The Embodiment of the Ephemeral:

Live Coding Adaptive Systems

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The incompleteness and the uncertainty of our knowledge,

our precariousness, suspended over the abyss of the immensity of what we don't know,

does not render life meaningless: it makes it interesting and precious.

Carlo Rovelli , 2017

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1. Introduction

The present dissertation concerns the tension between ephemerality and embodiment that emerged from my philosophical inquiry into technology and how it affected my activity as a computer musician and live coder. As a young artist undertaking this research project, I found myself thrown into a world of endless possibilities, essences and perspectives mediated by the interaction with technological artifacts. This exploration has inspired me to create a personal artistic practice centered on an idiosyncratic use of technology, which I later expanded into a framework for collaborative improvisation.

By deconstructing the concepts of technique and instrumental relationship, I realized how a philosophical inquiry could provide knowledge beyond mere technical proficiency, eventually including the opportunity to understand and question the values and meanings inscribed in technologies. This shift in focus towards technology as a subject of study rather than a mere tool to achieve pre-established goals, led me to explore the tension between controlling technology and letting it free to reveal new possibilities. Starting from the awareness that technology cannot be neutral, I explain my choice to adopt a bricolage approach to software development and how it allows me both to inscribe personal aesthetic values and to design the affordances of technological artifacts. Resorting to examples from my own work, I explain how this approach often yields surprising results that encourage to re-evaluate one's initial intentions and come up with better, more informed ideas. Moreover, I investigate the kind of embodiment that can be developed with such artifacts in computer music practices, and how this is intertwined with the development of a hermeneutics of the artifact itself. Beginning with a reflection on performance practices such as live

coding, I explain how my ideas on embodiment affect the aspects of virtuosity and liveness. These reflections are then incorporated in my practice as a digital artist, where software is tackled as an ongoing research process, and in my work with live coding and adaptive systems where the technological artifact is valued for its ephemerality, and whose ability to change becomes one of the values inscribed within it.

Building from these considerations, I develop a reflection on a possible reconciliation between the development of an acquaintance with technological artifacts necessary to embody them, and the desire for continuous evolution and self-questioning that motivates my artistic practice. This raises the fundamental question that I attempt to address in this thesis: can the ephemeral be embodied?

2. The intangible hammer

As an artist who has embarked on a research project, I believe that one of my responsibilities is to spread awareness about aspects of my research that are not yet fully understood or grounded in established practices. Therefore, it is crucial for me to communicate to people what I am doing, whether it be through an academic lecture, an interview for a magazine, or a casual conversation after a concert or workshop. In my case, this often involves trying to explain in accessible terms what my practice as a computer musician and live coder entails, and in particular, the type of relationship I have with the computer. To emphasize the distinctions between my approach and others, I depict the computer as a medium for envisioning and discovering novel sonic ecologies, and my work as an investigation into new approaches entailing the invention of instruments that are conceptually distinct from those found in the realms of acoustic and analog. While such a description provides an initial intuitive explanation, it often raises questions from my interlocutors about the appearance of these instruments and doubts about how they can be played by a musician, especially on stage. These frequent questions highlight how the common understanding of technology in music is still limited to a very narrow notion of musical instruments, that regards them as physical objects that are mastered through manual skills and dexterity, similar to the expertise possessed by a carpenter. The issue goes beyond redefining instruments, as such definitions come with preconceived notions about the act of playing and performing, the creative process, and the ability to define one's own personal aesthetic values. In this chapter, I will investigate how these ideas are grounded in past philosophical perspectives whose dualistic approach winds up separating knowing from doing, and mind from body.

Furthermore I will illustrate how this makes them inadequate to describe many contemporary art practices using digital technologies.

2.1 Beyond dualisms

In ancient Greek philosophy technical skills fell under the name of technê – which stands for craft or art – and which differs from its complementary concept of epistêmê – literally translated as *to know*. The definition of these two terms is attributed to Aristotle in the *Nicomachean Ethics* (1962), where he defines epistêmê as scientifically certain context-independent knowledge that finds an aim in itself, while tecnhê as a set of methods and strategies involved in the accomplishment of a goal that can require some theory, but focuses on the making. In the context of music, acquiring the ability to play an instrument requires extensive practice of technê. This is because playing is mainly a practical activity that cannot be mastered solely by reading books or theoretical study, but instead requires several hours of practice daily. However, even those who succeed in flawlessly performing the most complex pieces do not acquire a comprehensive understanding of how their movements lead to such results only through physical practice. If one sticks to the definition of technique as something goal oriented, we can see how activities that involve high levels of reasoning and mental effort can also be oriented towards achieving specific goals, just like physical activities can enhance knowledge and understanding. When musicians are concerned with an activity regarded as mental, e.g. composing, they still need extensive practice to develop expertise. At the same time they cannot acquire a comprehensive understanding of this process just by going through trial and error, or by blindly applying pre-established rules. The dichotomy between technique and knowledge often leads to the separation of physical and cognitive abilities, echoing a dualistic view that separates

mind and body as in Descartes's philosophy. Applying this dichotomy to music, splitting theory and practice, is highly problematic since it leads to defining technique solely as a physical skill acquired through muscle memory ignoring the mental aspect involved in playing music, and reduces knowledge to cognitive skills disregarding the physical components involved in music performance. As someone who has been playing the piano since an early age, I recognize how these aspects are deeply intertwined. The type of muscle memory I have developed through the piano keyboard is directly linked to my thinking and understanding of harmony as structured on equal temperament with 12 divisions of the octave. For example, when I need to imagine a harmonic progression, I mentally visualize the piano keyboard and almost find myself moving my fingers as if I were playing it. Many theories in cognitive sciences[1] provide frameworks that challenge the traditional dualism between the mind and the body, as they recognize that our cognitive processes are inextricably linked with our bodily experiences. This integration of sensory and motor systems with cognitive processing is crucial in understanding how the knowledge acquired through music-making is always grounded in a practical activity. In this regard the activity can be seen as both practical and theoretical, and even if these two aspects can be distinguished, they can never be separated or thought of independently.

2.2 The intangible hammer

Many of the problems that arise when we talk about a musical instrument stem from the fact that we approach it as if it were a tool as simple as a hammer. In the text *Being and Time*, philosopher Martin Heidegger (1962) uses the famous example of the hammer to describe how technologies can

[1] For example see embodied cognition in (Varela, Thompson and Rosch 1991), situated cognition in (Brown, Collins and Duguid 1989).

become embodied in the human subject. His example shows how knowledge of the hammer does not emerge from a theoretical study of its operation, but from the familiarity with the action of hammering acquired through the reiteration of the task and the development of an acquaintance with it. For Heidegger, the user becomes interested in the inner workings of the hammer only when it stops functioning properly. Although the musical instrument also requires an embodiment developed through repeated practice, while the purpose of the hammer tends to be making a physical task easier, with the musical instrument we interact for an expressive purpose. Defining when a musical instrument ceases to function properly – or goes from being *ready-to-hand* to *present-at-hand* to follow the Heidggerian terminology (Heidegger 1962) – is something that emerges from the artist's aesthetic and expressive needs and cannot be determined precisely, as in the case of an object as simple as the hammer. The idea that the relationship with the musical instrument is primarily technical stems from the interpretation of art as something that has a means to an end, thus following the ancient Greek interpretation of techne. In the *Republic* and in the *Laws* for example (Edith and Cairns 1961), Plato suggests that art should follow precise rules in order to mirror the perfection of the Ideal World[2]. This is why Plato's metaphysics leads to suspicion toward the fine arts, because it considers the artist's work as a simulacrum of things in the world of material objects, which are themselves imperfect imitations of things in the world of Forms (Young 2023). Although viewing art as a practice that must imitate certain canons does not undermine the fact that it remains an expressive discipline, from such perspective the role of the instrument takes on a goal-oriented approach, that is, of facilitating the attainment of an ideal of beauty, and to reflect predetermined values.

[2] Plato attributes specifically to music a strong ethical value, given its ability to influence souls (Young 2023).

In the post-postmodern world, the idea that artists should stick to eternal canons of beauty has eventually been rejected, as has the existence of absolute values. In this context, calling musical instruments *instruments* can introduce a number of ambiguities, as often the kind of relationship we have with these artifacts is not instrumental at all, and the design of the instrument becomes an important part of the artistic research. As Magnusson suggests:

> "The instrument becomes epistemic, composed, often directly fusing the instrument with the composition" and "[...] a specific technique becomes the theory and aesthetic of a new piece." (Magnusson 2019: 57)

The issue I refer to here as the *intangible hammer* arises when the term *instrument* is used to describe an artifact in terms of its intrinsic nature, rather than its function. The term could refer to a hammer, a musical instrument, or a computer program and in this sense it does not convey an ontological characteristic of the object, but rather a state that is defined in the context of its use by the user. I therefore argue that the concept of *instrument* does not exist in and of itself, but is rather contingent to activities directed towards pre-established human ends. By *intangible hammer* I mean the set of assumptions and preconceptions hiding behind the term *instrument*, when it is used to describe the interaction with highly sophisticated technological artifacts for expressive purposes, as if it were a simple process of hammering in the most primitive sense. To understand the intangible component inherent in each instrumental action, it is necessary to refrain from viewing technological artifacts as mere physical objects solely involved in physical activities, or engaged with clearly established goals. If a hammer enhances the tangible component of a technological artifact, to investigate the intangible counterpart, we can take the example of a book[3].

[3] for a deeper look into technology as text see (Grint and Woolgar 1997).

What defines a book is neither its physical appearance nor the way it is leafed through, it is the content of what is written – or inscribed, in the case of technological artifacts – that defines it. Ultimately, while artifacts can often manifest through tangible objects we interact with, their tangible counterparts are only one of the aspects of the intricate set of relationships that are established with them.

