Mirroring the past, from typewriting to interactive art: an approach to the re-design of a vintage technology

Giacomo Lepri
Augmented Instruments Laboratory
Centre for Digital Music
Queen Mary University of London
g.lepri@qmul.ac.uk

Andrew McPherson
Augmented Instruments Laboratory
Centre for Digital Music
Queen Mary University of London
a.mcpherson@qmul.ac.uk

ABSTRACT

Obsolete and old technologies are often used in interactive art and music performance. DIY practices such as hardware hacking and circuit bending provide effective methods to the integration of old machines into new artistic inventions. This paper presents the Cembalo Scrivano .1, an interactive audio-visual installation based on an augmented typewriter. Borrowing concepts from media archaeology studies, tangible interaction design and digital lutherie, we discuss how investigations into the historical and cultural evolution of a technology can suggest directions for the regeneration of obsolete objects. The design approach outlined focuses on the remediation of an old device and aims to evoke cultural and physical properties associated to the source object.

Author Keywords

Media archaeology, DIY, interactive audio-visual installation, tangible interaction design, digital lutherie

CCS Concepts

•Applied computing → Media arts; •Human-centered computing → *Interface design prototyping;* **•Information systems →** Multimedia information systems;

1. INTRODUCTION

In the context of interactive art, the practice of re-inventing and re-purposing existing objects and technologies is well established. Design approaches inspired by Do-It-Yourself (DIY) culture, circuit bending and hardware hacking often provide powerful and compelling methods for the creation of new artworks. The act of reviving obsolete objects is a key notion within the practice of contemporary art. Duchamp's *readymades*, ordinary manufactured objects that the artist selected and modified, represent a pivotal example of consumer commodities creatively reused.

In media theory, the attempts to understand new and emerging technologies by taking into account the history and evolution of *past* new media is defined as *media archaeology* [30]. These cultural studies focus on the critical scrutiny of forgotten technologies, observing that new media often renovate old interactive paradigms and communication techniques. Hertz and Parikka propose a methodology for contemporary artistic practice introducing the concept of *zombie media*: "a media that is not only out of use, but resurrected to new uses, contexts and adaptations" [16].

The cultural scrutiny of technological development can be particularly relevant while considering embodied interaction design. As noted by Dalsgaard and Koefoed Hansen: "we perceive and act in a world laden with meaning, and meaning is constantly being enacted and renegotiated through our interactions with each other and the world" [9]. Therefore, embodied interactions are here conceived as meaningful experiences arising from physical actions and practices.

Dourish conceives the relation between interaction, objects, and meaning as constructed through social and cultural practice [11]. Thus, while designing a new object, it is possible to elicit, augment or alter physical actions associated to existing objects, situations and environments. Horn proposes an approach to tangible interaction design concerned with the "overall experience around an interactive artifact by cueing productive patterns of social activity" [17]. Likewise, Norman introduces the notion of *social signifiers*, which he defines as perceivable cues that suggest social activity or appropriate social behaviour [29]. Hurtienne & Israel recognise the importance of cultural form in their continuum of pre-existing knowledge (e.g. innate, sensorimotor, cultural and domain expertise knowledges) [18].

The work here introduced focuses on the redesign of an old device by evoking existing cultural and physical resources associated to the source object. The device functionalities were re-composed by exploiting shared knowledge linked to the machine. Historical and cultural considerations informed the re-assemblage of the device's usage within a new interactive context. The result of this design process is the Cembalo Scrivano .1 (CS1): an interactive audio-visual installation based on the renewal of an old typewriter. The strategy adopted combines media archaeology studies with instrument design principles to elicit specific cultural and musical notions. The public presentation of work allowed us to reflect on how a given object can acquire new behaviours and identities while maintaining its original aspect and functionalities.

This paper therefore presents the design of an interactive experience whose ultimate goal is to serve aesthetic and artistic functions. First, considerations related to media archaeology, instrument design and the re-use of everyday objects in artistic contexts will be introduced. Subsequently, the main conceptual and technical features of the CS1 will be illustrated. Finally, we will discuss some of the cultural implications that can be drawn from the CS1 project.

