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When technology goes out of control

Eleonora Oreggia and Graham White

School of Electronic Engineering and Computer Science, Queen Mary University of London, London, UK

ABSTRACT
This paper uses the example of software and electronic devices used in musical improvisation to develop a critique of the dominant view of technology, specified by function and input–output behaviour, and optimized so that it is as domesticated as a faithful dog. The optimization in question attempts to avoid discontinuity and, more generally, unforeseen responses from a system, assuming a human being's need for an interface is purely functional. Against this, we argue that some devices are, by their nature, complex and chaotic, and also that, because of this complexity, we can form deep attachments to them. These interspecies forms of affection are rooted in the sense of incompleteness of the *human*, its uncertainty in relation to an *other* and the reasons why, while a synthetic companion *can* be desirable because more predictable, in the case of improvisational interaction we desire our machinic counterparts to surprise us.

KEYWORDS
Live; composition; improvisation; interface; companion; interaction; control; chaos; catastrophe

1. Introduction

There is an underlying idea in contemporary forms of progress and development that envisions technology as something that is made for us, programmed to support us and designed to be trustworthy, so that we can hardly ever rely on a human as much as on a technical apparatus. The imperfection of cells and flesh and wet matter casts the quality of being human with the property of imperfection, whereas machines and the supernatural can, instead, still tend to be immutably perfect—as they are to be so programmed.

The principles of design and engineering identify the main scope or existential paradigm of an object or device in the question of function,[1] as a machine is commonly defined as an object having moving parts that performs some form of work. Electronics and software (especially self-built and open-source) in the form of media and techniques,[2] and science and engineering in the form of disciplines, have slowly conquered a space alongside and within traditional arts—such as painting, sculpture, scenography and performance. This process, in the course of about hundred years, has progressively transmuted itself, starting from a form of representation—see velocity, speed and movement in Futurist and Cubist painters—to a form of illusion—cinema and video use sequences of still images to trigger the senses. Finally, more contemporary aesthetics use the virtual to construct, expand or superimpose this to another reality.[3] Kinetic and robotic art, on the other hand, attempt to generate signification through actual movement and physical materiality.

We argue that a new idea of the machine is forming in the work of contemporary electronic

CONTACT Eleonora Oreggia xname@xname.cc Electronic Engineering and Computer Science, Queen Mary University of London, London E1 4NS, UK

artists and performers, a semiotic transversal machine (Guattari 1995) created to make us feel uncomfortable, insecure, frustrated or discontent, but also loved and completed. Machines and interfaces that can use our habits to question those conventions that are so encoded in our expectations to become almost spontaneous. We hypothesize that a generation of coders and engineers is emerging, composed of artists who are more interested in developing instruments which leave a space for the machinic to express itself and respond to us in novel unpredictable ways (Oreggia and White 2016).

Our creations, then, can become our companions, and interacting with them is a journey to rediscover our senses and what we can perceive. In contrast to traditional instruments, such as the violin, these interfaces allow for contemplation, and in contrast to a traditional work of art, such as a painting, they allow for interaction. The capacity to surprise their creator, eluding control even when mastered, makes these digital and electronic creations hybrid agents which transcend the distinction between medium and object, artist and tool. Their fluid input is transforming our aesthetics, challenging, expanding or contradicting the forms of expression we had previously explored—before electronics and software began.

2. Artificial companions

It seems that the need for social interaction and intraspecies relationships is part of the biological constitution of humans and more in general mammals, distinguished by the property of generating each new member inside the other, so that two animals, mother and child, are initially physically attached and stay so for a long time even after birth, as if still connected by an invisible line that is hard to break.[4] Along with the genetic, cultural heritage is transmitted from being to being. The cyclic and spiralling shape formed by individuals physically attached to one another through history, over millennia, may contradict the linear progressive arrow of male-dominant evolution, substituting instead the projection over time of intertwined umbilical cords, forming a braid of women turning into one another and descending towards the centre, through the ancestors and further down to the roots of humanity.[5] This monstrous formation, if we could see in the blink of an eye the projection of time in a single image, is made of flesh. There is, in fact, a singular line connecting every individual woman to the archaic mother, as the property of being human had been, until the 'biodigital era' (Parisi 2004), transmitted via carnal interaction rather than synthetic design.

This idea and search for an external centre, this inner desire to make things with others and the sense of completion or incompleteness that was cast on us humans on the day the first umbilical cord was cut, or when Paradise was shut[6], that haunting sense of separation has turned into a desire for companionship, affection and creative counteract. This sense of loss is well described, as an intrinsic property of humans, in the words of Victor Frankenstein's creature, in Mary Shelley's novel:

> They were not entirely happy … I saw no cause for their unhappiness; but I was deeply affected by it. If such lovely creatures were miserable, it was less strange that I, an imperfect and solitary being, should be wretched. Yet why were these gentle beings unhappy? (Shelley [1818]1994)

To rebel from fate, the loss of his mother or the general destiny of being mortal, Victor Frankenstein had the idea to create life from inanimate matter, when, at the beginning of the nineteenth century, the discovery of electricity had infused enthusiasm and excitement around the possibilities of science and the experimental method (Caronia 2008). This attempt to design and create artificial life, breaking the hyper-temporal connection made of flesh, has continuously developed over the past two centuries, oscillating between reality and fiction, from literature to Artificial Intelligence to biology, in the form of a rebellion against death and birth with an attempt to discover the secret ingredient of life (and thought).