2.3 Questioning technology

In ancient Greek philosophy, the relationship toward things as a means to an end was often regarded with suspicion, and the prevailing belief held that true purification and access to authentic knowledge could only be attained through contemplative and disinterested study (Russel 2015).

It is interesting to see how John Burnet explains the importance of aimless contemplation in Pythagorean doctrine by stating that there are three types of people in life " just as there are three sorts of people who come to the Olympic Games. The lowest class is made up of those who come to buy and sell, the next above them are those who compete. Best of all, however, are those who come simply to look on. The greatest purification of all is, therefore, disinterested science[...]" (Burnet in Russel, 2015: 52). Following this logic, it would not be the musician, but the audience who deserves true admiration, as they play a more important role – they have an aimless interest in the music. On the contrary, the general modern interpretation puts the musician at the center of attention and admires their ability to use the instrument rather than the interest of the audience. As an artist who extensively employs technology in my artistic practice, I have observed how its affordance can sometimes lead to engaging the creative process as a mere means to an end instead of a research. The constant promotion of increasingly powerful and accessible technologies,

particularly in the commercial sector, leads artists to focus on generating content in an imitative manner while the pressure to remain productive and deliver rapid results hinders the deeper questioning of fundamental aspects of artistic research. In the famous essay *The Question Concerning Technology*, Martin Heidegger (1977) highlights how the modern interpretation of technology carries the risk to impose an instrumental relationship with the world that leads to exploitation instead of the development of knowledge and awareness. In his essay Heidegger remembers how techne in ancient Greek was a term used to describe both technology and art.

> "There was a time when it was not technology alone that bore the name techné. Once that revealing that brings forth truth into the splendor of radiant appearing also was called techné. Once there was a time when the bringing-forth of the true into the beautiful was called techné. And the poiésis of the fine arts also was called techné." (Heidegger 1977: 34)

Both technology and art here are seen as two modes of revealing the essence of things in the act of poiesis – that is to bring something into being. While technology bears the danger to impose a totalising world-view, art has the capability of revealing the essence of things. Ultimately, for Heidegger art has the potential to save the human from the dangers of technology.

> "Because the essence of technology is nothing technological, essential reflection upon technology and decisive confrontation with it must happen in a realm that is, on the one hand, akin to the essence of technology and, on the other, fundamentally different from it. Such a realm is art. But certainly only if reflection upon art, for its part, does not shut its eyes to the constellation of truth, concerning which we are questioning." (Heidegger 1977: 35)

Reading Heidegger as an artist who works with and designs technological artifacts, I realize the importance of gaining a deeper understanding of the underlying concepts of the technologies I use, and what could be their role in revealing the world. Instead of being concerned with technology only for the purpose of employing it, in my work I shall also inquire into this essence, by freeing my vision from the all-encompassing and blinding modern technological perspective, by looking at technology in a way akin to how a Pythagorean would observe the Olympic Games. Therefore, in my capacity as a digital artist, computer musician, and live coder, I deem crucial to communicate my perspective on technology. This implies not only to outline how technology serves as a tool to achieve specific outcomes in my work, but also striving to look at it from an epistemic perspective and examine the very essence of this relationship, which differs from the mere instrumental use. At the same time, observing the world around me I notice that this essence is never a fixed, one-dimensional concept, but a complex entanglement in constant reconfiguration and observable from different perspectives. The philosopher Don Ihde proposed the term Multistability (Ihde 1990) to describe how technologies do not have a fixed essence, but are instead always repurposed, and acquire different forms and meanings depending on the context and perspective from which they are tackled. In digital technologies, the emergence of new ideas and approaches is intrinsically linked to their ceaseless update and development. The design of these technological artifacts therefore is not a search for absolute values, but a flow in which these values are challenged and redefined. As an artist, I aim to uncover the diverse approaches that are not grounded in the essence but rather in the essences of technology and art. This process is informed by the knowledge previously accumulated, but its strength lies in its ability to change and adapt.

3. Beyond intentionality / non human agency

In a famous essay, the French philosopher Bruno Latour raises an ethical question regarding the use of equipment that parallels artistic practice (Latour 1995). Latour uses the example of an angry citizen armed with a gun to introduce his question and explains how holding the weapon can influence the person's intentions, channeling anger towards a murderous act, instead of another milder reaction. The issue raised by Latour is whether it is the individual who pulled the trigger or the gun, which provided the chance to kill with ease, that should be accounted as responsible for the murder. Latour suggests two possible answers: "the myth of the Neutral Tool under complete human control" (Latour 1995: 32) – where the human is accountable, and "the myth of the Autonomous Destiny that no human can master" (Latour 1995: 32) – where the gun is the culprit of the killing. For the purpose of the present dissertation, the question could be rephrased as: how to tell when the outcome of a creative effort is coming from the artist rather than from the instrument?

3.1 The myth of the neutral instrument

If we condense the myth of the neutral instrument into one sentence, it would likely be this: technology itself is neutral, it is merely a matter of how you use it. However, this view assumes that interaction with technological artifacts takes place after a mental process that clearly establishes the goal to be achieved. This implies that the artistic result is entirely defined *a priori* through reasoning, and is unaffected by the interaction with technological artifacts. From a philosophical perspective, it perpetuates the Cartesian dualistic interpretation of consciousness, where reasoning

and acting are considered as two separate processes. In other words, while the human mind directs the activity, the instrument simply obeys the commands.

During the 20th century many composers who extensively worked with new technologies considered them as subservient to their genius. I would like to elaborate on how a contemporary interpretation can reformulate the desire for neutral technology resorting to two iconic examples: Let us first consider this famous quote by the composer Edgar Varèse:

> "I dream of instruments obedient to my thought and whim, with their contribution of a whole new world of unsuspected sounds, which will lend themselves to the exigencies of my inner rhythm." (Varèse 1936).

In envisioning the Liberation of Sound, Varese was aware of how new technologies would have played a central role in freeing music from the constraints of traditional musical instruments. For him the ideal instrument is obedient and allows to express the new music he envisions, a music made of organized sound instead of traditional pitches and structures. For Varese it is undoubtedly the composer's imagination that drives the artistic process, at the same I find an interesting tension in his words as it is not clear how the instrument can be obedient, and at the same time help unveil new unsuspected sounds. What I read in his words, and encounter in my own practice, is that interaction with technology is always a trade-off between transparency and the unveiling of new possibilities. The ideal instrument, as Varese suggests, would be both obedient and capable of unveiling new worlds of unsuspected sounds. Unfortunately these two aspects are in conflict and technology always seeks for a compromise between them.

Similarly Iannis Xenakis (in Solomos 2014) maintained :

"The computer, as well as any technical means of expression, is only the instrument of the one who uses it. The computer offers more possibilities, that's all. The result depends on the person, his genius, his inclinations. The computer is not a guarantee, but a source of possibilities."

In this passage Xenakis stresses clearly how technological artifacts are means of expression of the user. Advanced technologies, such as the computer, offer more possibilities, yet they are still considered as transducers of the composer's genius. From today's perspective this seems contradictory to me especially considering his extensive work on stochastic processes. As Xenakis' artistic practice was based on an highly idiosyncratic approach to technology, he attributed the results produced by the instruments to his own person. However, in works such as Gendy (Serra 1993), Xenakis voluntarily preserves a degree of autonomy for the computer, and thus there appears to be a willingness on his side to be surprised by technology instead of being in control of it. My intent here is not to simplify Xenakis's philosophy of technology, which is a very articulate and deep thinking that certainly cannot be condensed into a quote. When Xenakis argues that technology must be controlled, I do not think he means that it is neutral. On the contrary, it is precisely because it is not neutral that he wants to control it. Like many modernists, Xenakis is inclined to control technology in response to the widespread distrust in technological progress influenced by the atrocities of the war (Solomos 2014). By controlling the instrument the humans implicitly take responsibility for their actions expanded by the power of technology, which can be used for both positive and destructive ends.

3.2 The myth of the autonomous destiny

Nowadays the idea that technology must be obedient is no longer prevalent. The design of technological devices involves having complex functionality already built in, sound presets, project templates, libraries of pre-recorded sounds, complex algorithms trained on large amounts of data and intelligent features that can suggest settings and possibilities. The quality of these artifacts is not measured by their obedience, but instead on their ability to influence the creative process in a certain direction that is considered appealing. In the commercial sphere there is a great deal of speculation on this aspect. Software and equipment manufacturers consistently present their latest models as the ultimate solution, complete with all the features necessary for artists, including the ability to provide inspiration and fill gaps in areas where the user lacks expertise. This often happens in parallel with a mystification of the tool's operation that takes on an almost esoteric fashion regarded with suspicion and reverence. So while the paradigm of the instrument being subservient to the composer's genius is somewhat outdated today, it seems that the reasons why this obedience was once desired have been forgotten by the majority of artists, who approach technology simply as users. As highlighted by McLean:

> "This can lead to the bizarre situation where programmers make commercial software which practically generates music, and yet somehow the users of the software are seen as being more creative than the programmers. Here the programmers encode their musical style in the software, and the users go little beyond guiding the software to a destination pleasing to them. [...] The creativity of programmers is tapped into flattery of paying users." (McLean 2008: 230)

