Exploring Open Hardware in the Image Field

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Abstract: The project documented in this article, developed under the Image Design master degree program at the University of Porto, aims to explore the production and transformation of imagery through the use of open platforms for electronic prototyping and physical computing. This field for exploration encompasses the construction, hacking and deconstruction of electronic, analog and digital devices, both as a means for creative research and a quest for alternatives to work processes established as de facto standards. Practical development is focused on modifying, designing and building devices to generate and manipulate imagery with analog and digital components. This study is framed by the relevance of open source technologies, shared creativity and produsage models, as well as the promotion of hardware literacy.

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1. Introduction

Images are increasingly contaminated by technology, in aspects well beyond a merely functional role (Bolter and Grusin 2000, 45–50). How a certain image reaches us, how intimate is the channel through which we view it, can be as determining to its perception as the visual matter itself. However, technological literacy remains focused mainly on promoting software packages and training end users. While plural in their use, devices are increasingly averse to being modified or repurposed by users, be it through physical properties or legal restrictions. In view of this setting, we seek to retrieve technological matter as part of an open creative process, as opposed to a set of defaults. A pliable tool instead of a workplace.

In liberating oneself from predefinitions found in most media-capable devices, strategies such as hardware deconstruction, repurposing and hacking can provide stimulating paths in a search for alternatives to established workflows, framed by the relevance of computational technologies, open source standards, shared models for creative productivity and the promotion of hardware literacy.

In this frame of mind, we set out on a practical exploration of open hardware and electronic prototyping platforms, ultimately geared towards developing operational devices for the production and manipulation of images and sound. Developments and results are freely available as a contribution to further work in this field and retribution to those that have generously contributed with their knowledge and experience. As this project required a good amount of learning about electricity, electronics, prototyping, building, testing and debugging, it offered an opportunity to assess both its feasibility for the average layman and its applicability to learning programs focused on visual communication. This learning process also seeks to point out the benefits of *libre* and open-source resources, particularly their uncompromising flexibility and adequacy to shared creativity models. Finally, the critical reading of experiments, processes and results is an opportunity to reflect on convergence points between images and their technology.

This convergence has deep historical roots, such as Thaddeus Cahill's Telharmonium, which gathers a set of features that make it relevant to this day. Patented in 1898,[1] predating both the Theremin and the Ondes Martenot, it is the first widely known instrument to synthesize polyphonic sounds from electricity, breaking the record-playback loop of contemporary inventions like Edison's Phonograph and rooting the idea of device-generated media. Incidentally, it also preluded streaming, as it was Cahill's intention to broadcast music to public spaces and private homes via telephone wires, on a subscription basis. Sadly, the massive infrastructure required by this invention was the main cause of its early demise.

1. Patent document available at the United States Patent and Trademark Office website (http://patimg1.uspto.gov/.piw?docid=00580035).

In what Marshall McLuhan called an era of illumination (2008, 353), more recent technologies like video, personal computing and digital photography were rapidly embraced by a thriving consumer's market and a notably disruptive artistic community. The growing ubiquity of technology-based media marked a turning point in art and design practice, urging a more widespread thought on media and our connections to (and through) it. The *Experiments in Art and Technology*, started by Robert Rauschenberg and Billy Klüver in 1966, remain especially relevant to this topic, as they so memorably achieved the goal of "*developing an effective collaborative relationship between artists and* *engineers*" (Klüver et al. 1980). These experiments reverberate far and wide, from intersections with Nam June Paik (Wardrip-Fruin 2003, 227) to works such as Bruce Nauman's *Live-Taped Video Corridor* (Shanken 2009, 31) or even Roy Ascott's admonition on how dazzling effects achieved through skillfuly crafted technology can replace the creation of meaning (2008, 358). More recent works, such as *Hektor*[2] by Jürg Lehni and Uli Franke, or Zimoun's reduced technological structures,[3] denote how researching technology for its expressive potential has kept a continued interest. This is also evidenced by well-known academic laboratories dedicated to this area of research yielding influential results, such as the Processing IDE.[4] Here we narrow our focus on the cultural influence of makers and users in technological developments, as well as the technological origins of that influence (Lister et al. 2009, 320), for if some devices or technologies cater to a perceived need or want, others are ultimately shaped by unforeseen usage.

2. Documented at http://hektor.ch/

3. Documented at http://www.zimoun.net/

4. http://processing.org/

2. In the lab

A good number of electronics prototyping platforms are now widely available, allowing one to assemble devices useful to this study with reasonable speed and economy. Arduino,[5] now a staple in the maker's tool chest, was selected for its strict conformity to industry standards and open hardware definitions. Its extensive documentation and massive popularity also provide a fertile ground for exchanging knowledge and practical applications.