2. SHAPING PAST-PRESENT MEDIA

The CS1 ideation and development have been influenced by musical notions and DMI design principles [8]. A few considerations on new musical interface development and media studies might help to introduce the CS1 design process.

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2.1 Instrument design and media archaeology

Notions such as corporeal intentionality and embodied interaction are considered as core aspects of musical expressiveness [21]. From this viewpoint, designers of New Interface for Musical Expression (NIME) inherit a centuries-old body of knowledges and practices. New instruments are often discussed in relation to traditional instruments [33, 19]. This suggests that historical and cultural practices are easily projected into the design of the new instruments.

Far from being obsolete technologies, nowadays, traditional instruments steadily persist in contributing to most of the musical contexts. On the other hand, a debate around the longevity of the many DMIs presented at NIME is gradually gaining attention [27]. The project here presented is grounded on the idea that *new media re-mediates old media* [3]. The design of a novel instrument can be approached as a migration process in which features associated with existing musical technologies are integrated and negotiated into a new context. Parikka writes "media archaeology sees media cultures as sedimented and layered, a fold of time and materiality where the past might be suddenly discovered anew, and new technologies grow obsolete increasingly fast" [30, p.3].

NIME literature offers different examples on the practice of re-evaluating, reusing or adapting old and obsolete musical technologies. While introducing his Phantastron synthesiser, Parker offers a comprehensive overview of previous musical research involved with the re-appropriation of vintage technology [31]. In his book "Handmade Electronic Music: The Art of Hardware Hacking", sound artist and author Nicolas Collins provides a valuable introduction to hardware hacking and circuit bending for the performance of electronic music [7]. Composer and contemporary artist DeMarinis has extensively explored the practice of reinventing "orphaned technologies" with many sound installations [10]. Freed et al. question the idea of technological development *per se* and they emphasise that DMI longevity of use depends on a constant process of re-implementation to maintain the required stability of performance of players [13]. However, even if many DIY musical subcultures are engaged with the re-purposing of older technologies, on the extent of our knowledges, only Parker discusses media archaeology studies within the context of instrument design.

The research outlined is therefore concerned with the practical application of ideas coming from cultural studies. Within the NIME context, this approach can be contextualised around the notion of instrumentality. Instrumentality refers to those features that determine the specificity of a musical instrument as "distinguished from other sound-producing devices" [4]. In his 1987 article entitled "Instrumentalities", Burrows suggests that a musical instrument is ultimately defined by the intentions and purposes of the person that interact with it [5]. Cance et al. presented an interview study in which a number of experts had to give their personal definitions of musical instrument [6]. As a result, they argue that instrumentality is not so much dependent on the properties of a device itself, but rather on the actions and meanings that are embedded into it. Thus, instrumentality seems to be a "dynamic concept that is not tied to an object *per se* but is rather a matter of cultural negotiation" [15].

2.2 Remediating everyday objects

Drawing on the works of McLuhan [24] and Bolter and Grusin [3] remediation can be defined as the *formal logic* by which new media refashion prior media forms. This implies that characteristics typical of an existing media are transferred into the new media. Digital media often remediate analog media, for instance the pages of a web portal might remediate those of a printed newspaper. Nowadays, thanks to low-cost microcontrollers and embedded systems, everyday objects can be easily digitalised in order to expand their functionalities and remediate of other devices.

DIY and musical practices often imply the migration of specific functionalities and purposes amongst different technologies. A pioneering work is *Imaginary landscape no. 4* for twelve radios by John Cage: from radio to musical instrument. NIME literature offers various examples linked to the remediation of music technologies using everyday objects. The Peripipe is a tangible remote control for a music player in the shape of a wooden tobacco pipe [12]. The Wheel Quintet is a novel musical instrument comprising four bicycle wheels and a skateboard [22]. Rasamimanana et al. presented an ensemble of tangible devices and software modules designed for musical interaction and performance [32]. One goal of the project was to let users assemble the wireless interfaces with everyday objects favouring the customization of the various items' musical functions. Digital commodities such as laptop computers and mobile phones have been often co-opted to remediate musical instruments, amongst others the Laptop Accordion [25] and the Smule Ocarina [35].