For example, there are devices capable of suggesting engaging harmonic progressions, sound and preset libraries for creating specific sonorities of popular musical genres, percussion loops containing specific grooves and rhythms, and mastering assistants capable of finalizing a track based on a specific musical genre. In all these cases, through the design of specific affordances, it is the instrument rather than the user that dictates the end result. In the Actor Network Theory framework elaborated by Latour (2005) and others, this kind of dynamic arises since "the more technological systems proliferate, the more they become opaque" (Latour and Venn 2002: 251). Sophisticated technological artifacts consist of multiple components that work collectively to determine their behavior and affordances. However, the complexity of these components also makes the inner workings of these artifacts opaque and difficult to understand. As a result, in Latour's opinion, technological artifacts tend to behave as black boxes, whose internal functioning remains inscrutable, and can only be observed in terms of their inputs and outputs. For instance, in a laptop, the motherboard, *CPU, GPU, RAM,* and *SSD* collectively define how the object functions, and work as a single entity, thus enabling the user to focus on the core activity rather than worry about the underlying infrastructure. This enables musicians to have complete confidence in their laptop's functioning without losing energy in questioning its internal workings, and channel all their efforts into creating sounds with it. At the same time, a musician who spends many hours working on a computer does not acquire knowledge of its internal functioning, which remains an opaque process occurring under the hood. By making the inner workings opaque and inscrutable, the process by which an artifact becomes a black box hides all the decisions made by the developers and the biases they might carry. As Magnusson points out, musical instruments don't escape this process and are "impregnated with thoughts; they are embedded with ideologies that

have ethical, political and aesthetical implications" (Magnusson 2009a). The keyboard of a synthesizer for example encapsulates the Western view of the octave subdivision. The staff may suggest that pitch and duration are the two most important aspects of musical notation and a drum machine or *VST*[4] that the kind of sounds of a digital instrument should mimic those of an acoustic instrument. For these reasons, through the study of technological artifacts we can gain knowledge that goes beyond mere technical proficiency and also includes the values inscribed in technology. While I do not think that this knowledge on technology should necessarily pass through an engineering understanding of its operation, relying on cutting edge technologies without understanding them makes the artist a pawn in the hands of technological development. This occurs both when an artist blindly follows the affordances of technology determined by the industry, and when the artist places the use of innovative technology at the foreground of their practice, thus creating an aura of mystery and reverence around their work, but without developing a reflection on the implications of its usage. As an artist whose practice is closely intertwined with technology, I think these trends are deeply problematic. From my perspective I do not think my role is to promote new technologies developed by industry, but rather to critically question their operation and affordances and ultimately the worldview they encapsulate.

3.3 The detour

Given these premises, how can we address the initial question regarding the origin of intentionality as something that belongs to the human or the technological realm? Latour's conclusion is that both these options are implausible, as both subjects involved exert their influence on the other

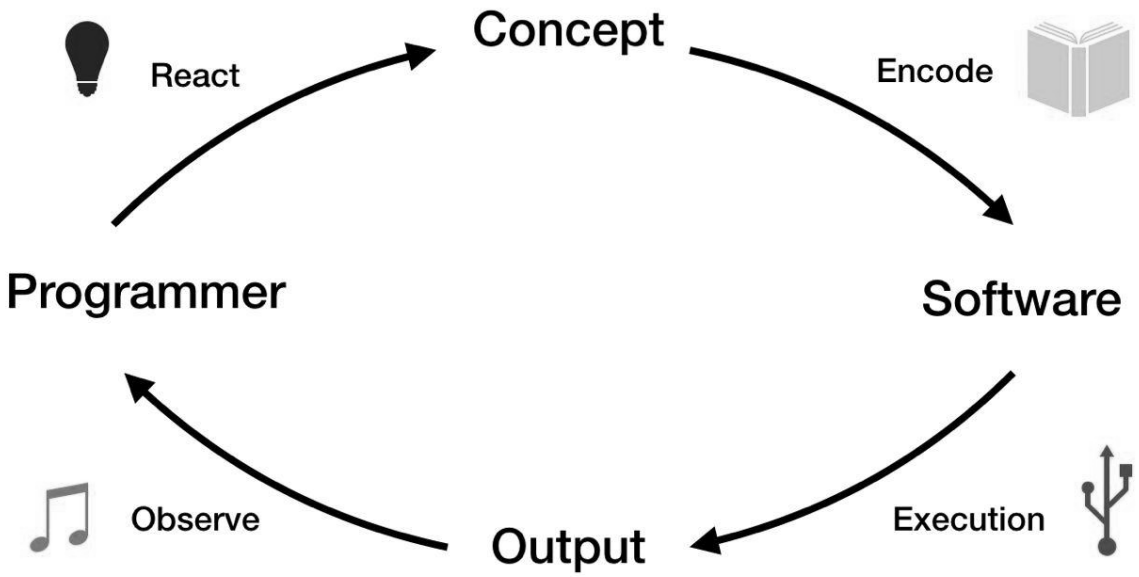
[4] virtual software instrument.

symmetrically. For Latour agency is not exclusive to the human, nor to the technological artifact, but rather something emerging from a network of relationships between human and non-human actants. By seeking a continuity between human and non-human agents, Latour shows that the moment when the citizen holds the gun, the dichotomy between the user and the tool vanishes and they become inextricably linked to each other, and the final outcome is the result of a new agent resulting from the interaction of the two. As highlighted before referring to the quote from Varese, the moment musical instruments unveil unsuspected possibilities they are exerting an influence on the final results. This interaction often creates an uncertainty about the goal, a shift from the initial intentions, or to put in Latour words: a *translation*. That is:

> "The creation of a new goal that corresponds to neither agent's program of action.(You had wanted only to hurt but, with a gun now in hand, you want to kill.) I call this uncertainty about goals translation." (Latour 1994: 32)

The encounter with technology is, according to Latour, the beginning of a detour where through insight and trial and error a goal is achieved, yet this goal is not always what we had originally set out to achieve. In my artistic practice I am constantly facing this type of dynamic. I begin by posing a series of questions, which I then explore through interactions with technological artifacts. This process of interaction often leads to a shift in my perspective and a reframing of the original question. Reflecting on this process retrospectively, I realize that the initial question was often trivial or poorly formulated, and that the value of the resulting work should not be measured solely by how well it addresses the original question, but rather by how effectively it lays the groundwork for further research and the development of more relevant and thoughtful questions. This is also reflected in my approach towards software development, which is not directed towards achieving a

specific and predetermined goal, but rather towards exploring various configurations of said software. In my workflow, I engage in a continuous iteration process where I observe the output of the current configuration and use it to formulate new concepts that are then encoded into the software to create the subsequent output. This creative process does not follow a linear logic, but instead adopts a bricolage approach (McLean and Wiggins 2010), where various components are continuously assembled in different ways.



For example, the initial idea behind *Time Debris* was to look for a new paradigm to represent musical time using the computer. If I were to make an evaluation of the work I was developing based on the goal I had initially set for myself, I would have considered the work to be not promising because the results it was yielding were very different from what I had envisioned.

Despite these considerations, several new possibilities have emerged while the research was being carried out, be it through the interaction with technology, by listening to the sound results or from feedback received from colleagues, teachers, and friends. These considerations set the stage for future work and explorations, which were in fact carried out in *Adapt*. Eventually these insights have been incorporated in *Time Debris*. This detour has revealed that the initial idea of constructing an autonomous system based on a new temporal paradigm was vague, imprecise, and probably impossible to achieve from my starting point, but it has also disclosed a series of possibilities regarding how the system responded to the performer's intervention and how sound processes could interact with one another. In this process, I did not merely implement a pre-existing idea into the software, but rather the idea itself took shape during the implementation process. I find resonance with a passage from a recent book by musician Mark Fell, in which he explains his creative process with the software Max/MSP:

> "In researching this book, I looked for plans and sketches of processes to be implemented in MaxMSP, but I didn't find any – simply because the software platform itself is the space where these ideas are shaped, through several iterations" (Fell 2021: 21).

By continuously observing the response of a technological artifact, a bricolage programming approach enables the artist to shape the affordances of technology and to meet their individual needs, rather than being limited by preconceived notions of what technology can or should do. In this way, the artifact becomes an intimate extension of the artist and reflects their own specific aesthetic values. In this process, software is not only the tool for translating ideas into executable programs, but becomes the environment in which ideas take shape and are actively processed.

Ultimately, I think that when we approach technology having in mind discovery rather than a predetermined goal, we should not worry too much about getting exactly the results we had in mind in the first place. To develop a personal and idiosyncratic practice and to disclose alternative perspectives one has to challenge the affordances of the technological artifact by repurposing and redesigning them. This approach often leads to unpredictable results whose significance may become clear only in hindsight. In this sense the detour becomes more interesting than the achievement of the final result we had set for ourselves, therefore interacting with technological artifacts that have a certain autonomy can be more desirable than having a transparent tool.

4. A post-phenomenological approach to embodiment

In the previous chapter, I discussed non-human agency starting from Bruno Latour's work on technical mediation, which posits that the relationship between humans and technological artifacts is entirely symmetrical. The work of Latour considers both human beings and technological artifacts as two agents on the same level, highlighting their common traits. By doing this, it looks at the interaction between human and technology from an extrinsic point of view, namely from the perspective of an external observer. A phenomenological approach, instead, tackles the analysis of the relationship with technology on the assumption that it is always mediated by the perception of the human subject, who is directly involved in the activity (Rosenberger and Verbeek 2015). As such, rather than treating humans and technological artifacts as agents on an equal footing, it emphasizes the role of subjective experience in shaping our interactions with technology and gives human perception a central role. In this perspective, these two frameworks are complementary, and as much as I am aware of the agency of non-human artifacts, I recognize how an analysis of the involvement of perception becomes crucial since, as an artist myself, I am directly involved in the interaction with technology. As I have previously emphasized, in my practice artworks do not arise from a solitary mental process. I am instead interested in exploring the agency of technological artifacts to establish a bidirectional interaction. To me the relevance of phenomenology in this context stems from the consideration that this interaction is consistently constituted by the perceptual feedback originating from the technological artifact. It is through this feedback that the artwork ultimately emerges. Simultaneously, reasoning is essential to transfer my experiences into new circumstances and abstract general behaviors. It also enables me to envision the potential

interaction between processes without limiting my approach to trial and error. In music-making, it is impossible for me to distinguish whether it is reasoning or experience that takes precedence, as these two aspects occur simultaneously. Although I recognize that it is possible to create a work based only on imagination and to experience it only when it is at an already advanced stage, I would argue that this process of imagination would also be based on the previous experience of the artist in terms of music listening and on their familiarity with their equipment. The phenomenological approach emphasizes this aspect by highlighting that the relationship between human and artifact is not merely of use or mediation, but rather one of mutual constitution. In this relationship humans create technologies, but in turn, technologies define humans.

