts, as strings of guitars. On the other, it involves both the acoustics and aesthetics of design, where the interaction of computers and instruments give its own specific configuration of the outcome. New instruments enter the scope of music adapted to various genres that come to forth in specific time periods. Plastic has revolutionized industries in many ways, from cutting-edge technology of the 1960s toward the cheap production for the mass markets from the 1980s to today. Plastics and electronics brought about a range of novelties in instruments and genres, if one thinks of only a guitar: from acoustic toward an electronic bass guitar. The interplay of traditional forms and concepts with new shapes and combinations is present in all the examples illustrating experimentation with printing musical instruments. Amit Zoran (2011) describes how standardization during the years on one hand had optimized the qualities of the instrument for the trained player, and simplified the production, on the other he warns of the risk of getting closed into a specific evolutionary path not allowing for adopting new designs.

Musical instruments are complex systems, thus they constitute subsystems, and elements that are combined in a given hierarchy (Simon, 1962). Elements rely on each other and are bound together: the more integral the system is, the more difficult it is to break it into separate elements and subsystems. The more modularized a system is, the more clearly it can be broken into parts that can be substituted. We know from scholarship that modularization is at hand for solving complex problems (Baldwin & Clark, 1997; Langlois & Robertson, 1992). Printed artifacts can be integral ones, but many times these are elements that need to be combined, so as constructed at the end to get the artifact. For printed spare parts, they need to be assembled, and very often fine-worked upon to finalize them. As mentioned above, a combination of simple elements with clear architecture (so as, the rules of design of the elements following Henderson & Clark, 1990, Baldwin & Clark, 2000) allows for room to experiment on, give away some parts to the users for DIY and to personalize.

Business models emerging from digital fabrication sell both integral artifacts, but large interest is around selling spare parts, and selling the tool (printer) for creating spare parts that are needed randomly (a broken lamp in a home environment, or a mold for spare parts in an industrial environment), as well as modular products. Musical instruments are made of elements that are later fused together. In this case, modular design is at play when parts can be printed individually, and simple CAD-files are shared. In sum, modular design of an artifact thus creates possibilities to adjust the printed parts, to create mix and match of fixed elements and customized/ personalized ones. Also, 3D-printing is important in the production of rather complex parts, that cannot be reached with subtractive technologies:

> For prototyping 3D printing can be used for almost anything, be it simple or complex, just because it allows you to test your ideas quickly (but, if you are 3D printing a square, or some other very simple 2D shape, you may seriously want to consider some other way of making it (like laser cutting it instead, or even cutting it by hand, for example). But, for real manufacturing of sell-able products, it's important to use 3D printing only in those areas where it really adds value, like incredibly complex parts, parts that need to be customized for every user, light-weighting of parts, part consolidation, etc. (Olaf Diegel[3]).

Additive technologies above the accessibility of design and exploration of new shapes for prototyping, also feature the process of iteration, thus a constant trial-and-error of the prototype adjusted to the desired function, standard or adaptation to a specific style. By opening up the design (backed by modularization) a community can enter the iteration: improve the prototype, then share the recipe: the CAD-file, the tutorial, etc. This brings about the legacies of the DIY ethic being participatory in its ultimate self-reliance and democratic nature of creating a collage of contributions of anybody willing to enter. In contrast, industries having their interest in communicating their innovativeness and cutting-edge technology rather rely on in-house development of the desired product and shape (closed innovation). The forthcoming examples illustrate that simple and modular design of printed musical instruments favors sharing and, while a more integral design or complexity of shape can be reached with a larger investment (e.g. in machines) and closed innovation. Instruments of the Monad Studio[4] (forthcoming) based on additive technology, thus adding material and not subtracting for achieving the desired shape makes possible for forms as with no other technique. They play with the "complexity of the forms (…) the violin or any of these instruments, is closer to the complexity that you find in nature in structures like roots of trees" (Eric Goldemberg[5] founder) of organically integral artifacts. Radical innovation requires integral systems to be developed or innovated on (Henderson & Clark, 1990), where a company interested in radical solutions might want to invest in radical solutions developed in-house with a closed team of experts invited.