But where does this idea of artificial companions come from? In a sense, the mastery of life implies the resolution of its uncertainty, uncertainty which is perpetuated into love and companionship by the mere fact of being two, threatened by desire (for consumption, and therefore destruction) and love (which entangles the self with its protective net): 'that act of remoulding an other into the quite definite someone … means rendering the future indefinite' (Bauman 2013, 20)

If 'Art and engineering are natural siblings' practices for engaging companion species' (Haraway 2003, 22), we may parallel the attempt to create and design another self to the creative act of those children who project around them a fictitious being commonly called an 'imaginary friend', a phenomenon prevalent among children aged two to five and sometimes more, which is considered an imaginative way to develop rather than a pathology. The 'transitional self' mediates between inner and outer worlds, desires, expectations, rules and reality.

> The imaginary companion allows the child some respite from the depression of realizing a separate sense of self. (Klein 1985)

Victor Frankenstein does not give his creation a name, and, consequently, neither an identity—as the monster who is refused by its creator remains his own self, without fully becoming otherness.[7] The sense of loss that follows a death or a separation seems connected to the creation of another split (Taylor, Cartwright, and Carlson 1993): in adults, a similar process of acceptation of the self, and of loss, may result in the desire for the creation of a synthetic companion onto which the person 'projects his ideals, his fears, his aggression and his love' (Klein 1985, 7). Splitting, far from being abnormal, can thus be seen as an inherent characteristic of being human, even though

> … the concept of transitional phenomenon as an intermediate area of experience between inner and outer reality … is allowed to the infant or to the adult artist, but … may be considered madness in others. (Klein 1985, 3)

Media artist **xname**, also author of the sound instrument that will be described later in the article, confesses the emergence of a form of affection between her computer and herself as she produces a work of art: this affection is documented with the attempt to 'copy the self into a new domain' (xname 2005). The 'carnal vector to "digitality"'[8] visually represents the expanding feminist politics of desire and reconfiguration of the body which Luciana Parisi defines as 'abstract sex' and which 'brings into question the pre-established biological possibilities of a body' (2004, 10).

The nature of the maternal relation—the importance of temporally extended dependencies which lead both mother and child out of their own bodies—leads to an ontology of individuals whose identity can only be complete in relation to the other, and, consequently, their behaviour will reflect this ontology.[9] If we try to draw the directions of this temporal geometry, reconnecting the idea of birth to that of *turbulence* and extending it to expression and the processes involved in the creative act, 'there is a shift from thinking of evolution in terms of a tendency toward disorder, entropy, and death to thinking of evolution as a heterogeneous process, assembling distinct modes of transmission unpredictably' (Clough 2004, 20).

In the biological materiality of their bodies, women experience time as cyclic, while chaos and catastrophe inform the experience of conception and birth. Companionship unfolds as a process of becoming one only by splitting from another, and then search for another to tend to that alterity which informs the self. In this geometry, women participate of otherness, and creativity implies the play with another, even if invisible. Comparing the human tendency of being inventive and the condition of physical intimacy of their birth and immediate upbringing, we question whether in this intimacy and rupture of identities and in the concerted play between self and other (Oreggia 2015) there maybe traces of insight into the creation of instruments and interfaces which creatively expand the self. Plant (1995), in her treatise on women and cybernetics, while re-evaluating the importance of weaving as a form of pervasive proto-technology, and comparing women and technology in their historical functions as adjuvants to men, and their undercover role of reproduction and mimesis, makes a tragicomic description of the *historical man* who 'at the peak of his triumph, the culmination of his machinic erections, … confronts the system he built for his own protection and finds it is female and dangerous' (Plant 1995, 62).

3. Live composition

In the context of electronic music, often performed with self-built interfaces and instruments, we prefer to call acts of improvisation *live composition*, to distinguish them from other traditional ideas of improvisation. For example, in jazz music, the musicians respond to each other following a certain set of rules, with the exception of free jazz where the main rules are beginning and ending (McCormack and d'Inverno 2016). Improvisation in traditional African music and percussive systems[10] have again another meaning, because different rhythms form a rather wide and varied set of *states* that musicians can use to convey different meanings, becoming a sort of language where slight variations or more complex differences can be used to respond to other instruments as well as the dancers, and groups and individuals use those rhythmic patterns to communicate and construct ceremonies which have social and spiritual values.[11] Improvisation in those cases can also be defined as the space between syntactic and religious rules, the interaction between individual players, musicians, dancers and the ceremony itself, or, it may happen, the attending daemons.

> At certain intensity level … performers will momentarily disassociate from the time line (without losing the flow of the basic timing relationship of the piece) to indulge in some sort of dialogue. (Anku 1997)

In classical music, on the other hand, often improvisation is performed as a collage of repertoires. The liberty lies in the particular way the interpreter performs those parts, and, in the case of interaction between different players, the way each player responds relating to the other and to the repertoire, embedded in a memory given by hours of exercises performed by the hands, in the attempt to potentially surpass or follow those automatic mechanical movements, as well as the rules of symphony and harmony.

In electronic music, instead, especially that music which surpasses the limits imposed by the layered timeline imposed by the hegemony of sequencers and commercial software, composition can have a performative aspect, as electronic music is often created in real time, and possibly recorded. We can distinguish among a few forms of notation, that which precedes a work, and underlines the plan for a certain composition a priori, and the descriptive method that can be implemented a posteriori, when a composition has been recorded and for some reason, the musicians attempt to find or invent a system to notate and describe it.