5. http://arduino.cc

For a practical exploration of translations between sound and image, a working base permeable to different formulations is needed. To serve this purpose, two complementary devices were planned: one to produce images from captured sound, the other to reverse this flow by generating sound from captured images. This configuration allows the devices to operate together and independently, accepting both mutual and external stimulus. The sound component externalizes part of the machine translation process and increases susceptibility to interference.

In a most simple description, the audio input stage uses amplified electret microphones, while the output is performed by salvaged speakers. Video capture uses inexpensive micro cameras and image output is fed to small LCD screens. These choices were biased toward the development of portable devices, easier to carry and use in any location, with low production costs. Composite analog video was used, as it is less taxing on limited microprocessors and more widely compatible with equipment salvaged from obsolescence. Also, the use of only black and white furthers the economy of processing resources, reinforces an aesthetic penchant for deprecated media and provides a more focused canvas, one less prone to diversion maneuvers. Programming on Arduino microcontrollers brings this flow together, managing analog to digital to analog conversions and affording computational control over response, variability and operational autonomy.

A project of this nature requires a small laboratory with a few specialized tools and basic knowledge of how to use them, such as a multimeter or a soldering iron. Also, while many tutorials and instructional documents are readily available online, reference literature in electronics is strongly advised. Obtaining such resources and knowledge is quite painless and inexpensive, especially when aided by a community of enthusiasts and open laboratories, as was the case in this endeavor. Organizing development in stages, defining tasks and intermediate goals, proved critical to progress through incremental gratification.

The first device generates imagery based on data collected from a microphone. Sound is routed through an operational amplifier, in order to achieve adequate current values for the Arduino, where an RMS[6] algorithm is applied to the sampled data. This averaging method enables fluctuations to more closely resemble a human perception of the sound environment, favoring a more obvious correlation between cause and effect in sound and image relations. Images are generated through the TVout library[7] and output to a 3.5 inch LCD screen, usually sold as a monitor for aftermarket car reversing cameras. Designed to operate on the 12 V standard automobile power, the screen was modified to work on 5 V by performing a bypass on a voltage regulator. This enabled the entire device to be powered from USB or a 9 V battery, thus allowing its assembly on a small reused plastic box. Once a stable build was achieved, with a fully functional bridge between sound input and image output, experimentation turned to the programming of various graphic visualizations of the captured audio data sets. While not an initial requirement, this process occurs in as close to real time as the technology in use allows, with negligible[8] delay. The initial purpose of testing and verifying sound-to-image correlations was progressively skewed towards exploring possibilities afforded by the images' aesthetic properties and the device's physical features. All programs resort to strict black and white on a grid of 128 by 96 pixels and each frame reflects, in some way, the averaged volume of the sampled sound.

6. Root mean square, i.e. the square root of the mean of the squares of a set of values.

7. Code library for the Arduino IDE by Myles Metzler, available on Google Code (http://code.google.com/p/arduino-tvout/).

8. Close to the minimum of 0.1 milliseconds, the time required by the Atmel 328p microprocessor to perform a reading on an input.

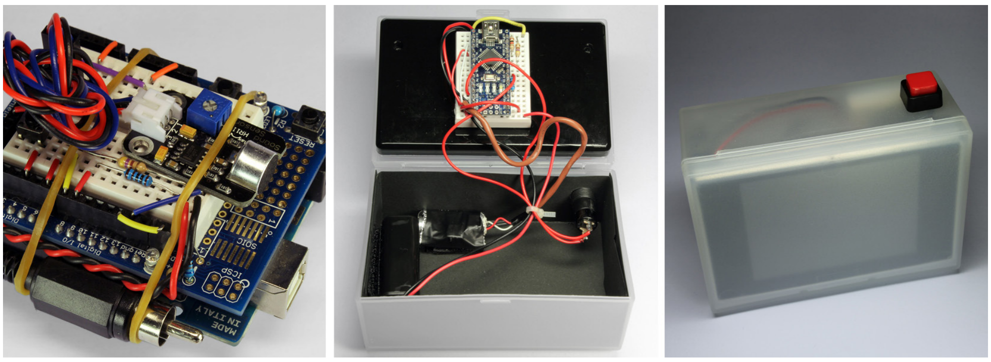

Fig. 1. Prototyping and building device 1.