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[3] Retrieved from http://www.odd.org.nz/sax.html.
[4] Retrieved from www.monadstudio.com.
[5] Retrieved from https://www.entrepreneur.com/video/245600.

And this is the domain where the fetish of technology can flourish. By demonstrating the lyrics of the forms stretching the limits of available technology while pushing the industry toward newer fields to explore is inducing the discourse on the boundaries of art and design, artisanery and technology that can be read as the ritual path from nature to culture of Levi-Strauss (1978). It seems that technological fetishism, induced by companies having their interest in producing and selling machines is putting its way through in the design created by enterprises communicating their values of high-end technology, quality, innovativeness. If looking at the broader field, there is a paradox between the accessibility of design and the fetish of technology represented by the 3D-printed artifacts. My examples here stress this tension of discourse.

Technological fetishism however, in these cases has nothing to do with the fantasies about control over nature (Harvey, 2003), rather it is brought about from the perspective of forms: where an organic shape can be reached, the parallel with nature is expressed here. As such, it moves toward the concept of technology as spectacle for consumption, where the consumer is a "passive spectator of the spectacle" (Harvey, 2003, p.17) in the fantasy production of the companies enhancing the "the lust for the new, the fashionable, the sophisticated" (Harvey, 2003):

> In this, the fetish of technology, the lust for the new, the fashionable, the sophisticated, has its own role to play within populations at large. The production of this fetish is promoted directly through fantasy production, using advertising and other technologies of persuasion, in particular that aspect that reduces the consumer to a passive spectator of spectacle.

4. Printed instruments

4.1. F-F-Fiddle

F-F-Fiddle [6]is an electric violin, created with a desktop printer by David Perry, mechanical engineer and designer, who claims that within his OpenFabPDX: *"I help people make things real, manage open source projects, and enjoy using 3D printers to make functional, beautiful objects".*

The violin is available for download open access and is easily printed with a FFF-type 3D-printer. How to manufacture, assemble and design it, is also shared, as well as the estimated price of individual manufacturing (250 USD). This violin is an ongoing project, while the shared version is the result of the 8th iteration round, where improvements overwhelmingly focus on playability. The license under the Creative Commons Attribution Non-commercial Share Alike allows for non-commercial use, where anyone can innovate on the design given it is open: shared with all, and paternity is indicated.

The aesthetics of design of the violin is functional and playful questioning the traditional assumptions of a violin's shape. However, classical violin was the starting point for feeding the CAD-file with dimensions and shapes. What 3D-printing adds is the possibility to customize the chin and shoulder rest positions, and an internal wire-routing. The violin is printed in 3 parts, and spare parts (like strings, truss rod, tuners, pick-up, plug) are added. The ideation phase[7] of the violin was done in cooperation with an industrial designer, Dan Nicholson. The whole design process, research, ideation, design, prototyping is shared on the blog[8]. On how he got to printing a violin David claims[9]:

> (…) I've always wanted to make a violin, but I thought I'd wait until retirement — the barriers to entry for that kind of craftsmanship are so high. Then, in early 2013, I bought a 3D printer. Suddenly I had this robot that could make complex, accurate parts that I modeled on the

[6] Retrieved from http://openfabpdx.com/fffiddle/.
[7] Retrieved from http://openfabpdx.com/2014/10/22/you-can-make-anything/
[8] Retrieved from http://openfabpdx.com/blog/
[9] http://openfabpdx.com/2014/10/22/you-can-make-anything/

computer. All I needed to do, then, to make a violin, was to design and model it on the computer and print it out (22/Oct/2014).