In this sort of musical performance, we can distinguish three entities which enter into the production of the music: the performer, the genre constraints (rules of harmony and so on) to which the performance is answerable and the instrument. As we see, although these elements may all be present in any of the above types of performance, their roles can differ substantially. It is tempting, for example, to situate the performer–instrument boundary at the surface where the performer's body encounters the instrument, but this may get the agency of improvisation wrong: if, as we have seen, the performer has well-practised routines which can be activated automatically, then the performer's agency is perhaps more naturally described in terms of invoking these routines rather than in terms of contact between the performer's body and the instrument (hybrid cases are, of course, possible). Similarly, it may be tempting to think of the genre constraints as existing outside of the performer, and prior to the performance, but this picture obscures the extent to which these constraints may be continuously emerging as performance modifies the practice that it itself obeys (one thinks of the excitement caused by a deliberate, and finely judged, transgression of the constraints during an improvised performance). The picture becomes even more complex in the case of live composition, where the hardware and software may be designed in order to facilitate a continuous, evolving dialogue.

In all of these cases, we can see that the picture is more complex than it appears at first, and that the boundaries between performer, instrument and genre are less clearly defined, and subtler, than they might have initially seemed to be. It would be tempting to think that this sort of contestation is specifically a characteristic of the aesthetic realm, but this does not seem to be the case: both the relation between brain and world (White 2011a) and that between the inside and outside of a computer (White 2011b) are similarly contestable.

4. Metaphysical software

We now have to investigate how traditional ideas of devices and interfaces fare in a world of pervasive dynamics and improvisation; specifically, we want to find a description of interactions between a person and a device. Getting away from the simple idea of a stimulus–response interaction between human and device, we are also being somewhat vague about where the boundary between player and instrument lies: assuming any instrument requires hours of practice to be played, and leaving open the question whether virtuosity belongs to the instrument, the player or both, we may, for the purpose of analysis, draw the performer–instrument boundary so as to include the embedded abilities with the instrument.

So, we start with the idea of a device which produces output, possibly after an appreciable time delay, for a given input:[12] this is crude, but it will get us started. We first want to see how the output is related to the input, supposing that the device is a (possibly chaotic) dynamical system. We need, then, to get our concepts straight.

- There is a tendency in some of the literature to identify determinism (that is, whether a device or an algorithm always produces the same output for a given input) with controllability (that is, whether we can work out how to find the input that produces a given output). Many things are deterministic without being controllable; this section will be concerned with explaining some of the differences, and interactions, between these two concepts.

  This definition uses the term 'control' in a rather neutral sense: it just means being able to produce an input which generates an appropriate output. Hegemony, in any overtly political sense, is not implied.
- Suppose, for simplicity, that we have a deterministic system. For controllability, we need two things: firstly, we need to have a practical algorithm relating input and output, and, secondly, assuming the first, we need to be able to produce an input accurately enough to produce the output that we desire. The two are closely related. Let us consider the first: a law relating input and output would (if it were practically useful) be computable by an algorithm that would take less time than simply following the evolution of the dynamical system: but there are dynamical systems where such a computation is not possible. That is, in order to find out the state of a system at time t, we would have to observe, or simulate, the behaviour of

the system up to *t*, going through all the intermediate stages.[13]

Suppose, though, that the system *does* have an algorithm linking input to output: so, we think, we might be able to make the system end up in the desired output state by specifying a particular input state. However, here we encounter another difficulty: how precisely do we have to specify the input state in order to get the output state we want? Is it even physically possible, given the imprecision of all physical apparatus, its propensity to error and inaccuracy, and so on?

Now this sort of problem will arise particularly in cases when slight differences in the initial conditions will be amplified as the system evolves: in technical terms, the trajectories of the system *diverge*, or the system has *sensitive dependence on initial conditions*.[14]

The two phenomena are linked: if a system has sensitive dependence on initial conditions, then it is quite often possible to prove that the system has positive Kolmogorov entropy, and thus that it is algorithmically incompressible.[15] And such systems are 'not exceptional, "pathological" cases'.[16] Systems like this are called chaotic.[17] So it seems that our initial model was (as we warned) too naive, and that the problem which we want to address—namely, of the human use of systems, and, in particular, of musical instruments—needs another approach.

- If, on the other hand, we change the framework to that of *continuous control*, then other possibilities become available. That is, we have a system which senses its own state, or has its state sensed, continuously: at a particular time *t*, it will sense its state and adjusts its parameters (at *t*, or maybe at *t*+something small to allow for the time its calculations take). If we do this, then we can do the following sorts of things:

  Firstly, we can, by this sort of parameter adjustment, change the behaviour of a system so that, instead of having diverging trajectories, it behaves stably and robustly. Secondly, we can (if the underlying system is chaotic) exploit the sensitivity to initial conditions and make large changes to the system's trajectory by using small feedback nudges at the appropriate moments. This possibility is used in the control of spacecraft.[18] Finally, we can deliberately make a system's behaviour chaotic (this may be useful 'in the chemical and biological technologies, as well as in handling of the loose materials').[19] So the change from the input–output paradigm to continuous control actually has quite a profound effect.

  This distinction has an obvious resonance with the two paradigms of improvisation described above: the paradigm of musical and rhythmic systems, where 'slight variations to more complex differences can be used to say and respond', compared to the paradigm of improvisation in classical music, where improvisation is a matter of selection among repertoires.

- We should notice that systems with chaotic behaviour can be either continuous or discontinuous: that is, their evolution can exhibit abrupt changes of behaviour or not. What links both of them is nonlinearity (using 'linear' here in the dynamical systems sense): that is, they are systems in which a change of output is not proportional to the change of input. (Chaotic control of spacecraft, for example, shows a system which is chaotic but, nevertheless, continuous.)

  There has been a good deal of research on discontinuous chaotic systems: work of Arnold (1986) and Thom (1989) allows one to say a good deal about their geometric structure. Discontinuous chaotic systems are already well known in music: bowed string instruments rely on discontinuous, chaotic behaviour of the system which consists of the bow and the string (Popp and Stelter 1990).