4.1 Embodiment and hermeneutics

The framework I find particularly useful to describe the phenomenology of technological artifacts is the post-phenomenological one, more specifically the work of the philosopher Don Ihde. In his approach, Ihde carries out the analysis of technologies from an empirical investigation of how they manifest themselves, starting from the idea that they should not be considered as merely instrumental objects, but as mediators of the relationship between the human and the world. Instead of trying to classify different types of technologies according to their functioning or appearance, Ihde focuses on the various types of relationships that can be established between technological artifacts and humans. The central questions addressed by Ihde are:

"What role does technology play in everyday human experience? How do technological artifacts affect people's existence and their relationship with the world? And how do instruments produce and transform knowledge?" (Verbeek 2001: 121)

To represent the wide variety of possible relations between humans and technological artifacts, the framework developed by Don Ihde defines numerous modalities of interaction between humans and technologies (Ihde 1990). As highlighted by Magnusson, (2009) this approach is particularly well-suited to describe the types of technological artifacts used in music making. Specifically, Magnusson focuses on two of Ihde's modalities - embodied and hermeneutic relationships - and their application to the acoustic and digital domains. I am now going to summarize these concepts.

Embodied relations see the artifact as an extension of the body, thereby making the artifact transparent by shifting the focus on the activity rather than on the artifact itself. Ihde's embodied relations are strongly influenced by the previous works on embodiment by Martin Heidegger (1962) and Maurice Meralu-Ponty (1962). Some examples of artifacts that foster an embodied relationship are eyeglasses (Ihde 1990) or a white cane (Meralu-Ponty 1962). In both cases the artifacts mediate the subject's perception by becoming an extension of their sensitivity. As Magnusson highlights, an example of embodied relations in the music field, is the one developed with acoustic instruments, "where trained musicians are able to express themselves through incorporated knowledge that is primarily nonconceptual and tacit" (Magnusson 2009b: 168).

In hermeneutic relationships instead, the artifact provides a representation of the world that needs to be interpreted by the subject. A hermeneutic technology provides a non-transparent representation that places some aspects in the foreground and others in the background. For example, music notation fosters a hermeneutic relation by offering a transcription of music. The

purpose of notation is not to enhance our bodily perception, but to provide a symbolic representation. By doing so, it narrows the expressive space of the representation to certain parameters, while also revealing features that were previously hidden, therefore opening up new possibilities. Another example could be the representation of a digital audio file by means of a spectroscope. When sound is represented in this way we lose any kind of semantic information about the type of sound in question. At the same time, however, one can acquire more detailed information about the spectral content of the sound, to a degree that would be totally impossible simply by listening. According to Magnusson, it is more likely that digital technological artifacts encourage a hermeneutic relationship with the subject. This is due to the fact that the interaction with digital artifacts is based on the knowledge of a symbolic system that defines the design and the operation in the form of code. This knowledge is not immediately intuitive or embodied, but rather requires an effort to be interpreted and understood by the user.

The purpose of distinguishing these two modalities is not to create a dichotomy between embodied and hermeneutic relations, but rather to highlight how each artifact fosters a relationship that lies on a gradient between the two, eventually contributing to both our sensory-bodily perception and our interpretation of the world. The ability to mediate the perception of technologies leads to two complementary aspects of perception itself. Ihde calls them microperception and macroperception. Micro perception is primarily associated with bodily-sensory perception and is therefore related to embodied relations. Macro perception is linked to general interpretations of the world and to hermeneutic relations. In conclusion, what Ihde is showing is that "both dimensions of perception are closely linked and intertwined" (Ihde 1990: 29). Thus these modalities should not be understood as separated categories, rather as

complementary and interconnected aspects of how technology mediates our perception of the world, as Verbeek explains in the following example:

> "A bodily perception can no more exist without being interpreted than an interpretation can exist without something to be interpreted. The two-fold meaning of the word perception to which Ihde points is illustratively present in the verb 'to see', which we can use to describe a bodily-sensory perception ('I see a tree') and to characterize an interpretation of the world ('Since that talk I see things completely differently')." (Verbeek 2001: 124)

This perspective rejects the body-mind dualism and considers technological artifacts as an inseparable entanglement of embodied and hermeneutic relationships. The bodily component, which arises through physical interaction and sensory perception, and the mental component, which enables reasoning through artifacts and influences the interpretation of the surrounding world, are two co-existing and mutually reinforcing aspects.

4.2 Embodying the hermeneutic

The post-phenomenological approach offers a different perspective on the relationship between the artist and the computer in practices such as live coding and computer music. The moment we acknowledge that embodied and hermeneutic relationships can exist only in relation to one another, the point is no longer about whether or not there is an embodiment with the computer. The very presence of a hermeneutic relation – the prevailing one as Magnusson suggests in (Magnusson 2009a) – already implies the presence of embodiment. The question now becomes what this type of embodiment consists of and how it differs from other types of technological artifacts.

In the practice of live coding, a first aspect of embodiment is manifested in the act of typing on the computer keyboard. Similar to a musician playing a keyboard instrument, a live coder has incorporated the position of all the characters and can type quickly without looking at the keyboard. However, such action occurs in a temporal and expressive domain that is completely different from that of an acoustic instrument. The live coder does not have to type in time with the music and can take a break from typing to think about the next modification to the code without interrupting the musical flow. Furthermore, the act of typing lacks expressive gestuality. Although one may type by pressing the keys with different intentions, this does not influence the artistic result, which is ultimately determined by the characters that appear on the screen. To limit the embodiment of the computer to typing on a peripheral device would perpetuate the fallacious interpretations already criticized in the first chapter of the thesis. Magnusson (2009) suggests that the concept of virtual embodiment, which occurs in video games, can also be applied to digital technological artifacts used in the arts. This highlights how digital artifacts can reflect the phenomenological experience of interacting with tangible objects. For instance, one can consider the movement of an object in a 3D environment or the act of scratching an audio file using a mouse as examples of virtual actions that mimic a physical one. This type of embodiment, although distinct from typing on a physical keyboard, follows a paradigm that is ultimately similar. Whether we press buttons on a tangible object such as a keyboard or on virtual ones that appear as pixels on a screen, our activity is ultimately one of button pressing. Based on my own experience, emulating the behavior enacted on a physical interface with our behavior while dealing with virtual interfaces, can be useful yet misleading. While mimicking the appearance of physical objects in virtual spaces can enhance the intuitive understanding of users by relating them to familiar concepts, it also risks

imposing the limitations and interpretations of physical objects onto the virtual ones. In my artistic practice, becoming accustomed to the logic of a symbolic system has led to the embodiment of a hermeneutic related to that system, namely the development of the ability to interpret the system immediately and intuitively. I see a connection with the words of Marija Baalman, suggesting that "the longer we spend programming in a particular language the more our mind gets attuned to the language and shapes our thinking about concepts to express" (Baalman 2015: 2). As my interest in symbolic systems and digital artifacts lies in their potentiality to create new, unexplored virtual worlds, I envision embodiment as the ability to navigate the reality that the new system of signs reveals and to express myself within and through it. For example, in the case of computer music, this embodiment could entail developing the capacity to intuitively understand the state of a complex system and, in live coding, anticipate how certain modifications to the system could lead to new and desirable interactions for the artist. In this context, relying on the plain and cryptic appearance of a text editor can be interpreted as a deliberate choice. By relying on the artist's imagination rather than on visual elements, this approach stimulates the search for a personal idiosyncratic interpretation, not conditioned by the appearance of a sophisticated interface. I think this is a way to develop a type of embodiment that is closer to the computational process itself rather than to the interface representing that process.

5. Embodiment, liveness and virtuosity

In my practice as a computer musician, I have often struggled with widespreads assumptions of what a musical instrument should be as well as preconceived notions of what it means to play and, more generally, to perform. In this chapter, I would like to elaborate further into why I believe that a reconsideration of these ideas is necessary to understand contemporary musical practices that employ the level of abstraction provided by the computer. To address this issue, it is necessary to delve into how a broader perspective on embodiment necessitates a reinterpretation of other aspects of the interaction between artist and technological artifact. This includes a particular focus on the concepts of virtuosity and liveness.