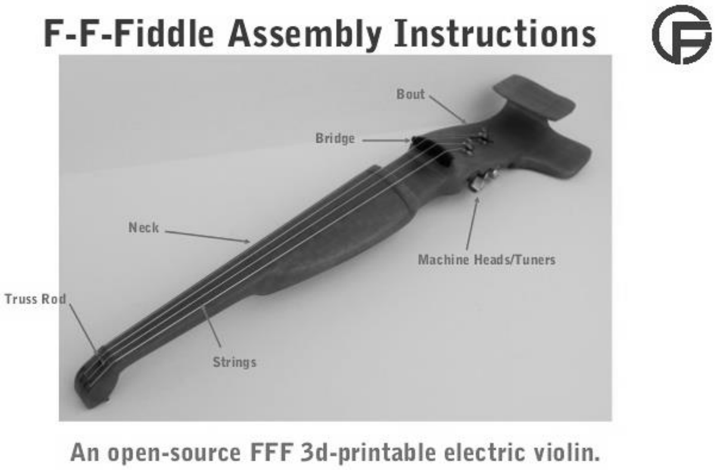

Figure 3: OpenFabPDX: F-F-Fiddle.
Source: Retrieved from http://openfabpdx.com/fffiddle/

The the OpenFab PDX, LLC behind the F-F-Fiddle project, is a digital design manufacturing and consulting firm focusing on low-cost digital solutions, the services of which range from developing new products and projects to raise productivity in existing businesses. Being open source (it was launched on thingiverse 24/March/2014), F-F-Fiddle has inspired further prototypes (there are 28 made and published since). The Electric violin[10] designed by Firecardinal (Rafael) is based on six printed parts, and can be found on thingiverse[11] (this violin has been made and published by seven makers). He claims to be inspired by the Elviolin[12] of Stepan83, whom later owns his inspiration to "(…) the project F-F-Fiddle for idea of the violin printing" (Stepan83).

4.2. 3D guitars

Downloadable design of various 3D-printed guitars is available for example on thingiverse, where one of the most important concerns is the playability of these instruments. The most liked guitar is maker Sergei225[13]'s instrument. Sergei225 himself has launched seven guitars: acoustic and electric, where his most recent one is a travel guitar (printed with MakerBot Replicator) along with the amplifier: made of a long list of spare parts to be printed and then assembled, licensed under CC non-commercial.

Other companies have also entered the scene, as the long-known Fender that uses 3D-printing for creating guitar bodies, and custom guitar parts[14].

4.2.1. ODD Guitars designed by Olaf Diegel

In the entrepreneurial domain Olaf Diegel, design engineer, and professor at the Lund University (Sweden), has created a series of spectacular guitars, where the printed bodies take on shapes that

10 http://www.thingiverse.com/thing:767536
11 www.thingiverse.com
12 http://www.thingiverse.com/thing:745940
13 Retrieved from http://www.thingiverse.com/thing:1708396/
14 Retrieved from https://www.youtube.com/watch?v=plAjJKJTlxA

could never be achieved with a traditional mold. ODD guitars can be purchased easily, and they illustrate a wide range of designs to be accustomed, or personalized upon request. The guitar itself is made up of traditional components, and fabricated ones (CNC, and laser-cut), other add-ons that shall be purchased and used for assembling with the printed body that is made with the Selective Laser Sintering technique (where thin layers of nylon powder are fused in the correct locations of a particular slice of the component. Further layers are spread on top until the process is completed). The color is reached with a special dying technique that allows for no two shades to be the same. The sound is defined by the material of the body, and can be checked here by Nadav Tabak playing the guitar[15].

Figure 4: Olaf Diegel: the Hive-B model.
Source: Retrieved from http://www.odd.org.nz/hivecolour1.jpg

The Hive-B model above (in Figure 4) has insects within the body of the instrument. About the traditional shape of the classical instrument and the future of 3D-printing:

> (…) what's important to me, is not to see it as replacing conventional manufacturing, but to be a complementary technology to traditional ones, and to use it only when it truly gives us an advantage. My guitars are a good example of this: the bodies are 3D printed, which allows me to do incredibly complex shapes that could not be otherwise manufactured, but the necks and wooden cores are CNC machined, the bridge is cast, the plastic bits are injection molded, the inlay work is done with laser cutting and engraving, etc.