- This comparison, between straightforward input–output prediction and continuous

> control, points out that programming, or control, takes place in a particular context, and that this context influences when control interventions can be made, and what sort of influence they will have. And contexts vary: in particular, the continuous control framework allows the programme to learn, continuously, from the context, and modify its interventions accordingly. The salient features of the context, as we have described it, are what input and output are expected and at what times, and what the goal of the process is: whether it is expected to end up in a particular end state, or whether the goal is to achieve a trajectory of a certain sort, or a combination of the two.

We can reflect on this. 'The Machinic' that which can be seen as 'singular power of enunciation' rather than a mechanical imitation of a living process with 'vital autonomy' (Guattari 1995) seems to arise from the failures of controllability: for example, we think of a humanoid robot which cannot move its limbs gracefully, or which reacts to humans in an abrupt, jerky way, or we think of a device which stops reacting to input but which endlessly produces output.

The idea of behaving well in a social context probably falls out of the input–output paradigm, to be replaced by ideas of negotiation and improvisation, backed up by continuous attention to one's conversational partners. Can we construct machines which do that? We should note that, in real life, we do not usually want conversational partners that we can predict, or control, perfectly: otherwise, what would be the point of conversation, and, specifically of those aspects of conversation which went beyond the mere seeking and providing of information?

One way in which the two control paradigms differ is that the roles of the controller are different in each case: in the first, the controller's knowledge of the system configuration is given from the start, and the system configuration does not change. In the second, the controller is constantly getting information from the system, and is constantly modifying the system in response. So, in the second case, controller and system are constantly reacting to each other. In the first case, that of simple input–output behaviour, the controller can predict the system's behaviour from the start: in the second case, the controller cannot (although it may know, because it knows its own planning algorithm, where the system may end up). So there is more uncertainty in the continuous control system, it is uncertainty that the controller can deal with.

So, chaotic control is, as it were, a bargain with the problem: we may think that it would be better to be omniscient, but this may not be possible, and, in any case, our control of the system may simply work better if we abandon the epistemic privilege of being able to plan, accurately, the entire trajectory before it starts.

5. Chaos and catastrophe

There is an aesthetic and ethical appeal in exposing crude electronics on a table:[20] a box is a container, but it is also a limit to the expandable usages of a device.

At the same time, while encasing an object, the focus on the functions that are embedded in the box, and make it playable, discloses new possibilities to the musician, defining the structure of the improvisation and suggesting otherwise hidden paths.

As a simple example requiring constant control and receiving input from the environment, we will describe Cyborg1, an electronic instrument which uses logic gates to make music.

Cyborg1 is six voice oscillator[21] with six light-dependent resistors (LDRs), developed by one of the authors of this paper at Signal Culture in Upstate New York in May 2017 (Figure 1). The instrument is inspired by the experiments outlined by Collins (2006) and years of practice as a live performer and composer of improvised electronic of the designer of the

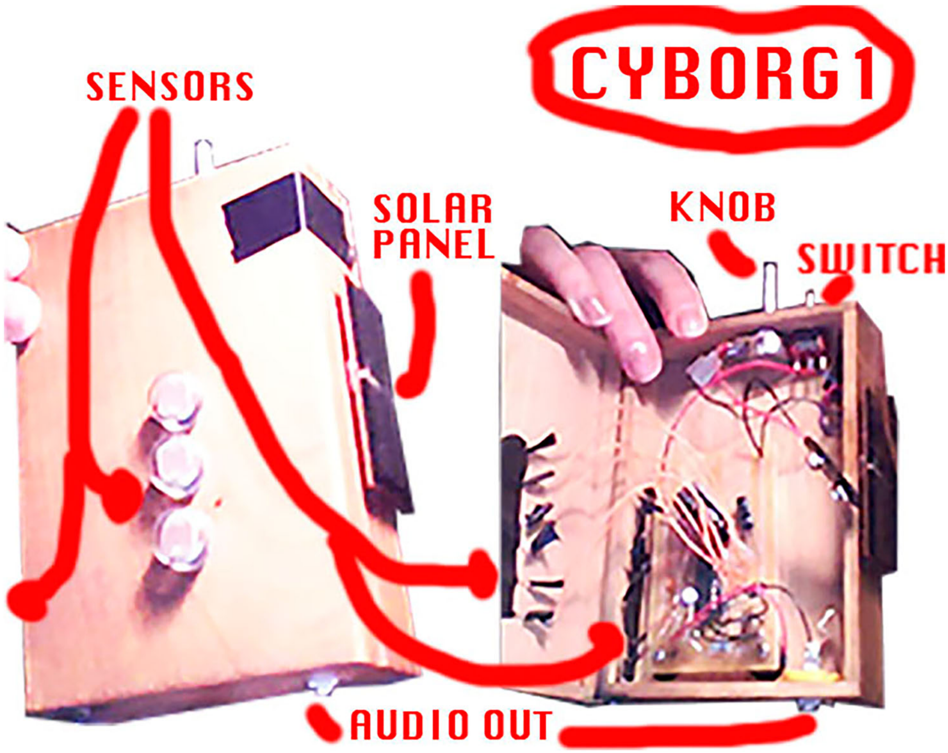

Figure 1. Cyborg1. Image courtesy of the author.

instrument.[22] Its main reference is Michel Waisvisz's Crackle box designed and built in the late 1960s together with Geert Hamelberg (Waisvisz 2004), but also Chua's oscillator, a simple electronic circuit that exhibits a behaviour that exemplifies classic chaos theory (Chua et al. 1993).