5.1 Embodiment and Virtuosity

In a recent interview, the techno DJ, producer and performer Jeff Mills has declared "I'd advise anyone who makes electronic music to just go into your studio, pick one machine and try to do something with it that you've not done before. Try to make it do something different. No one has to know what you did, but see where that leads." Continuing the interview, when asked "Do you need an understanding of what's under the hood?" Mills replies "Yes. For example, I know exactly how long the ride cymbal sustain lasts for on the 909 so I can connect sounds together and make it sound almost seamless. If you hit the snare with a drum stick in a certain way, you know how long the resonance will be; with a drum machine you're not supposed to have that understanding, but if you fool around with it long enough you'll find a way to make that happen. So I know the limitations of the crash, the ride, the clap, the snare, the kick drum and all the tunings, and it's

important to fool around with a machine to understand it as an instrument [...] When you master a machine you start to become a *virtuoso*, which is an interesting way to look at it." (Mills 2022)

There are several interesting points raised by this interview that resonate with the topics discussed so far. First is that for Mills it is important to "fool around" with the machine trying to make something new rather than using it with a predefined goal in mind. His interest is not geared toward transposing an already defined idea, but toward exploration by making numerous detours to broaden his understanding of the instrument, even of things he "shouldn't suppose to". His interest does not lie in the transposition of an already defined idea. It rather lies in exploration, which consists of a number of detours meant to broaden one's understanding of the instrument, even when such knowledge is not expected or required. Secondly, the tweaking Mills speaks about is not only a bodily activity, but also concerns reasoning about the inner workings of the machine. It is by "fooling around with it long enough" that he develops both a clear understanding of what goes on "under the hood" as well as the awareness of the limits and of responsiveness of the drum machine, ultimately becoming a *virtuoso*. Within the jargon of electronic music, expressions such as tweaking, fooling around, or playing with are often used to refer to the exploration of a synthesizer or a patch. From a phenomenological perspective, this exploratory activity is essentially a way of developing an embodiment with the technological artifact. For Mills, this should not occur through theoretical analysis, such as reading the manual, but through spontaneous and intuitive interaction. By ignoring the directives of the instrument's designers and instead playing with it in an almost unconscious manner, Mills is pushing the readers to repurpose the instrument, explore new paths and uncover hidden possibilities. In this sense, fooling around and trying new things is a way around the affordances of the technological artifact. I find a suggestive parallelism between

Mills' words and Heidegger's concept of thrownness (Heidegger 1962). For Heidegger, humans are thrown into the world and must make sense of their existence and their surroundings through their experiences, who are always mediated by the things that they encounter in their environment, including the tools and technologies. This existence is already embedded in a web of arbitrary and varied concepts, meanings, and histories. By experimenting with the parameters of a synth or a patch, Mills is not only manipulating sound, but also engaging with these concepts, meanings and histories inscribed within the artifact. So, if on one hand Mills sees the drum machine as a sort of Heideggerian hammer with which he can establish an embodied relationship, unlike the process of hammering which is directed toward something external to the tool, here the focus is oriented on the artifact itself. The main aspect of embodiment here is not the acquisition of specific skills related to muscle memory, but rather to develop the ability to interpret the internal functioning with the artifact, and thus to establish an hermeneutical relationship with it. According to Mills, it is at this point that the musician becomes a *virtuoso* of the machine, when they are able to understand the mechanics of the artifact together with its responsiveness and limitations.

This first example highlights a first connection between the concepts of embodiment and virtuosity. To become a virtuoso implies to develop an embodiment, both physical and mental, through which the artist becomes acquainted with the response of the internal functioning of the artifact and its expressive characteristics. In this sense, a drum machine is not so different from a traditional acoustic instrument. Even though it uses features offered by non-acoustic technologies, these are employed to emulate something that already exists[5]. In other words, it does not take advantage of the unique possibilities offered by the new technologies it employs to create something that is fundamentally different from what already existed before. To understand more

[5] See the concept of Remediation in (Bolter and Grusin 1999).

broadly how the concept of virtuosity translates in many artistic contemporary practices we need to consider that these encompass a wide range of aspects that extend well beyond mastering a specific machine. As Magnusson highlights:

> "If we are tempted still to operate with the concept of virtuosity in twenty-first-century musical culture, we need to explore how the role of the musician (equally composers and performers) has now expanded to include instrument design, composition, stage performance, and all kinds of multimedia productions." (Magnusson 2019: 8)

If I look around me I notice how many artists who relate to technology in a speculative way are blurring the distinction between various roles that before were often thought of as separate. The composer is now also the performer, and the performer is also the designer of the instrument. This convergence is not simply a practical matter of convenience, but has strong implications on the type of embodiment developed with technologies that use the new possibilities of the digital, such as creative coding environments[6]. Being a musician/designer means that the embodiment with the artifact is not only established by playing with it, but also through the design of the artifact itself. Unlike commercial software, this design does not necessarily aim to create something usable by everyone, but it can be a way of developing an idiosyncratic practice that reflects the artist's specific expressive needs. The shift is from composing with the artifact (for example, with the drum machine in Mills' case), to composing the artifact itself, which becomes a very intimate extension of the performer.

Previously, I have drawn a comparison between a digital technological artifact and a book, emphasizing that both are defined by its inscribed content rather than its appearance or form.

[6] For example see Supercollider, Max/MSP, Pure Data, Csound, Faust.

Building upon this metaphor, we can define the virtuosity of a digital artist as the development of an embodiment that enables them to acquire the necessary proficiency in understanding the symbolic system specific to the artifact and inscribing values within it. This arises since, owing to its intricate and symbolic nature, the digital artifact has a high propensity to become a black box, where the contents become opaque and difficult to comprehend. As a result, virtuosity in digital practices also includes the ability to open the black box and to demystify its contents. The tendency of the digital artifact to become a black box is one of the reasons why I prefer to use open-source technology in my artistic practice. Although open source is often associated with the idea of being free, this is actually a misconception as there are many free software programs that are not open source and many companies that make considerable profits by developing open-source technologies. For me, the most interesting quality that I look for in open-source software is the ability to open the black box and study how things are implemented. Instead of approaching open-source software as a free product, my interest lies in understanding its development process to analyze the strategies and ideas that underlie it. Often, this process leads me to use open-source software as a guide to develop something different or to acquire new knowledge.

To get a comprehensive picture, we need to consider that the virtuosity of digital artists involves not only navigating the symbolic nature of their work but also engaging in an iterative process in which these symbols create expressive outcomes. Thus the embodiment entails not only understanding and writing complex codes, but also acquiring the ability to relate the combination of symbols on the screen to a series of perceptual results. From this perspective, code is not solely a matter of demystification and rational comprehension, but it should be explored in relation to its artistic output. As explained by Gunnarsson (2018), black boxing in programming languages may

be regarded as a deliberate decision on the part of the artist to ignore and hide certain aspects. This approach shifts the understanding of artifact responsiveness from a symbolic comprehension to a heuristic principle, basing the interaction on perception and listening instead of abstract reasoning. In the first chapter I highlighted how being an instrument is not an ontological reality, but rather something defined by a state of interaction with a user. Following this reasoning we can consider the black box as a way for the user to relate to the artifact, more specifically providing a placeholder for its specific abilities of doing. The virtuosity of the digital musician therefore consists not only in demystifying the black box, but also in being able to take advantage of it, approaching the various abstractions analytically or heuristically according to the needs of the moment.

In conclusion, we can say that virtuosity in the digital domain can be acquired through an embodiment of the logic and abstractions of programming languages. This skill involves being able to demystify the symbolic system in which the artifact is defined, but also to understand its expressive response intuitively. In my practice as a computer musician this heuristic understanding is achieved by tweaking the software, both its parameters and its structure, and is a necessary component to develop an embodiment as much as understanding the code as a formal language.

5.2 Embodiment and Liveness

In the world of electronic music, the term *live* is used frequently, but seldom with a precise definition of its intended meaning. While often the distinction between what is considered live and what is not is taken for granted, as highlighted by Simon Emmerson (2007) there seems to be a considerable disagreement on what the term live actually refers to in recent practices. According to Philip Auslander (1999), the concept of liveness is not an absolute or ontological condition, but

rather a factor that emerges from the historical and cultural context in opposition to the mediated, thus highlighting how the appearance of new media requires a continuous redefinition of this term. Technology plays a central role in this context, as it enables the recording and playback of performances, creating the necessity for differentiating between the live and the mediated. By giving various examples ranging from broadcasted concerts, to live-albums, to *DJ* performance, and theatrical productions that incorporate video projections, Auslander shows that live and mediated can actually coexist and that mediation can enhance the feeling of liveness. As noted by the American composer Kim Cascone, the feeling of liveness in many of these cases does not necessarily imply authenticity, but often involves counterfeiting the aura through the use of "technical wizardry" (Cascone 200: 3). Reflecting on the concept of liveness in my capacity of performer, I realize that rigidly defining what qualifies as live and what not is not so important. Instead it is crucial to comprehend what might be perceived as live, and to explore the liveness of new and emerging practices that are currently carving out their own niche in the public understanding. This perception can be influenced by various factors, including the audience's expectations and their acquaintance with the type of performance they are attending, the level of interaction between the performer and the audience, the degree of spontaneity, and the presence of imperfections and unexpected events.

One of the primary issues frequently raised in discussions on liveness within the realm of computer music is the absence of gestural communication by the performer. For example, consider the following quote from electronic musician and vocalist Dafna Naphtali, who reflects on her own experiences of incorporating computer-based technology into her experimental collaborative practice.

"The musicians I played with both appreciated and supported what I was doing, and reacted very musically to my electronics, experimenting along with me. After our shows, however, people would often say "... fabulous, but you really should do more!"; they thought I was only *doing something* when I was singing. My sound manipulations were not attributed to me because the audience could neither visually identify these sounds as coming from me, nor identify them aurally as my contribution." (Naphtali 2017: 1)

It is evident here how the lack of liveness is associated to the assumption that the performer activity must be a physical action directed towards a tangible object[7]. Many performers have addressed this issue by incorporating a gestural dimension into their performances, for example, by using sensors, hardware synthesizers, acoustic instruments, or having a strong stage presence. While I think these strategies are undoubtedly effective in conveying a sense of liveness to a mixed audience, in my experience this can also become an impediment in exploring new interpretations of the concept of liveness. Ultimately the question is whether the performer's interest is in communicating a sense of liveness by emulating established strategies, or in challenging what is considered and perceived as live. I am not denying that using the above-mentioned means can lead to innovative results in terms of perceptual liveness, I am rather arguing that a computer music performance can possess its own liveness that should not necessarily be sought in analogies with other ways of playing considered at present as live. As a computer musician, I find it more intriguing to attempt a personal redefinition of the concept of liveness and to integrate this process into my artistic research, even if it entails the risk of not being perceived as live according to current expectations.