Olaf also prints many other spectacular instruments: like *Atom,* the 3D-printed drum kit. The Saxophone[16] Olaf created on the invitation of the 3D systems, one of the largest companies. Introducing the first iteration in a short video, he claims[17]:

[15] Retrieved from https://www.youtube.com/watch?time_continue=3&v=MWa8sEgpOrM
[16] Retrieved from http://www.odd.org.nz/sax.html
[17] Retrieved from http://www.odd.org.nz/sax.html

> I am not a sax player, so be amazed by what 3D printing is capable, rather than by how my awful sax playing might be. And, yes, a couple of the notes are slightly out of tune because of air leakages. The next iterations will be perfect, I promise! (…)
>
> One of the reasons I was keen to undertake the project was to show that 3D printing can be used for applications beyond trinkets, phone cases, and jewelry. Note that there is nothing wrong at all with those, but I want to explore real-world applications for more complex products that go beyond single component/ single material/ single manufacturing method.

Figure 5: Olaf Diegel: Saxophone.
Source: Retrieved from http://www.odd.org.nz/saxassemblysmall.jpg.

4.3. Monad Studio

Eric Goldemberg and Veronica Zalcberg, architectural designers, run a multifaceted architectural studio with various projects from landscape to urban plans, from buildings to art installations. In collaboration with Scott F. Hall, musician, the studio has launched a series of unique musical instruments exploring how violins and guitars can be perceived and reformulated in shape, sound and conception. These instruments are radical not just in their aesthetics, but also in their approach to sounds, and components used: one-string travel guitar, two-string piezoelectric violin, 1-string piezoelectric monovioloncielo, small and large didgeridoo (these are part of the 'MULTI' sonic installation), suggesting the: "new conception for violin core functionality" (BBC[18]), as the functionality of these instruments do not defer from the original. The strings are reduced strings into one and two, while the instruments are meaningfully nested into the system attached to a sonic wall (see below) that also creates a sonic environment: an experiment questioning the visual and sonic experience (3D show NY concert here[19]) with a traditional approach to performance. The concerts serve events presenting advances of 3D-printing technology around the world, promoting the aesthetics of design and sound, inviting the audience into the fantasy of cutting-edge technology. Behind developing the instruments was:

[18] Retrieved from http://www.bbc.com/culture/story/20150330-the-weirdest-musical-instruments
[19] Retrieved from http://www.monadstudio.com/MULTI-Sonic-Installation-3D-Printed-Instruments

> Our desire to create unusual instruments emerged when we realised the aesthetic and technical issues we were facing as architects did not differ much from those of musicians and composers" (Eric Goldemberg[20]).

The instruments follow the rhythm of aesthetics of the buildings and art installations of the studio's creations: layers, very detailed, diagonal connections within the system of aggregated modules, aggressive penetration into the space and questioning the given structures and interactions of human and object. In an interview Eric Goldemberg and Veronica Zalcberg claim that the forms were inspired by nature: "strange roots grow over other trees and become one with the host" (the Guardian[21]). Instruments thus communicate the aesthetics and values of the Monad Studio in an organic manner, widening the scope of the audience reached, and also enhancing its communication to those that are familiar with the studio's work.