The six LDRs, one per oscillator, are divided into two series of three, placed on two different sides of a box. The instrument can be played using six fingers, three per hand; the sensors can receive different lights that the performer places on opposite sides of the box. This allows for the creation of complex melodic and polyrhythmic patterns. If the input to a sensor is a pulsating light, the result (output of the oscillator) will be rhythmic, where the speed of the pulsation will affect the bpm (beat per minute) and the luminosity will modify pitch and timbre. Alternating coloured lights tend to create melodies, where the scale is formed by the different colours that the light source can produce, and the intervals between each individual frequency. These are general rules for turning light into sound, as the nature of the chip, the logic gates and the circuit designed will create effects and complexify the internal behaviour of the device, and therefore the nature of the output. Another difference is that these kinds of instruments detect light in two different ways: through light sensors, therefore in the form of resistance (R); or through solar panels, therefore in the form of electric power, or direct current (DC). We know that these units are in a proportional relation given by Ohm's law.

$$V = IR,$$

and therefore as current increases, resistance decreases, and vice versa. Most of our instruments use either solar panels, or LDRs, or both. The interaction of the two creates the most interesting results, but generally, solar panels are suitable for producing really low tones, whereas light sensors used in circuits that have constant current, supplied by either battery or external DC, allow for the exploration of an extremely wide and rich range of middle and high frequencies.

In order to implement in a single instrument all these possibilities, Cyborg1, on the third side of its case, has a solar panel[23] that can be activated instead of the 9V battery.

The practical experience of the designer was crucial in defining the final form within which to encase the electronics, opening different possibilities for playing the instrument. The physical design of the device took into account a series of important factors, such as the position of the hands, the weight and size of the box, how a player would move it, how to move it in space or leave it on the table, etc. Finally, the distance between the different actuators was important, because certain actions could be simultaneous, while others had to be mutually exclusive.

The aesthetic research looked at minimality of controls and functions versus a multiplicity of creative possibilities and variety of sounds and interactions, with the intent to obtain wide variation, maximum expression, and some degree of unpredictability from a minimal set of affordances.[24]

The shape of the box, and the possibilities opened by positioning the actuators in specific parts of it, allow forms of chaotic interaction between different inputs and the six oscillators.[25] In addition, there is an interaction between the different lights, whose frequencies would create interferences before reaching the sensors, and the chaotic output of the six oscillators mixed into a unique signal by six diodes. Thus, a single controller allows the instrument to display a behaviour at times catastrophic. The term here does not attempt to mean that the instrument is following the specific geometry of catastrophe described by Zeeman,[26] but that it displays behaviour in which, as with Zeeman's *catastrophe machine*,[27] its state can jump discontinuously even though the changes applied to its *control parameters* are arbitrarily small (Arnold 1986) (Figure 2).

Cyborg1, the instrument described above, has only two controllers: a switch, which alternates between solar and battery power, and a knob controlling a potentiometer which proportionally increases or decreases the amount of power that is supplied by the battery to the chip. This means that there is a series resistance with the battery because the battery voltage has to flow through a resistor before it gets to the circuit. Ohm's law says that current through a resistor is accompanied by a voltage drop across the resistor. This means that, as the current drawn from the battery increases, the voltage the circuit sees will get lower (which normally is not a significant effect).

Since the amount of current drawn by the circuit may change rapidly depending on what it is doing, having the supply voltage move up and down in response to that creates a form of feedback,[28] which may change its behaviour. Exactly how it will change is almost unpredictable, and that is part of the interest of it, because this behaviour can trigger interesting dialogues within the improvisation. In some cases, very minimal movements in front of the light or almost imperceptible twists of the knob can give extreme—in a sense catastrophic—changes in the output, i.e. the sound.

When we say almost unpredictable we intend to say that experience in playing the instrument can lead to the development of a certain knowledge of how to approach a zone of non-control, therefore inducing a controlled loss of control.

There is a common trope in the critical theory literature about nonlinear dynamics, which is to assume that all nonlinear dynamics is of the same kind; that there are basically two kinds of dynamics, the linear and the nonlinear, and there is some fundamental principle underlying all nonlinear dynamics. Thus, Plant (1995) claims that

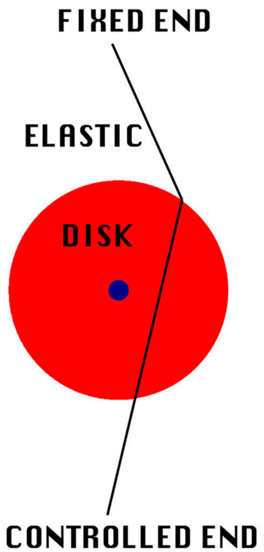

Figure 2. Zeeman's catastrophe machine.

> Rather than a linear operation, in which information comes in, is processed and goes out without any return, the cybernetic system is a feedback loop, hooked up and responsive to its own environment. Cybernetics is the science—or rather the engineering—of this abstract procedure, which is the virtual reality of systems of every scale and variety of hard and software.

Although some nonlinear systems have in them a feedback loop, some do not. For example, the solar system can exhibit chaotic dynamics without any feedback (Laskar 1997). The other, following from this, is the idea that there are two types of systems, differentiated by the flow of control: there are linear systems, in which control follows a straight line from input to output, and there are nonlinear systems, in which control follows a feedback loop. Several things are wrong here: the first is the assumption that the word 'linear' in the phrase 'nonlinear dynamics' has to do with the above distinction between two types of flow of control. It does not: it describes 'a system whose output is not proportional to its input' (Borgo and Goguen 2005). From this nonproportional response, an infinite variety of behaviour can emerge. The physicist Murray Gell-Mann, according to Borgo and Goguen (2005), described the study of nonlinear behaviour as 'the study of non-elephants': that is, there is a relatively small amount of variety in elephants, but non-elephants—that is, all of the phenomena which we do not call elephants—can be anything at all. There is no way in which we can even catalogue the things which are not elephants.