Keyboard devices have been explored to support music production and performance. Live Writing is interactive performance in which the process of typing a poem is captured and augmented to create audiovisual elements. The idea behind the performance is to establish natural links among the components of typing gestures, the poem being written and audiovisual artefacts [20]. Nash augmented a computer keyboard to capture velocity and other continuous musical properties, in order to enhance expressive interaction with music software [28]. Armitage and McPherson explored alternatives to the QWERTY keyboard as physical interface to laptop live coding by augmenting a stenotype keyboard which permits continuous gestural control of keys [2]. The typewriter has been used in many artistic contexts, often as part of installations involving the coupling of digital and analog technologies.[1] A Project from 1970 by Carl Fernbach-Flarsheim used a program called "Conceptual Typewriter" to generate random spatial outputs of letters and numbers. The typewriter installation "On Journalism #2 Typewriter" writes generatively constructed stories about journalist who have been killed worldwide since 1992 based on the existing data of their lives as well as their published work.

It is possible to argue that typewriter and modern computer often remediate each other. This link seems to be present within the overall history of digital technology: JOSS, one of the very first interactive, time-sharing programming languages developed in 1963, featured a typewriter as input interface.[2] On the other hand, nowadays it is possible to buy conversion kits to use vintage typewriters as USB keyboards for MAC and PC computers.[3]

3. THE CS1: MIRRORING THE PAST

The Cembalo Scrivano .1 is an interactive audio-visual installation based on an augmented typewriter. By detect-

[1] `http://rhizome.org/editorial/2013/jan/16/prosthetic-knowledge-picks-typewriter/` last access April 10, 2018

[2] `https://www.youtube.com/watch?v=AIWZ_pbLYqQ` last access April 10, 2018

[3] `https://www.usbtypewriter.com/` last access April 10, 2018

ing the user's typing activity, the CS1 generates in real-time audio and visual materials. The project is inspired by the writing machine created in 1855 by the Italian inventor Giuseppe Ravizza. Ravizza's machine is considered a precursor of the later Sholes and Glidden Type-writer (the first commercially successful writing machine, invented in 1868). In fact, the Cembalo Scrivano features noticeable similarities with the Sholes and Glidden design. Giuseppe Ravizza called his invention Cembalo Scrivano (Scribe Harpsichord) due to the usage of piano-keys (see Figure 1). Ravizza's invention reworks the harpsichord interface: an existing musical instrument was used as source of inspiration for the development of a new machine (from art technology to typewriting). The CS1 aims to mirror this process: a typewriter is converted into an interactive art installation (from typewriting to art technology). Oscillating between two domains (musical and literary), the same technology travels across history, carrying knowledge, behaviours and meanings.

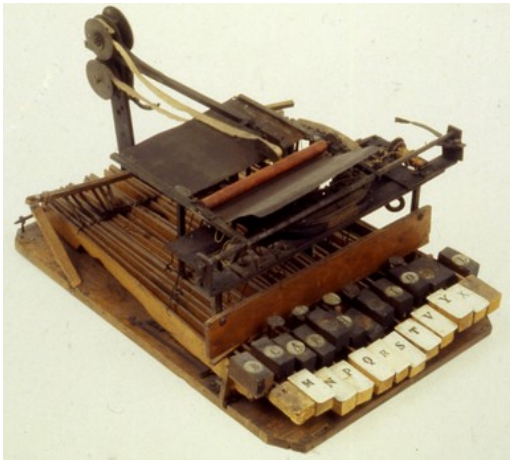

Figure 1: The Cembalo Scrivano invented by Giuseppe Ravizza in 1855. Picture retrieved from Museo Nazionale della Scienza e Tecnologia Leonardo da Vinci, on-line archive.

3.1 Design approach: reverse the analogy

Ravizza borrowed the Harpsichord's interactive paradigm for the implementation of his machine: by pressing the keys, instead of playing notes, it prints symbols. The idea behind the CS1 is to adopt the same design approach but establishing the inverse analogy.