[7] Although it is not the topic of this chapter, it is worth noting that Naphtali's testimony also highlights a gender issue; to explore this further, please read the original text in (Naphtali 2017).

In the world of live coding, for example, it is common practice to project one's computer screen in front of the audience to involve them in the process of live creation. This practice is summarized in the slogan *show us your screens*, which is spread by the *TOPLAP* organization (Ward et al. 2004). As a performer, I have played in many live coding concerts, ranging from extreme computer music to collaborative improvisation and rhythmical late-night Algoraves[8]. Having approached live coding with primarily an artistic background rather than a programming one, the practice of sharing my screen is interesting to me since it makes the performance a hypermediated experience (Bolter and Grusin 1999) composed of multiple media. In this case, the text editor interface used in live coding becomes an example of mediation that enhances the feeling of liveness, becoming a virtual space that the performer can navigate and use to engage with various media including the sonic, the visual and the textual. From an aesthetic point of view, my interest in projecting my screen has always focused on how these three media could relate one another, not simply via their connection, but trying to blur the boundaries between them[9]. My loose interpretation of mine of the concept *show us your screen* has been raising mixed feelings among the people attending my concerts. This is because although my performances were generally considered engaging from a musical and multimedia perspective, my focus was not the coding aspect in a strict sense and it was not possible to clearly read the code on my screen, let alone follow the interplay between code typing and artistic output. These conflicting feelings arise because, while some viewers immerse themselves in the sensory experience created by the performance, others observe the code projection with the intention of deciphering it and understanding how it produces the artistic outcome. However attempting to decipher the code displayed on the screen can also detract

[8] This neologism has been coined in 2013 by Alex McLean and Nick Collins see (Chesire 2013).

[9] For a practical example see section 11.2 that shows an excerpt of my performance Live coding with Adapt (Corvi 2022a) around minute 15.

from the overall experience of the performance (Burland and McLean 2016). Therefore in my opinion artistic live coding performances can be better appreciated and understood through the expressive outcome they produce. In this regard, I find interesting the words of live coder and researcher Elisabeth Wilson:

> "Perhaps surprisingly, as practising live coding musicians ourselves, we find that listening to code can be a more important part of live coding than writing it in the first place. In other words if code is a map and music is the territory, then the code can only be read and understood when you listen to the territory that it generates." (Wilson et al. 2021: 79)

While I am not concerned at all with putting the code on the foreground, through interactions with other live coders I have come to understand that some consider making the code legible as a critical aspect of the performance. This belief aligns with the ideology of live coding, which critiques obscurantism and aims to demystify the artist's creative process. However, as an artist myself, I believe that projecting the code is not a particularly effective way to convey these ideas. Instead, I frequently explain and discuss my creative process in workshops, interviews, and post-concert discussions with the audience. I find that this approach is more informative than to encourage deciphering a block of code that would be incomprehensible to most of the audience. Furthermore, I believe that not concealing the process behind a performance does not necessarily entail that the technical and poietic aspect must necessarily become the subject of the performance itself. In my case, the choice to engage in live coding is not a technical challenge, but rather an expressive choice that allows me to develop a reflection on aspects that may have little to do with code projection. While these are all personal considerations arising from my own artistic vision, I

think it is counterproductive to try to define what is a better or worse approach to live coding and the practice of screen sharing[10]. Live coding is a practice that still has much to explore, and it should not stick to a particular way of performing since a diversity of approaches can stimulate discourse, and promote the exchange of ideas. As an artist with a primarily musical background, one of the main aspects that interested me in exploring live coding was the expansion of sonic possibilities. For this reason, in some works such as *Time Debris*, I deliberately decided to limit as much as possible any sensory input but sound. This choice was motivated by the belief that listening to music through the observation of code or projection leads to loss of attention for all the nuances in sound that do not emerge in these other media. In this perspective, the projection of the screen can turn into a distraction rather than being an object of interest. This approach seeks to engender the kind of attentive and immersive listening experience typical of acousmatic music, albeit with a crucial distinction: it arises from a real-time process wherein the performer engages with its unfolding. Consequently, this approach exhibits a degree of liveliness that is difficult to attain with the fixed media approach commonly associated with acousmatic music. This exploration can be placed within a set of contemporary practices that are often referred to by the neologism post-acousmatic (Adkins, Scott, and Tremblay 2016). Viewed through this lens, live coding could potentially play a role in a larger shift in contemporary music towards a more fluid and flexible understanding of acousmatic practice, emphasizing the potential for reconfiguration, real-time interaction, and collaboration among performers. Despite the risk of falling into the pitfalls of a Shefferian phenomenological reduction, a study conducted in 2014 (Brown, Bell and Parkinson) sought to

[10] For example Magnusson in (Magnusson 2014) makes a distinction between strong and weak live coding in relation to how much code is prepared beforehand and how much is typed on the moment. While I agree that starting from prepared code or not is a factor that can substantially change the output of the performance, I find this terminology unnecessary and contradictory to the inclusive spirit of live coding that wants to encourage beginners to perform.

examine the perception of liveness through the isolated experience of sound listening. Building upon the framework of Auslander, the study highlights how the perception of liveness in electronic music is changing among people exposed to recent works and to the new technologies with which it is made.

> "It could be argued that audiences have simply adapted to the nature of liveness in electronic music. Audiences may perceive the sonic activity itself as a type of performance [...]. They may simply not conceive of energetically performing persons as part of the experience of live music." (Brown, Bell and Parkinson 2014: 1)

From this study, it appears that the perception of liveness in electronic music can be mainly traced back to the decisions made by the performer on stage. These decisions are linked to bodily gestures such as pressing a button or tweaking knobs on a controller, as well as to cognitive decision-making processes[11]. While this approach may imply that the lack of bodily activity is inconsequential for audiences accustomed to electronic music, the decision-making process that defines the perception of liveness remains associated with human agency. This contradicts the view of many musicians who do not see the computer as an instrument to be controlled, but rather as an agent that should have some degree of autonomy. These musicians wish to interact with the computer processes rather than merely control them. In this regards Nystrom suggests a post-human concept of liveness:

[11] in this regard Brown, Bell and Parkinson (2014) propose the term cognitive liveness.

"[T]he instrumental analogy is tied to gesture and the notion that sounds carry human expression and body language, thus anchoring the music in human cause and intention. Gesture also draws attention away from many of the characteristics that are distinct about computational or electroacoustic sound, which carry material qualities and a spontaneous autonomy not linked to human and acoustic causes. My post-human perspective takes interest precisely in the reframing of human agency by the encounters with more speculative sound ecologies, where humanity has to define itself in relation to the unfamiliar" (Nyström 2021: 34)

This relates back to how virtuosity in such practices involves embodying a hermeneutic. In this approach, the human agency consists of making few decisions that can influence the behavior of the system substantially. Therefore, much of the effort consists of understanding the behavior of the system rather than controlling it. In this context the feeling of liveness does not emerge from the activity of the performer, but from the system's response and the sound behavior it produces.

6. Ephemerality, music and time

6.1 The ephemerality of technological artifacts

As previously emphasized, technological artifacts, including musical instruments, embody cultural and aesthetic values that reflect human behaviors. However, as human behaviors are continuously evolving, these values cannot remain fixed and immutable. This creates a dynamic relationship between humans and technology, where each defines and shapes the other and both evolve together. Philosopher Bernard Stiegler's concept of technogenesis sheds further light on this dynamic relationship. It emphasizes the role of technology in shaping human evolution by transforming our perception, cognition, social organization and culture (Stiegler 1994). For instance, in the book *On Sonic Arts*, the composer Trevor Wishart (1985) highlights how technological artifacts employed in music making play a significant role in imposing a specific organization of pitches and duration. In the western musical tradition this gives rise to what he calls a lattice-based interpretation of music, where pitch and duration are the most relevant musical parameters and all the other parameters are represented in relation to these two[12]. The relationship with technological artifacts here is not merely a means of altering our perception and amplifying our capabilities; rather, it becomes a medium that participates in the creation of cultural memory and the development of a tradition preserving certain values over time. However, these values should not be considered absolute and unchanging truths, but a step in the ongoing process of how humans think about pitch. When composers such as Harry Partch or La Monte Young explore

[12] I find a striking parallelism between this point raised by Wishart (1985) and Ihde's concepts of micro and macro perception (1990). It is the phenomenological mediation of technological artifacts that leads to the lattice based interpretation that ultimately represents an hermeneutic of music, in which sound is interpreted based on the parameters best represented by the format of its transcription.

different tuning systems they are challenging and changing the values inscribed in technological artifacts, thus contributing to this ongoing evolution. When John Cage inserts objects in the piano and Helmut Lachenmann writes scores for concrete instrumental music without pitch indications, they demonstrate even more radically that musical instruments do not possess a fixed, one-dimensional essence, but rather a multistability (Ihde 1999) that allows them to be redefined through their use.