Maybe a hidden assumption, behind a lot of these critical and cultural theories, is that knowledge has a finite shape: Kant, for example, has a relatively fixed, finite architecture of knowledge (this is what his account of constitution does), and he thought that one could know a priori what things were knowable and what things were not.[29] However, the notion that knowledge could be thus finitely described fell apart in the mid-twentieth century, with Gödel's theorem and the collapse of the Vienna School programme.[30] And the vast amount of stuff that we do not know about cannot be captured in a finite way.

It is also worth noticing that there is a common misconception that 'scientists have focused the bulk of their attention, until recently, on the elephants (that is, on linear systems)' (Borgo and Goguen 2005). There is one very famous nonlinear system (which exhibits a lot of the behaviour of nonlinear systems that we can, so far, understand), and that is Newton's laws of gravitation, and, in particular, the behaviour of the solar system as described in Newton's laws. And it was when working on them that Poincaré, at the end of the nineteenth century, founded the modern theory of dynamical systems (Barrow-Green 1997).

If we connect the desire to play with tools to the ontological sense of incompleteness of humans, the cyclic perception of time to that which can be defined 'feminine' (intended as a definition of gender beyond bodily constraints), we arrive to a 'virtual multiplicity out of which novelty emerges through swerves', against a Darwinian and neo-Darwinian interpretation of evolution (Clough 2004). Accepting creation and conception as inherently chaotic and catastrophic occurrences, or microbiological encounters, we question whether we could identify, in the ontology of the female (an open and mysterious body), a useful theoretical framework for approaching code and instrument design. The study of these phenomena leads us to instruments which are open to unpredictability and which work gracefully, or brutally, in a situation of imperfect knowledge.

We could, then, suggest, within a discourse of the redefinition of gender,[31] that these novel approaches to the creation of improvisational instruments can benefit from a mindset towards writing code and designing electronic instruments and machines which is intrinsically feminine.

6. Displacement and affect

The fact that there are discontinuous changes does not mean that the behaviour of a system is unknowable: Zeeman's catastrophe machine, for example, has discontinuous behaviour which can be given a simple and easy geometrical description as what is called a *cusp catastrophe* (Wikipedia 2017). Zeeman and others (Arnold, Thom) have been able to classify the catastrophes which arise in relatively simple situations.[32] However, there are infinitely many different types of catastrophe which escape this classification, most of which are so far unexplored.[33]

If we are using discontinuous behaviour for such things as musical performance, then the language above of a bargain with the problem will apply: we know that any single system cannot represent all of the different types of discontinuous behaviour; no single system can. However, we can choose one which will give us enough discontinuity to allow behaviour which is rich enough for our purposes. But such a system cannot represent all of the different types of discontinuous behaviour that there are: it is not *universal* in the sense that Turing machines are universal.

A form of virtuosity allows for subtle plays with outer spaces of the unpredictable, a discontinuity that so much reminds us of ourselves and the world around us. If the use of indeterminacy in art has been thoroughly explored by artists representing different disciplines and using a variety of techniques, going back to John Cage (Cage 2011) and Marcel Duchamp (Duchamp 1973), and the use of drastic effects can be reminiscent of 1970s video feedback experiments (López 2005), in this study we consider indeterminacy as a form of behaviour which can be generated by particular approaches to the development of performance instruments.

Data Musician Shelly Knott's work 'Controller' (Knotts 2014), for example, is an interface where the musicians have to improvise a piece of live music while knobs and controllers appear and disappear under the click of a mouse: this is an example of this rebellious attitude of technology, and the emotional response that performers want to have with their instruments, while navigating the sound between accidental discovery, masochism and hysteria (Figure 3).

In the performance 'Robot Music', artist GOTO80 uses an uArm robot arm that plays the Commodore 64 using the defMON music software (Figure 4). The robot is controlled using Processing on a laptop. It can do things like: upset the rhythm by inserting or removing steps in the sequencer, insert, delete or transpose notes, mute channels and so on. A number of randomizing features make its behaviour non-deterministic. If this project may well remind of Harold Cohen's AARON, the painting robot (Cohen 1995), or, more recently, Patrick Tresset's Paul (Tresset and Leymarie 2013), the portrait drawing robot, as well as Shimon, the marimba-improvising robot (Hoffman and Weinberg 2010), what we find compelling for our argument in this very recent piece is the affective relationship that emerges when the robot and its creator start performing together.

The author, Anders Carlsson (aka GOTO80), talks about his robot in a written conversation with one of the authors of this paper:

> There is some kind of magic seeing the robot remix my music, even if what it's doing is very 'basic'. It doesn't feel basic.

> The idea for the future is to do more *deep improvisation* together: I'd love to have a jam partner that is available all the time, and who makes unexpected things that I would never be able to do myself.

As we have seen, these new generation of interfaces are not just allowing for random interaction or casual improvisation, they are more subtle: they give us the possibility to control the emergence of zones of chaos or in some cases catastrophic behaviour, and to develop an affective sensitivity to them.

7. Conclusion

This process of thought shows us two things: one about machines, and one about the process of composition. We are tempted to think of a machine in purely functional terms, as if it were fully specified by its input–output relations, and as if it always worked perfectly.