Starting from the interaction paradigm of the typewriter, we develop an interactive system that could be used in the context of interactive sound and visual art. Both machines share features with the technologies to which they refer. For instance, both the Cembalo Scrivano and the harpsichord produce specific punctual events (letters and notes) by pressing the keys with the fingers. Likewise, the CS1 and the typewriter are based on the same principle: in order to modify the internal state of the system and its output it is necessary to convey physical energy to the object through fingering activity. Rather, the final goals of the interaction have been re-established and shifted into a new domain.

The CS1 design approach can be contextualised within the discussion on interpretation in Human-Computer Interaction (HCI) introduced by Sengers and Gaver [34]. In particular the CS1 aims to support multiple interpretations exploiting two specific design strategies presented by Sengers and Gaver. The first refers to the intention of clearly outlining usability (typing activity), while leaving the audience free to interpret the sonic and visual materials generated. The second concerns the idea of stimulating new interpretations by purposefully blocking expected ones (i.e. the produced elements are not those normally associated with the use of a typewriter).

The CS1 aims to combine physical and digital realities, conceiving the two dimensions as linked within a continuum [26]. Typing on a standard typewriter causes both the production of a sound (mechanical motions of the keys) and the impression of a symbol on the paper. The CS1 is conceived to synthesise in the digital domain analogous visual and sonic elements (animated letters and mechanical sounds). The presence of similar interactive feedback creates a link between the behaviours associated to the original object and the new outputs introduced. On the other hand, as distorted reflections, the sounds and symbols generated do not exactly behave as they do with the original object.

The user is therefore exposed to an ambiguous situation in which the behaviours generated do not match any more with those normally associated to a typewriter. As Ravizza did with his Cembalo Scrivano shifting from musical notes to letters, the idea is to alter the outcomes of the interaction: symbols becomes abstract shapes and sounds diverge from the resonances acting within the writing mechanism.

These design strategies can be linked to the work on ambiguity as a resource for design introduced by Gaver et al. [14]. Here, ambiguity arises in the way that information is presented (i.e. altered and aleatory). In addition, the tension that might emerge while presenting a typewriter in art gallery environment, should contribute to interpret the object in unexpected ways. Gaver et al. refer to this as "ambiguity of context" presenting the pivotal example of the Duchamp's Fountain.

From a more general viewpoint, the design approach here introduced is also concerned with fundamental social and environmental issue. Waste of electronic equipment is one the fastest growing waste streams. In the EU, 9 million tonnes of electrical waste were generated in 2005, and expected to grow to more than 12 million tonnes by 2020. [4] As noted by Parker "antiquated technology is in the common domain and ready to be utilised in the synthesis of new ideas" [31]. Since in the history of technology, patterns of interaction and communication often revive and recirculate, media archaeology studies are keen to see the distinction between new and past media as blurred [30]. Indeed, in the Western world, through the combination of consumerist trends and technological innovations "new media always becomes old" [16]. In a society in which technology assumes a predominant role in almost every aspect of our life, occasionally it seems natural to wonder if technology is at the service of humanity or vice versa. The CS1 design approach aims to question the need of new technology and it proposes a *reversed* solution that aims to re-discover the past in order to imaging the future. The notion of new (intended as better, more powerful and efficient) might be sometimes replaced by concepts such as reinterpreted, reused and regenerated.

3.2 System architecture: a look inside

The typewriter used in the project is an Olympia SM9 (Figure 2). The typewriter was distributed with a custom suitcase for transport. The CS1 interactions are based on the detection of the keys pressed by the user. Each key is connected to a metal bar that passes through the bottom of the machine. Once a key is pressed the bar slides down

[4] `http://ec.europa.eu/environment/waste/weee/index_en.htm` last access April 10, 2018