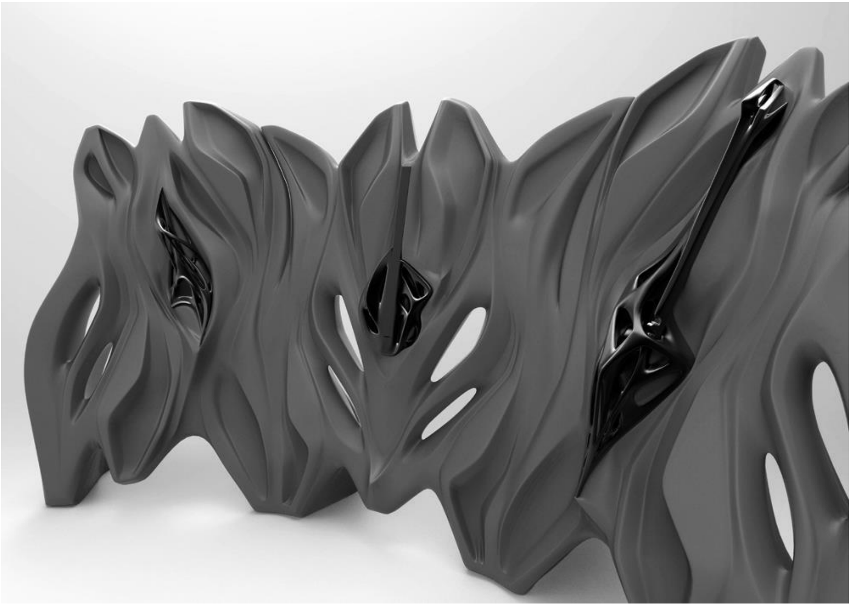

Figure 6: Monad Studio: MULTI Sonic Installation.
Source: Retrieved from http://www.monadstudio.com/MULTI-Sonic-Installation-3D-Printed-Instruments.

5. Conclusions

Experimentation with shapes and sounds of 3D-printed musical instruments by makers and emergent entrepreneurs can be interpreted by the ethics of do-it-yourself for its casualty of design, and strive for stretching the limits of own-produced objects and solutions with desktop technologies. Moreover manufacturing-by-yourself is an option created by open software and hardware accessible to all. However, the limits of the potential of 3D-printing are constantly being explored as for manufacturing only parts that show considerable complexity can be reached by additive technology. This need to be spectacular enough to invest in and be worth of manufacturing. It is worth to note that printed instruments in fact are not fully printed yet, as they need to be assembled using spare parts. Shapes of these musical instruments usually derive from the classical and traditional dimensions and concept of the instrument but through the process of iteration and the possibility of adding unseen complex shapes gives floor to wild experimentation for high-end companies in the realm of technological fetishism. Furthermore, electronics and

[20] Retrieved from http://www.bbc.com/culture/story/20150330-the-weirdest-musical-instruments
[21] Retrieved from https://www.theguardian.com/technology/2015/apr/30/revamping-violin-3d-printer

interaction design give further possibilities for hacking, and redefining the concepts of making and designing sound, the perception of the relationship of sound and instrument. Hence experimentation also shifts toward creating new goods, markets and scenes.

References

Anderson, Ch. (2012). Makers. The New Industrial Revolution. New York: Crown Business

Baldwin, C. Y., and Clark, K. B. (1997). Managing in the Age of Modularity. *Harvard Business Review*.

Baldwin, C. Y., and Clark, K. B. (2000). *The Power of Modularity. Design Rules, Part I.* Cambridge, Massachusetts: MIT Press

Baldwin, C. Y., von Hippel, E. (2011). Modeling a Paradigm Shift. From Producer Innovation to User and Open Collaborative Innovation. *Organization Science, 22*(6), 1399-1417. DOI: 10.1287/orsc.1100.0618.

Baldwin, C. Y., Woodard, J. C. (2009). The Architecture of Platforms. A Unified View. In A., Gawer (Ed.), *Platforms, Markets and Innovation* (pp. 19-44). Cheltenham: Edward Elgar Publishing Ltd.

Bennet, A. and Petersen, R. A. (2004). Introducing Music Scenes. In A., Bennet, R. A., Peterson (Eds.), *Music Scenes: Local, Translocal and Virtual*. Nashville, Tennessee: Vanderbilt University Press.

Bianchini, M., and Maffei, S. (2013). Self-Made Design From Industrial Toward Industrious Design. *Ottagono,* 257, 2-10. Retrieved from https://www.academia.edu/3793255/AUTOPRODUZIONE_DALL_INDUSTRIAL_DESIGN_ALL_INDUSTRIOUS_DESIGN

Chandler, A. D. Jr. (1977). *The Visible Hand. Managerial Revolution in American Business*. Harvard: Harvard University Press.