In this work I have emphasized that in my opinion the technological artifact is not merely a tool to be mastered or controlled, but also a book to be read and understood. However, my practice as an artist is not oriented solely towards understanding technology, but ultimately to question and continuously redefine it. From my perspective, the creation of stable artifacts would only make sense if my work aimed at addressing questions with the intention of establishing objective and verifiable truths. But instead of being interested in things for what they *are*, I am interested in the spectrum of possibilities of what they *might be*, and in the technological artifact for this plurality of interpretations it can help me to unveil. A central issue in the post-phenomenological debate is to explain how the material design of technologies fosters the multistability of technological artifacts by allowing some uses and excluding others (de Boer 2021). In this regard I argue that if a physical instrument inscribes these values in a tangible spatial discreteness that is somewhat stable – or to be precise evolving on a large temporal scale – the digital artifact, instead, due to its degree of symbolic abstraction can continuously change without limitations imposed by its material stability. According to the composer Bjarni Gunnarsson (Gunnarsson 2021), ephemerality and incompleteness are fundamental aspects of the design of generative applications in computer music. Gunnarsson argues that unexpected behaviors arising from the automation of processes can

introduce side effects expanding the potential behavior of the system. This points to a general difference in the approach to software development, which may not be directed toward the creation of a product, but instead valued for its process[13] (Frabetti in Gunnarsson 2021). This approach enhances how software development does not necessarily have to address the achievement of a final stage, but can become an ongoing research. Observing the technological artifacts employed in my art practice, I can observe a tendency towards prioritizing the ephemeral qualities over seeking a specific configuration. This does not simply mean that the artifacts I use are modified over time, creating various versions, for example between one performance and the next. The artifact's ephemerality arises when, instead of being a discrete moment in time, it becomes a constant flow in which it is impossible to define it precisely because its ability to change and adapt is part of the values inscribed within it.

6.2 The aesthetic of the ephemeral

In her book *L'Esthétique de l'éphémère*, the French philosopher Buci-Glucksmann explains how valuing stability over ephemerality is a characteristic of Western culture. In contrast, in Japanese philosophy, the concept of *Mujō* - which can be translated as ephemeral or impermanent - involves an apprehension of the interval and the consideration of ephemerality as something positive. As she explains, this difference reflects an interpretation of the world as something constituted by flows rather than objects and values the passage of time over the stability of things.

[13] Frabetti in (2015) distinguishes between these two approaches: software as a *product*, and software as a *process*.

"This is because the ephemeral is not a moment in time, the instant according to Aristotle, or the mere "presenteeism" of a time with no future. Instead, it is the passage of time, its modulation and delicate resonance." (Buci-Glucksmann 2014: 1)

As highlighted by Vincent Goudard, an approach that values ephemerality over longevity offers a perspective for recontextualizing many aspects related to the world of contemporary music, ranging from performance and technology, to economy and instruments (Goudard 2019). Ultimately, an aesthetic of the ephemeral can provide a key not only for creating technological artifacts that evade rigid formalization, but also for valuing a whole spectrum of musical practices that evade strict definition and are centered on improvisation, continuous change, and instability. This is because music, as a form of expression based on the organization of time, inherently embodies a philosophy of time[14] and manifests it in an experienceable phenomenon. Music engages time not only as a container for the listening experience, but rather it actively transforms our perception of time[15] into a multiplicity of meanings and interpretations that resonate with our subjective experiences. The distinction lies between the time that is evoked and the time that is simply occupied, and to the contrast between inner time and absolute time. Algorithmic music in particular describes this organization explicitly through a series of instructions that describe the unfolding of a process. As suggested by Julian Rohrhuber:

[14] For instance, it is interesting to note that Wishart traces the lattice based approach to a Cartesian view of space time, as highlighted in this quote where he critiques the serialist approach of the composer Pierre Boulez. "For Descartes, a phenomenon such as motion which could be given a direct quantitative mathematical description was regarded as primary, whereas qualitative phenomena such as colour were seen as secondary qualities and ultimately reducible to descriptions in terms of primary qualities. Exact mathematical representation, at least in theory, here plays the same role as accurate score-notation" (Wishart 1985: 31).

[15] For example the composer Oliver Messiaen (1994) highlights how the inner perception of time is conditioned by music listening and elaborates the two laws of *Sense of the present duration* and *Retrospective appreciation of the past*

"[A]lgorithms are on the verge of time, in so far as they are on the verge between constancy and change, on the one hand, and between concrete and abstract temporality, on the other. A possible first step for a philosophical consideration of algorithms is to better understand what this liminal position means; the consideration of music is likely to help us here. Eventually, algorithmic music will turn out to be not only affected by how we understand temporality, but also it will turn out to be a possible method to constitute and convey the peculiar existence of time." (Rohrhuber 2018 :2)

In a practice such as live coding, the unfolding of the program does not occur linearly or independently but includes an observer who alters this unfolding based on what they perceive. This means that the structure of the program is always designed to be changed, to be ephemeral and incomplete. Although developing embodiment requires a familiarity with the technological artifact, I do not think that the conflict between embodiment and ephemerality is an unsolvable tension. Earlier I highlighted how one aspect of virtuosity in digital practices involves becoming familiar with the mechanics of the programming language and learning to express concepts within its system of abstractions. However, this is never a one way interaction aiming at a rigid formalization, and embodiment is not only focused on the ability to use language, but also to reformulate it. Perhaps the most interesting feature of ephemeral artifacts lies precisely in their liminal position that always invites us to expand the horizon of possibilities.

As an artist and researcher I often find myself in-between. Between my old comfort zone and any new possible answer. I believe that personal and artistic growth occurs during these liminal moments, when I challenge my preconceptions and remain open to the diverse range of perspectives and interpretations I may come across. Therefore, my work is not oriented towards a conclusion or towards reaching an answer that defines the essence of something. Instead, I aim to

understand the value of those questions that inspire me, not necessarily for the answer they may lead to, but for the journey of exploration they encourage me to undertake.

7. Live coding adaptive systems

In this chapter, I will illustrate and motivate some of the strategies that I have developed as part of my research, along with some works that explore their expressive and artistic potential. Initially, I will explain the reason why I decided to focus on adaptive systems instead of other strategies, such as automatic code generation and machine learning. Following this, I will provide a brief introduction to the concepts of adaptive sound processing and machine listening before delving into more detail about how I have used these techniques in my work. I will present a series of *études* that I have created during the development of these techniques, which demonstrate the sonic results of these approaches. Finally, I will describe how these strategies have been applied in a performance setting.

7.1 Motivations and comparison with other approaches

During the research described in this dissertation I explored various technical and creative strategies through theoretical study, empirical experimentation, philosophical investigation, and discussions or collaborations with other artists. In this section, I would like to explain the reasons that led me to focus on adaptive systems instead of other approaches. My main interest in approaching this research was to make the computer an active part of the improvisation process. Previously, in my live coding practice, I often approached the use of the computer as an extremely powerful and reconfigurable sequencer, following the example of languages like TidalCycles (McLean 2014). While this approach was interesting and versatile, it left many sonic possibilities unexplored and limited the type of behaviors exhibited by the computer that I could interact with. As scholar

Alberto De Campo suggests, from a cybernetic perspective, "observing one's own influence on a system seems clearly more interesting than aiming to exert full control" (De Campo 2014: 219). Following this logic, I began to explore various possibilities that could leave a degree of autonomy to the computer, seeking to develop an interplay between my actions and the type of response exhibited by the system.

7.1.1 Automatic code generation

Live coders have explored various ways to make the computer capable of generating code on its own (Wilson et al. 2021, Stewart and Lawson 2020, Hickinbotham and Stepney 2016, Magnusson 2011). These approaches generally employ a virtual agent (Xambó 2020) trained on codes created by a performer or following grammatical rules to generate new syntactically correct code. Most of the current work implementing virtual agents for live coding is focused on languages that utilize patterns and communicate through OSC messages with an audio engine that handles all the sound synthesis and processing. The main limitation of the virtual agents working in this way is that they have little or none ability to analyze audio signals. This means that they have no information about the sound produced by the code they generate and that they cannot react to the sounds produced by the performer. While the code-based approach is valuable for conceptualizing novel ideas that can be explored by the performer in the form of both code and sound (Wilson et al. 2021), its use in an improvisational musical context is limited by the virtual agent's lack of understanding of anything beyond programming language syntax. Moreover, as long as the output of the virtual agent is confined to code representing patterns the resulting music is also limited to patterns and sequences. I believe that automatic code generation offers interesting possibilities to enhance the learning process and explore the full potential of a programming language. However, in the context

of my research, this approach did not seem to accomplish the task of bridging the gap between the domain of events and the domain of sound[16]. Ultimately, rather than being interested in manipulating symbols, my main focus was on exploring the interaction of processes in the domain of an audio stream.

7.1.2 Machine learning

At the initial stage of this research, I experimented with the use of machine learning to extract high level features from audio analysis. This approach involves training models on collected sound data in order to make predictions and decisions based on new inputs. One of the pitfalls of this approach is that it has a tendency to make the inner workings of the algorithm inaccessible, behaving like a black box. This is because once the model is trained, it becomes difficult to access and consequently hard to modify in real time. In addition, a machine learning system requires the preparation of a dataset of pre-existing examples that accurately represent the characteristics the model needs to learn. Therefore, in order for a machine learning model to be effective, it generally needs to be trained bearing a task in mind. While experimenting through trial and error is still possible, yet it is generally quite impractical, since training a machine learning model is often a time consuming and resource-intensive process.