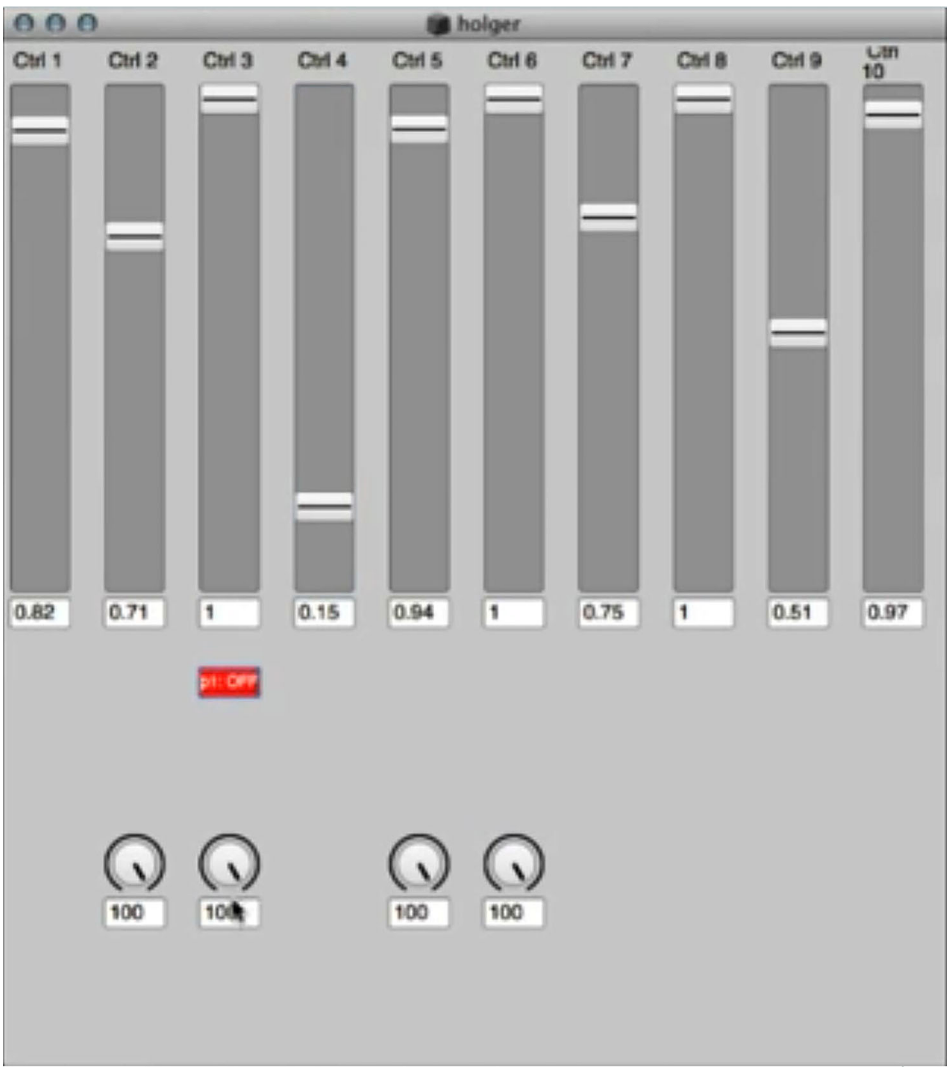

Figure 3. Shelly Knott's controller. Still from the video.

Figure 4. Robot music by GOTO80. Algomech Festival, Sheffield 2017. Photo by James Vanderhoven.

When we combine this with the idea (imported from human–computer interface design) that these input–output relations ought to be optimized for ease of use, then we arrive at a view of machines which is, when applied to musical instruments, somewhat dysfunctional. There are (and there always have been) musical instruments which just barely work, which are always on the verge of not working, or for which their ideal input–output relations are never fully specified. Difficult instruments are very prevalent, for all sorts of reasons: the possibilities for display and virtuosity that they give, the challenge that they pose to performers and so on.

Human beings are also underspecified: we are extended by the devices which we interact with, and some of this interaction is not done in order to make our lives easier, but to make them more difficult.

A sense of displacement can be created when we interact and improvise with interfaces which we cannot fully control as they become more uncertain and similar to life in that they are expressive. This otherness and uncontrollability generate that attraction which leads to a novel pleasure, to a novel art, because the improvisational dialogue with our interfaces becomes affective. Improvising with an artificial companion means in fact accepting a dynamic tension between ease and disconcert, chaos and complexity, playing with that which we know but also with that other sense of despair, the unexpected trigger that makes a device become uncomfortable, or simply sends us out of control.

Notes

1.

> A thing is defined by its essence. In order to design it so that it functions well—a receptacle, a chair, a house—its essence must first be explored; it should serve its purpose perfectly, that is, fulfil its function practically and be durable, inexpensive and 'beautiful'. (Gropius 1925)

2. From a fine art perspective, software and electronics are not only media but also techniques used by contemporary artists, not differently from engraving and xylography that diffused in Europe from fourteenth century.

3. See, for example, technologically aided forms of perception and virtual reality.
4. We are referring here not only to the relatively large percentage of time that mother and child spend in physical contact, but also to some more metaphorical (psychological, psychical and cultural) connection.
5. A notable property of this process is the fact that the line of physical connection from the present back to deep ancestry is uninterrupted only if entirely composed of women.
6. Arguments such as this are nothing new. For example, Adorno and Horkheimer (1937) describe the way in which traditional social theory conceives of human society as a rationally constructed mechanism, a mechanism which is a product of human actions: and, they claim, this excessively optimistic view of human society comes about because the members of a particular society identify themselves with it, an identification that is almost Freudian. So here, too, we get an argument from facts about early human development to the way that human beings behave in a wider context. Similarly, Honneth (2006) describes similar arguments in critical theory which use, instead of Freudian psychoanalytic theory, Bowlby's object-relation theory.
7. And it is no objection that the monster is commonly called and remembered with its creator's name, Frankenstein.
8.