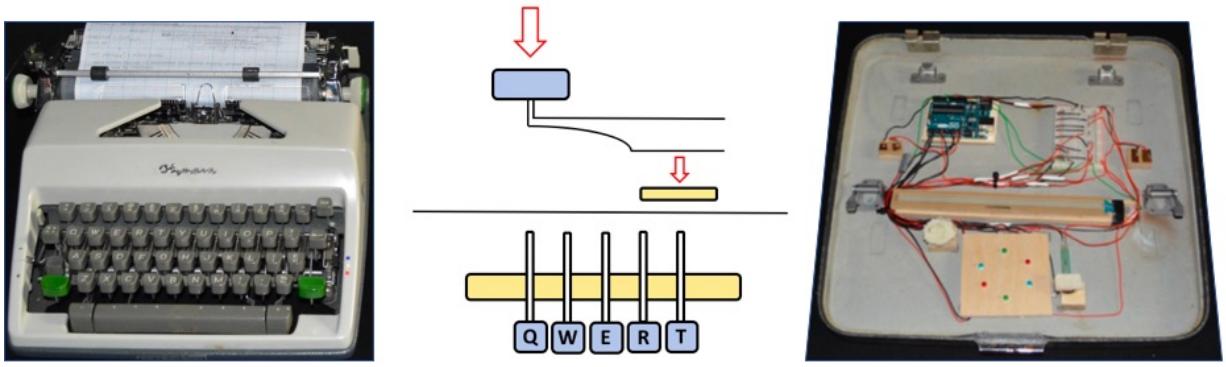

Figure 2: From left to right: the Olympia SM9 typewriter used in the CS1; the sensing mechanism - by pressing a key (blue) the metal bars touch the potentiometer (yellow) in a specific point; the Olympia SM9 suitcase base equipped with Arduino, sensors and LEDs

(a few centimetres). In order to detect this movement, we used a membrane potentiometer placed under the machine. The sensor was placed on the base of the typewriter suitcase. By shifting down, the various bars touch the sensor in different points. In this way, it was possible to assign a specific position-region of the sensor to a specific symbol of the keyboard. This procedure is the basis of all the new interactive elements developed.

The energy detected by the sensor is converted into digital information using the Arduino Uno board. First, the data are processed in order to: (i) associate the membrane values to specific ASCII values, (ii) control the behaviour of eight LEDs placed within the typewriter (see Section 3.3). After these processes, the detected ASCII values are sent to a computer and processed using Max-MSP and Processing. The communication between the various hardware and software units is based on serial port (Arduino to Processing) and OSC (Processing to Max-MSP).

3.3 Introducing the digital dimension

From an interactive viewpoint, the CS1 is characterised by two states. The machine state changes only if the user presses the keys. The first state is associated to a condition of quietness. If the keyboard is not touched (no letters are typed for more than ten seconds) a constant low frequency drone like sound is generated. Simultaneously, LEDs located on the bottom of the machine (see Figure 2) constantly fade in and out. Besides the slow and constant LED fades, during the quietness state, no visual feedback is generated.

If a key is pressed, the CS1 switches to the second state. The LED behaviour immediately changes: from slow and dimmed to impulsive and bright: LEDs turn on only for the time a key is pressed. The drone sound shifts to a higher frequency and decreases in amplitude. Once a key is pressed, additional sounds are added; pre-recorded and manipulated samples of the machine itself. This sonic material is characterised by an impulsive envelope with a sort of glitchy and flickering decay. The pressed key is also visually generated (see Figure 3). The letter is randomly located on the screen and it *lands* to its final position by moving with different behaviours. The juxtaposition of the various trails contributes to the generation of abstract shapes. While interacting with the CS1, it is increasingly difficult to keep track of the various typed letters. Additionally, the ways the letters appear is characterised by fast oscillations and shakes. This aim to establishes a direct connection between the generated visual and sonic behaviours (shaking letters and glitchy sounds).

The attempt is to implement interactions characterised by constrained behaviours affected by stochastic processes [23]. Consequently, at any new iteration of the same action, it is possible to generate a new variations of the same kind of conduct. It is possible to view a short demo of the CS1 at this link. [5]

3.4 CS1 set-up

The CS1 is conceived for intimate and silent spaces. This to evoke a deep and almost meditative writing activity: a quiet, private and focused practice. The CS1 should be therefore set up isolated within a small-sized room, in which the audience can interact with the machine individually or as a small group. Moreover, in order to appreciate the changes of light occurring within the typewriter, the environment should be dimly lit.