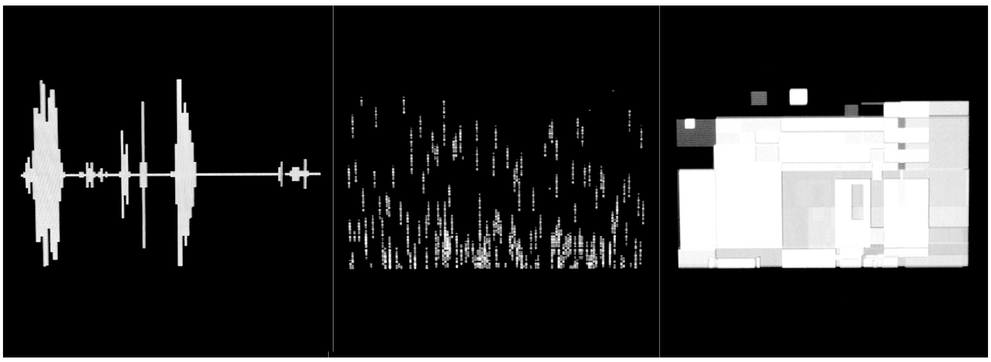

Fig. 2. Three examples of images produced by device 1.

In the second device, captured images are used to generate sound. The core of this device pairs an Arduino with a Video Experimenter Shield,[9] where a LM1881 integrated circuit generates 1 bit images from video frames supplied by a miniature surveillance camera. A potentiometer attached to this circuit allows the luminosity threshold to be calibrated according to the surrounding environment. A simple 8 Ohm shielded speaker with standard protection resistors, salvaged from a broken television set, completes the device. On the Arduino side, the largest continuous bright area in each frame is detected, with a minimum of 4 by 4 pixels defined for reduced response to noise and faster scanning by skipping pixels in the image analysis stage. The center coordinates of this area's bounding rectangle are then used as a basis for tone generation. Using pulse width modulation on an Arduino output pin, monophonic tones between 8 and 1024 Hz are fed to the speaker, corresponding to the 128 pixel horizontal dimension of the captured images. When the bounding rectangle fills the screen's width, the vertical coordinate is used instead. Finally, if the bounding rectangle remains centered, spanning the entire screen, the tone's frequency slopes down to 8 Hz, at which point the sound is muted for as long as the captured image remains unchanged.

9. Arduino shield designed by Michael Krumpus and distributed by Nootropic Design (http://nootropicdesign.com/).

Fig. 3. Building device 2.

3. In the wild

Having reached a stable version of both devices with essential programming in place, a round of tests with a diverse group of ten subjects in different locations was carried out, where the devices' behavior and material properties were submitted to varying approaches and interpretations. The following is a brief account of these experiences, focused on the effects of audiovisual products, of the artifacts' physical configuration and of their computational affordances.

The first device is more widely perceived as indicative of its purpose, leading subjects to prefer visualizations that add to what is seen as functional. Its shape, size and layout also immediately offer clues as to how it may operate. In particular, the appearance of a rudimentary digital camera induces a corresponding approach and expectation. The scale of the artifact favors an introspective experience, in which the subjects interpret the device's response as taking part in the dialogue they lead. Ambient sounds are usually the first trigger in outdoor settings. When indoors, speaking, tapping the device and snapping fingers are the most common first interactions, comparing the results of deliberate actions with those caused by the surroundings. Most subjects direct their actions at the screen in an engaged dialogue that surpasses the screen's natural magnetism, much as if it were able to accept input. This happens even after knowing the microphone's location on the device. The production of sound during the process of interaction is subjected to the visual dynamics afforded by the visualization programs, the most popular being those that offer longer resistance to predictability.

The second device imposes upon the user a more exploratory approach, as it instills a sense of doubt and uncertainty, more evident in subjects less acquainted with experimental devices and technology in general. Curiously enough, most subjects felt motivated by this challenge and were keen to decipher the device. Neither its purpose nor the causality of its operation are self-explanatory, and the inclusion of a screen for monitoring the image being captured proved very helpful to this understanding. Once the screen is activated, the image to sound correlation is more evident and the device becomes an instrument, allowing a more analytical experience. The expressive potential triggered by this mutation sometimes borders on the performative, with subjects moving spontaneously and 'reading' surfaces with the device. The limited tone range encourages a search for patterns and rhythms, as subjects try to master the machine's behavior. In many instances the generated sound becomes somewhat separate from the device itself as it is more closely linked to what the camera sees, thus turning the device into a prosthetic mediator, unnoticed until interest is exhausted.