Chesbrough, H. W. (2003). *Open Innovation. The New Imperative For Creating and Profiting from Technology*. Harvard: Harvard Business School, Massachusetts

Chesbrough, H. W. (2011). *Open Services Innovation. Rethinking Your Business to Grow and Compete In a New Era*, Jossey-Bass: San Francisco

Dell'Era, C., Verganti, R. (2010). Collaborative Strategies in Design-Intensive Industries. Knowledge Diversity and Innovation. *Long Range Planning*, *43*, 123-141. DOI: 10.1016/j.lrp.2009.10.006

Faludi J. (2015) KIBS in: *Innovation Patterns in the Design-Driven Industries. Opening Up the "Made in Italy"*. (Unpublished Doctoral Dissertation), University of Trento, Italy, Corvinus University Budapest, Hungary

Faludi J. (2016a). Printing Edible Solutions: Going Beyond Chemistry and Art. Cooks as Code-Writers? Manuscript presented at the EASA conference 2016, Milan, Universita di Bicocca. Manuscript submitted for publication.

Faludi J. (2016b). Kitchen…. Manuscript submitted.

Gawer, A., Cusumano, M. A. (2008). How Companies Become Platform Leaders, *MIT Sloan Management Review*, 49(2), 28-35. Retrieved from http://sloanreview.mit.edu/article/how-companies-become-platform-leaders/

Greshenfeld, N. (2012). How to Make Almost Anything. The Digital Fabrication Revolution. *Foreign Affaires*, *91*(6). Retrieved from https://www.foreignaffairs.com/articles/2012-09-27/how-make-almost-anything.

Harvey, D. (2003). The Fetish of Technology. Causes and Consequences, Macalester International: *13*(7). Retrieved from http://digitalcommons.macalester.edu/macintl/vol13/iss1/7

Hebdige, D. (1979). *Subculture. The Meaning of Style.* London: Taylor and Francis E-Library.

Henderson, R. M. & Clark, K. B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms, *Administrative Science Quarterly, Special Issue: Technology, Organizations, and Innovation*, *35*(1), 9-30.

Langlois, Richard N., Robertson, Paul (1992). Networks and Innovation in a Modular System. Lessons from the Microcomputer and Stereo Component Industries, *Research Policy*, *21*, 297-313. doi:10.1016/0048-7333(92)90030-8

Lévi-Strauss, C. (1978). *The Origin of Table Manners*, Mythologique. Chicago: The University of Chicago Press

Maffei, Stefano [2014]: Artisans Today. Understanding Contemporary Innovative Processes Between Design, New Forms of Creativity and Design, in Addition to the Development Production Models. *Design e Artigianato per il Trentino [DEA]*.

Moore, R, and Roberts, M. (2009). Do-It-Yourself Mobilization: Punk and Social Movements. *Mobilization 14*(3), 273-91. Retrieved from http://mobilizationjournal.org/doi/abs/10.17813/maiq.14.3.01742p4221851w11?code=hjdm-site&journalCode=maiq.

Moran, I. P. (2010). Punk: The Do-It-Yourself Subculture. *Social Sciences Journal*, *10*(1). Retrieved from http://repository.wcsu.edu/ssj/vol10/iss1/13

Schilt, K. (2004). 'The Riot Grrrl Is…' The Contestation over Meaning In a Music Scene. In A., Bennet & R., A., Peterson (Eds.), *Music Scenes: Local, Translocal and Virtual* (pp. 115–130). Nashville, Tennessee: Vanderbilt University Press.

Simon, H. A. (1962). The Architecture of Complexity. *Proceedings of the American Philosophical Society*, *106*(6), 467-482.

Zoran, A. (2011). The 3D printed Flute: Digital Fabrication and Desing of Musical Instruments. *Journal of New Music Research*, *40*(4), 379-387. DOI: 10.1080/09298215.2011.621541.