Ideally, the generated images should be projected on a wall behind the typewriter and the audio signal diffused trough a stereo PA system. Alternatively, the video can be displayed using a computer screen placed on top of the typewriter and the sonic output can be listened to via headphones.

4. PUBLIC PRESENTATIONS

The CS1 was presented in two art exhibitions: CruftFest at Queen Mary University of London and Dorkbot London at The Boxing Club, Limehouse Town Hall. CruftFest is annual mid-term showcase event in which students can present and demo interactive projects developed during the first half of the year. Dorkbot London is periodic informal gathering of artists, engineers, designers, scientists, inventors working under the umbrella of electronic art. At CruftFest, the installation was set up in an acoustically isolated and darkened room. The typewriter and the computer monitor were placed on a table at the centre of the space, the two speakers at two meters of distance on the back of the typewriter. At Dorkbot London it was not possible to recreate the same conditions: the CS1 was installed on a shared table in a large hall where many other activities were simultaneously happening. In both cases, the audience had the possibility to freely interact with the machine: no instructions were provided, though a verbal description of the work was given on request. Approximately 40 people interacted with the object. After trying the installation, the first author had the chance to discuss with some of the audience about their experience with the CS1.

[5] `https://youtu.be/o9BE7N6ER5w`

The CS1 was generally evaluated as playful and aesthetically pleasant experience. In addition, we noted that the audience usually approached the installation with good degree of confidence. Often, the fact of recognising a typewriter immediately triggered those behaviour normally associated with the object (e.g. fast typing). The presence of the machine functioned as strong incentive to participate and get involved with the installation. We also noted that a brief description of the work was usually requested by the audience after a few minutes of interaction. Generally, the first drive was to directly try the installation without seeking any specific information or instruction. Moreover, the quiet modality activated when no user interacted with the CS1 (constant drone sounds and slow LEDs fades), was often acknowledged as a stimulus to start the interaction.

During public presentation, it was possible to observe that the audience was engaged in questioning and negotiating the usage of the CS1. Indeed, during the interaction, they gradually changed their attitude towards the typewriter. This process has been confirmed by the participants during the interviews. Initially, the general tendency was to approach the CS1 as a normal typewriter, without giving much attention to the visual and sonic feedback generated by the installation. Once they realised that the words typed were not directly displayed on the computer monitor, the users started to pay more attention to the system's outputs. At this point, the audience started a more detailed exploration of the sounds and images generated. After the interaction, the audience comments on the nature of the CS1 were quite diverse. Most of them agreed on the idea that the CS1 is no longer a typewriter. Various participants interpreted the CS1 as a musical instrument. Some of them even began to imagine a little ensemble made out of typewriters.

The characteristics of the location in which the CS1 is shown drastically influence the perception of the work. While the isolated space available during CruftFest was ideal for the experience, the shared hall at Dorkbot London did not facilitate the fruition of the work. We noted that, the location being dispersive rather than immersive, the audience modalities of interaction were generally hasty and superficial. Indeed, compared to the CruftFest exhibition, only a few people were able to pay attention to the audio-visual interactions for a consistent amount of time.

The evaluation of designs inspired by media archaeology studies remains an open topic. In particular, further investigations might help to better frame how meanings and functions associated to existing objects can be re-designed to promote participatory and engaging experiences.

5. DISCUSSION

This paper introduced the CS1: an augmented typewriter that allows for the real-time generation and manipulation of sonic and visual materials. The project, presented in different exhibitions, features the re-assemblage of an obsolete technology into an interactive installation. The design approach outlined focuses on the remediation of tangible interactions inspired by considerations related to the history of the object. The analogy with the work of the Italian inventor Giuseppe Ravizza is the starting point for the exploration of a tangible interaction that refers to well-established cultural experiences (music practice and typewriting) and it is associated with a defined interactive paradigm (key-pressure like interaction) [1].

By presenting the CS1 in different venues it was possible to understand that the characteristics of the location drastically influence the perception of the work. The audio-visual interactions implemented are indeed based on slow and subtle behaviours that require some minutes of interaction to be fully perceived. We noticed that large, crowded and dispersive spaces do not promote a focused and immersive interactive experience. In order to properly appreciate the installation a calm and silent environment is required.