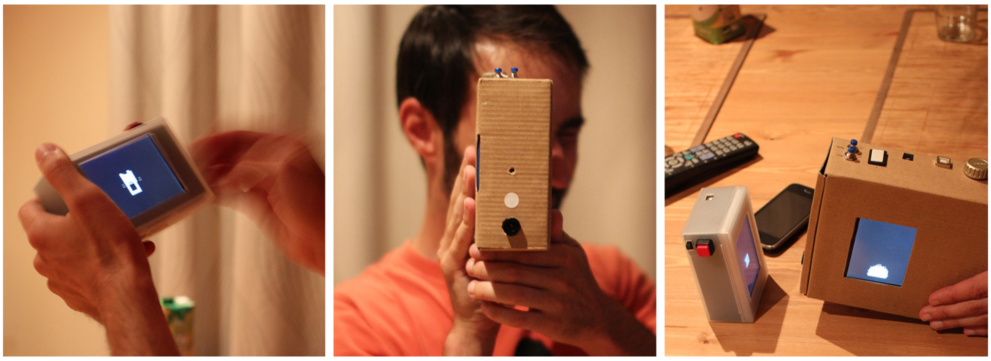

Fig. 4. Devices under exploratory usage testing.

Mutual interference between devices was the last stage of each experience, in which subjects restarted the process of improvising activities, exploring features and evaluating response to expectations (Ribas 2011, 226). Where previously the visual components were the primary focus for the majority of subjects, sound production became the main point of interest when using devices together. With few exceptions, subjects mostly held the first device as a trigger for the second, as if sliding a bow on a string, exploring the potential of the first device's visualizations as output to the second device's input. Naturally, the opposite would take place simultaneously, but that part of the process was overcome by the inversion of the first device's usage: now the subjects pointed the screen away from them, it was no longer an intimate collocutor but a playful proxy.

4. Considerations

These brief observations summarize the expressive potential observed in improvised experimentations, so long as devices were able to provide a path from cluelessness to instrumental mastery, a balance of predictability and surprise, and a graceful incorporation of glitches.[10] It became clear that physical properties afford the artifacts expressive qualities even before their use, adding layers of complexity to the interpretation of their experiences and results, while raising additional questions as to what might change with each possible reconfiguration. Computational properties are particularly relevant to this analysis, as devices with procedural behavior clearly benefit more deeply engaging experiences, thus enabling an active role in social contexts. This possibility of mediating or even generating dialogue through interaction, involving one's surroundings, reinforces the possible impact effected by this mediation, harkening back to what Ivan Illich designated as convivial tools (2001).

10. Intentionally or by serendipity, as discussed by Miguel Carvalhais (2010) regarding Peter Kubelka's short film *Arnulf Rainer* (1960).

Current computational technologies lend themselves quite aptly to experimentation and sharing activities. As makers and designers working with media technology, participatory action in accordance with open source standards adds a sense of accountability, by reclaiming and rethinking one's role in shaping the tools one uses and defining the nature of their benefits. It is important that this intervention be guided by long-term benign goals, as it inevitably contributes to reshaping the technological and cultural fabric of our time in history. In this spirit, most of the materials and components used were recycled or repurposed, and full documentation is available on a public wiki in http://mdi.takio.net, under a Creative Commons Share-Alike license, without commercial restrictions.

As this project hopes to demonstrate, open hardware is, both in its spirit and current state of development, a primed playground for what Janet Murray described as a sandbox for the development of computational systems and procedures through experimental exploration (2011, 339). Not just for end users of well-intentioned black boxes, but for an emerging breed of produsage[11] agents. The expressive potential of the devices built and used over the course of this research is not apparently crippled by lack of processing power, as was observed when they were experimented with by test subjects. Rather, their often unexpected configuration details and physical properties added to the perceived richness and complexity of interaction experiences. As curiosity was piqued by the unconventional nature and hand-made appearance of the devices, bridges were found to the development of a deeper hardware literacy, as many subjects felt they too could acquire the skills needed for similar projects, taking one step further from consumers to creators, actively engaged in generating value beyond wealth (Bauwens 2006). In retrospective, it is gratifying to observe the results achieved by using humble means and obsolete technologies, in a time where product life cycles end long before significant technological leaps.

11. As described by Axel Bruns in *Produsage: Towards a Broader Framework for User-Led Content Creation* (2007).

The devices here described are by no means considered final, and further variations are under consideration, especially regarding their programming, physical layout, scale and connectivity. Also of interest is the research of computational and procedural abilities in the most rudimentary possible build, for the accessibility and educational potential of such a device.

It is our humble hope that this project and its documentation may contribute to a deeper collective hardware literacy and a more distributed control over the tools we use to define our world and ourselves.

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