> A computer is a sort of partner for human beings; this connection can lead to physical attraction. When the affection becomes desire, intimacy, sexuality, the sentimental factor comes in. The attraction towards this entity renders to transmutation … The body, becoming digital image, changes its substance and penetrates the machine, establishing the possibility to start a new form of existence. (xname 2005)

9. We also attempt to reflect on the fact that, although every human is a child, not every human is a mother.
10. It is to be noted that Agawu and others believe that the concept of 'African rhythm', while being a topos, is a generalization and an invention of the eleventh century (Agawu 1995).
11. Anku in his enlightening paper about the structural organization of rhythm in African music distinguishes between two broad categories of music practised in Africa: 'free rhythm' and 'dance drumming', the second describing music that is generally organized as a social event (Anku 2000).
12. This behaviour is sometimes called *linear*; see, for example, Plant (1995) and Clough (2004). This terminology is a little confusing, because the term 'linear' is also used, with a very different meaning, in the dynamical systems literature: there are means that the output of a system is always proportional to the input. We will be using that literature in this section, and will use the dynamical systems meaning of 'linear'.
13. This behaviour is called *algorithmic incompressibility*: Galatolo (2003) shows that dynamical systems which have what is called *positive Kolmogorov entropy* have this property (strictly speaking, if a system has positive Kolmogorov entropy, its behaviour is algorithmically incompressible for almost all initial conditions).
14. See Andriewskii and Fradkov (2003, §1) for definitions and examples.
15. There is an example, the automorphism of the torus, in Sinai (2009).
16. Andriewskii and Fradkov (2003, §1).
17. The definitions of chaos are, it should be warned, somewhat technical and detailed: see Devaney (2003) and Ruelle (1993).
18. See Sliz, Suli, and Kovacs (2015) and Macau and Grebogi (2006).
19. For all of this, see Andriewskii and Fradkov (2003, §3).
20. We use the term aesthetics looking closely at its root in perception (αἰσθητικός), without following the most recent and superficial sense of appreciation of the beautiful, which Marchel Duchamp defines *callistics* (Duchamp 1973). In its original acceptation, aesthetics was as a branch of axiological philosophy strictly connected to ethics (ἠθική), which is sometimes considered to be its sub-branch. It is in this axiology that the opposition between good and bad comes into play. In Classical Greek society, virtue and beauty were considered interdependent, and were both connected to the body. See the concept of καλοκαγαθία (kalokagathia, the harmonious combination of bodily, moral and spiritual virtues), omnipresent in Classical Greek literature and philosophy (Rocci 1981).

21. Based on a CMOS inverter (74HC).
22. Consult http://xname.cc/phantasmata.
23. The solar panel used in the prototype has a limit of 1.5 V so the chip covers lower frequencies and when the panel receives too much power, it interrupts the connection.
24. Consult Jack, Stockman, and McPherson (2017) for a study on reduced control and constrained mappings on performance technique.
25. In certain conditions, some oscillators would not produce any sound, while in others they would be extremely loud and predominant.
26. For a demonstration of Zeeman's Catastrophe machine, consult https://vimeo.com/38108807.
27. Here we have a disk which can rotate about its centre: a point on the circumference of the disk is linked to a fixed point above the disk by a length of elastic, and to a moveable point below the disk by another length of elastic. Depending on the position of the moveable point, there will be either one or two stable positions for the disk: moving that point can bring about discontinuous changes from one equilibrium position to the other.
28. For some reflections on the creative potential in improvisation of feedback and resonance, see Bowers and Haas (2014) and McPherson and Zappi (2015).
29. See the metaphor of building a house in the Transcendental Doctrine of Method, *Critique of Pure Reason* A707, B735.
30. Although the question of the interpretation of Gödel's theorem is difficult (Raatikainen 2015), it certainly puts huge barriers in the way of asserting that all human knowledge has a fixed, knowable, finitely describable architecture.
31. We are not reducing here the essence of the feminine to the body or reproduction, and we are therefore including non-reproducing female or male and any other redefined gender who can potentially possess this intuitively in the argument.
32. Technically speaking, in the cases when the dynamics arise from the minimization of a potential and where the parameter space has a small number of dimensions.
33. Arnold (1986) describes the catastrophes which arise when one's viewpoint moves when viewing a three-dimensional scene: such a movement, even if arbitrarily small, can, with the viewpoint placed appropriately, cause sudden changes in the geometry of the image. The book also gives a good impression of the inexhaustibility of the subject: one gets a large number of catastrophes even when the three-dimensional scene is very simple, and the number of catastrophes increases rapidly when the number of objects in the scene increases.

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Notes on contributors

Eleonora Oreggia (also known as **xname**) is an Italian interdisciplinary artist, researcher and composer of electronic music from Milan. She received a Laurea (Summa cum Laude) in 'Literature and Philosophy' from the University of Bologna (DAMS, Drama, Art and Music Studies), with a thesis in Semiotics of Art (supervised by Paolo Fabbri). In 2003 she moved to Amsterdam to work as editor and researcher at NIMK (Netherlands Institute for Media Art), initially with a Leonardo scholarship. In 2008 she became Researcher in Design at Jan van Eyck Academie in Maastricht. Since then she lives in London, where she obtained an MPhil from Goldsmiths University (under the supervision of Matthew Fuller) and she is currently writing up a PhD in Media & Arts Technology funded by the Queen Mary University of London and the EPSRC. Her research, starting from a set of techniques to turn light into music, is now exploring methodologies to perceive the electromagnetic field and use technology to develop new senses.

Graham White has studied mathematics at Oxford and MIT, and has published on the history of logic (in particular in the late Middle Ages), on the metatheory of cognitive science, and on philosophy. He is a lecturer at the Queen Mary University of London.

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