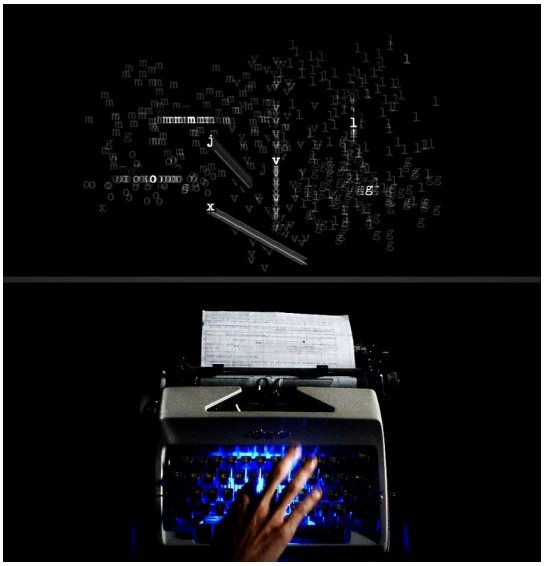

Figure 3: A view of the visual output generated by the CS1

While discussing various principles for the design of computer music controller Perry Cook argues that "everyday objects suggest amusing controllers" [8]. We believe that, in addition to the playful dimension, everyday objects can introduce powerful stimuli to promote the audience active participation. In line with the arguments of Lind and Nylén, we think that everyday objects provide a means for "enabling people to master the instruments when they first encountered them, and hence participate" [22]. In our experience, the audience, while approaching the CS1 for the first time, tend to directly engage with the machine without questioning the functioning and meanings of the installation. This has been perceived by the authors as a spontaneous and natural form of early participation.

During the interviews most audience members affirmed that the CS1 was gradually no longer perceived as a typewriter. However, the feedback received on the new nature of the CS1 were quite divergent. It therefore seems that the identity of the CS1 dynamically varies in relation to a subjective cultural negotiation. This can be considered a positive result, in line with our attempt of designing an engaging experience that could "suggest issues and perspectives for consideration without imposing solutions" [14].

Bolter and Grusin argue that remediation "rehabilitates other media" and it can be understood as "a process of reforming reality" [3, pp. 56]. The CS1 project suggests that, in light of existing goals and expectations, it is possible to alter the meanings and associations linked to an object by reshaping the device functionalities and contexts. Given the artistic nature of the project, the accountability of coexisting meanings is considered by the authors as a powerful and stimulating feature [34]. The installation therefore takes advantage of multiple interpretations in order to elicit and support audience engagement.

In the case of the CS1, the shift from typewriting to digital art was realised by twisting the results of the interac-

tions normally associated to the source object. As proposed by Horn, it is therefore possible to elicit new meanings and functions by focusing is on "existing cognitive, physical, and emotional resources" [17]. We suggest that investigations into the historical and cultural evolution of a technology might reveal hidden notions and archetypes. The exploration of the paradigms and ideas that a specific device embodied can be an effective strategy for the re-imagination and renewal of obsolete machines.

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7. REFERENCES

[1] A. N. Antle, G. Corness, and M. Droumeva. What the body knows: Exploring the benefits of embodied metaphors in hybrid physical digital environments. *Interacting with Computers*, 21(1):66–75, 2009.

[2] J. Armitage and A. McPherson. The Stenophone: live coding on a chorded keyboard with continuous control. In *Proceedings of the International Conference on Live Coding*, 2017.

[3] J. D. Bolter and R. A. Grusin. *Remediation: Understanding new media*. MIT Press, 1999.

[4] T. Bovermann, A. de Campo, S.-I. Hardjowirogo, and S. Weinzierl. *Musical Instruments in the 21st Century*. Springer.

[5] D. Burrows. Instrumentalities. *The Journal of Musicology*, 5(1):117–125, 1987.

[6] C. Cance, H. Genevois, and D. Dubois. What is instrumentality in new digital msuical devices? A contribution from cognitive linguistics and psychology. *arXiv preprint arXiv:0911.1288*, 2009.

[7] N. Collins. *Handmade electronic music: the art of hardware hacking*. Taylor & Francis, 2006.

[8] P. Cook. Principles for designing computer music controllers. In *NIME*, 2001.

[9] P. Dalsgaard and L. K. Hansen. Performing perception-staging aesthetics of interaction. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 15(3):13, 2008.

[10] P. DeMarinis. Firebirds and Tongues of fire - Artist statement, 2004.

[11] P. Dourish. *Where the action is: the foundations of embodied interaction*. MIT press, 2004.

[12] T. Feldt, S. Freilich, S. Mendonsa, D. Molin, and A. Rau. The peripipe: A sip-and-puff remote control for music playback. In *NIME*, 2015.

[13] A. Freed, J. MacCallum, and S. Mansfield. "Old" is the New "New": a Fingerboard Case Study in Recrudescence as a NIME Development Strategy. In *NIME*, 2013.

[14] W. W. Gaver, J. Beaver, and S. Benford. Ambiguity as a resource for design. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 233–240. ACM, 2003.

[15] S.-I. Hardjowirogo. Instrumentality. on the construction of instrumental identity. In *Musical Instruments in the 21st Century*, pages 9–24. Springer, 2017.

[16] G. Hertz and J. Parikka. Zombie Media: Circuit bending media archaeology into an art method. *Leonardo*, 45(5):424–430, 2012.

[17] M. S. Horn. The role of cultural forms in tangible interaction design. In *Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction*, pages 117–124. ACM, 2013.

[18] J. Hurtienne and J. H. Israel. Image schemas and their metaphorical extensions: intuitive patterns for tangible interaction. In *Proceedings of the 1st international conference on Tangible and embedded interaction*, pages 127–134. ACM, 2007.

[19] S. Jordà. Instruments and players: Some thoughts on digital lutherie. *Journal of New Music Research*, 33(3):321–341, 2004.

[20] S. W. Lee, G. Essl, and M. Martinez. Live writing: Writing as a real-time audiovisual performance. In *NIME*, 2016.

[21] M. Leman. *Embodied music cognition and mediation technology*. MIT press, 2008.

[22] A. Lind and D. Nylén. Mapping everyday objects to digital materiality in the wheel quintet: Polytempic music and participatory art. In *NIME*, 2016.

[23] T. Magnusson. Designing constraints: Composing and performing with digital musical systems. *Computer Music Journal*, 34(4):62–73, 2010.

[24] M. McLuhan. *Understanding media: The extensions of man*. MIT press, 1994.

[25] A. Meacham, S. Kannan, and G. Wang. The laptop accordion. In *NIME*, 2016.

[26] P. Milgram and F. Kishino. A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, 77(12):1321–1329, 1994.

[27] F. Morreale et al. Design for Longevity: Ongoing Use of Instruments from NIME 2010-14. In *NIME*, 2017.

[28] C. Nash. The 'E' in QWERTY: Musical expression with old computer interfaces. In *NIME*, 2016.

[29] D. A. Norman. The way I see it - Signifiers, not affordances. *Interactions - Designing games: why and how. Volume 15 Issue 6, November + December*, pages 18–19, 2008.

[30] J. Parikka. *What is media archaeology?* John Wiley & Sons, 2013.

[31] L. E. Parker. Repurposing the Past: The Phantastron and appropriating history as a DIY approach. *Organised Sound*, 18(03):292–298, 2013.

[32] N. Rasamimanana, F. Bevilacqua, N. Schnell, F. Guedy, E. Flety, C. Maestracci, B. Zamborlin, J.-L. Frechin, and U. Petrevski. Modular musical objects towards embodied control of digital music. In *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction*, pages 9–12. ACM, 2011.

[33] J. Ryan. Some remarks on musical instrument design at STEIM. *Contemporary music review*, 6(1):3–17, 1991.

[34] P. Sengers and B. Gaver. Staying open to interpretation: engaging multiple meanings in design and evaluation. In *Proceedings of the 6th conference on Designing Interactive systems*, pages 99–108. ACM, 2006.

[35] G. Wang. Designing Smule's Ocarina: The iPhone's Magic Flute. In *NIME*, 2009.