When comparing these two approaches, it is important to consider that they tend to aim at solving different tasks and each has its own strengths. Adaptive systems are good at adjusting system behavior in real-time, while machine learning is able to learn patterns from data. In this regard, I believe that adaptive systems are much better suited to incorporate ephemerality into their structure, as their formalization not only describes their current state through accessible code, but

[16] See the work on Time Debris for further clarifications.

also describes their capacity to change over time. This makes them much more suitable for a kind of practice such as live coding, which involves modifying a system on the fly. Unlike other types of processes that involve change, such as an aleatoric one, an adaptive process does not behave randomly, but instead exhibits a certain consistency in its responses. It is this consistency that allows the performer to become accustomed to the behaviors of the system and develop an embodiment with its ability to change. Another reason why I have chosen to use adaptive systems is that they belong to a tradition of experimentation associated with cybernetics and the study of complex systems, which has interesting applications in the domain of computer music (Sanfilippo 2022). What I find interesting about this approach is that it designs an artificial cognitive system and explores its emergent characteristics with a non-anthropocentric perspective, that is, without modeling it based on human behavior. In this sense, it represents an alternative to systems that seek to evaluate the creativity[17] of a computational system starting from the assumption that it must be understood and evaluated in relation to human creativity (see Boden 2004 and Wiggins 2006). In this regard Don Ihde suggests how "To characterize computer 'intelligence' as human-like is to fall into a peculiarly contemporary species of anthropomorphism, however sophisticated." (Ihde 1990: 217). The cybernetic approach represents a post-human perspective that moves beyond the notion of music as a solely human expression and physicality, instead viewing it as a tool to explore unconventional sounds that challenge our comprehension. I think my thoughts on this matter are well expressed by Italian physicist Carlo Rovelli, when he explains the roots of his passion for Physics:

[17] creativity here refers to the Creative System Framework (2006 Wiggins), a formalization based on the definition of creativity as "the ability to generate novel, and valuable ideas" (Boden 2004). It is important to note that this framework, while offering a mathematical representation of the creative process, does not delve into the question of whether the computer can be creative on its own, whose discussion requires a philosophical rather than computational inquiry (Boden 2009, Xambó et al. 2017).

"We are obsessed with ourselves. We study our history, our psychology, our philosophy, our gods. Much of our knowledge revolves around ourselves, as if we were the most important thing in the universe. I think I like physics because it opens a window through which we can see further." (Rovelli 2017: 9).

7.1.3 Machine listening and adaptive sound processing

One of the strategies I used to explore how the computer can actively take part in the improvisation process is to let the software monitor and react to sound signals in real-time. The analysis algorithms that fall under the name of machine listening offer a set of extremely useful techniques for this purpose which are available in most digital audio programming environments. Machine listening is generally intended as the possibility for a computer to simulate the auditory system of the human (Collins 2011). While this definition is useful to explain what machine listening is to a human, since it correlates it with human behavior, an explanation closer to a computational perspective could define machine listening as the ability of a computer to extract information from an audio signal in real-time, and represent it through a series of descriptors. Some techniques commonly used in machine listening applications include pitch tracking, onset detection, spectral centroid, spectral flatness, loudness, and MFCSS.

In my work, machine listening is mainly used to create adaptive digital audio effects, (Verfaille, Zolzer and Arfib 2006), also known as context-based transformations or intelligent effects. Adaptive effects use machine listening to transform features from the input sound into control values and change the result of a sound effect. This type of audio transformation arises from effects such as the compressor/expander, which controls the output volume by detecting the

intensity of the input sound with a non-linear curve, and the auto-tune, which uses a pitch follower to detect the fundamental frequency of an input sound and control the frequency of an oscillator. Adaptive digital audio effects are built on top of this logic. They employ various strategies to obtain a time-varying control of the effect parameters associated with a specific mapping to features extracted from an analyzed audio signal. In this way, the audio effect can adapt to the characteristics of the signal they are processing and therefore become context-based. Adaptive sound processes do not necessarily have to analyze the same signal they are processing, but can analyze another signal, thus creating a series of influences between various signals. A classic example of this procedure is the use of a compressor in side-chain mode, where the volume of one sound is varied in relation to the volume of another, thereby creating interactions between various elements. By expanding this approach, it is possible to construct networks of influences among various sound processes by defining the parameters of each process in relation to the analysis of sound characteristics contained in the others. This developing field has various applications that range from the mixing of musical pieces (Reiss and Brandtsegg 2018), to sound spatialization (Reiss 2011), to performance with various interconnected musicians (Baalman et al. 2018).

7.2 *Adapt*: a framework for distributed agency

Adapt is an ongoing project that aims to explore the use of machine listening, adaptive sound processing and distributed agency in a live coding context. Rather than focusing on the creation of virtual agents modeled on human behavior, *Adapt* takes a different approach distributing the agency between various smaller components that can perceive changes in their environment and react accordingly. The sonic outcome is the result of all these components playing an active casual role and jointly governing the behavior of the system influencing each other, distributing agency working as a cognitive assemblage (Hayles 2017). In *Adapt*, the cognition of the machine emerges through a series of action-perception relationships that connect each component with its perceived environment and keep track of the analyzed data. From the performer's perspective, their actions and decisions are propagated between components through this time-varying network of influences. By becoming familiar with the *Adapt* logic, the live coder learns to understand the response of this network and the quality of this adaptation becomes a compelling musical characteristic allowing a dialogue between the performer and the system. In order to explain how *Adapt* works, it will be useful to illustrate the three main concepts on which it is based: adaptive sound modules; adaptive agents, and the perceived environment.

7.2.1 Perceived environment

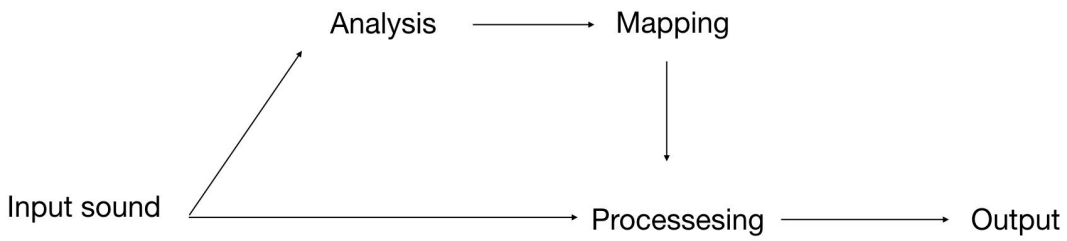
In *Adapt*'s logic, the perceived environment is the insight that each component has into the rest of the system. This consists of all the data observable from a component that can be used to influence its agency. In the case of adaptive sound modules, the perceived environment consists of a digital audio signal. In the case of adaptive agents the perceived environment consists of both a digital

audio signal and the current configuration of the software. Since the human is the only conscious component that can both make qualitative judgments about sound and define the point of view from which the system is observed, its role is of course fundamental in the perception of the environment. In general, we can say that the environment perceived by the performer comprises the sound diffused by the speakers, any information communicated through interfaces such as the screen, and the interaction with other performers and the audience.

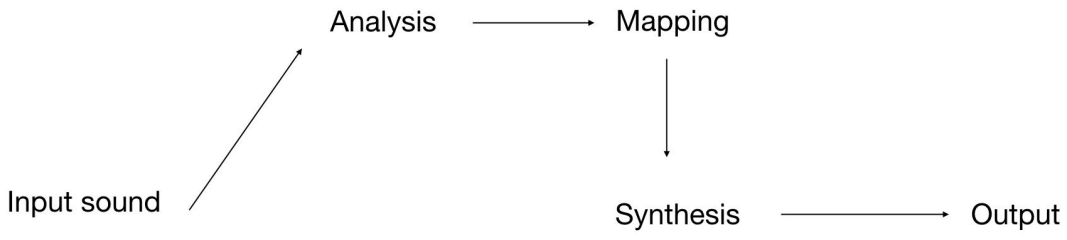
7.2.2 Adaptive sound module

An adaptive module consists of a context-based sound process. Each module is able to observe another audio signal (generally produced by another module), it extracts a set of descriptors from the signal through machine listening, and maps those descriptors to the parameters of a sound process contained in the module. In this way, each module can define its agency in relation to the output of another module that is being observed, thus creating a network of influences. Each adaptive sound module has the capability to change the signal it is monitoring in real-time using a routing system that allows it to switch between the output of all the other active modules. Switching can be considered as the assignment of a send in a mixer, which in the case of *Adapt* consists of assigning a specific bus[18] index to the module. By switching, the module is able to change its perceived environment and modify the overall structure of the network.

[18] A bus is an abstraction of the Supercollider (McCartney 2002) language. Each bus possesses a unique index that is used for accessing it and writing and reading signals.



Adaptive sound modules can be of different types and can theoretically implement any type of audio algorithm as long as it is real-time and associated with an analysis. This includes either processing an input signal as in the example shown in the figure above, or synthesizing a new sound from the features analyzed in the observed signal.



The analysis performed by the module can use any descriptor, combine them in various ways, and apply differentiation to include the change rate of the signal. However, in the design of an adaptive sound module one must consider that it is not possible to foresee the exact nature of the sounds it will analyze. These modules should not be thought of as a library of sounds to be used by the performer, but as components of a network that jointly work together and influence one another. In this sense, compatibility with the rest of the modules is more important than creating an extremely sophisticated process. For this reason, rather than trying to extract very detailed and representative information about the input signal, the module design should look for meaningful relationships between the descriptors and the process parameters to which they are mapped. For example, a sound process based on feedback that tends to increase exponentially can monitor the volume of another process and associate this analysis with the feedback coefficient to create a balance between the two processes. A process based on the creation of harmonic textures instead could monitor the spectral centroid of another process to modify its intonation. Sometimes it can also be interesting to create mappings between very different domains, such as mapping an amplitude analysis to a frequency parameter, creating *glissandos* in a sound as the volume of another increases. In this sense, the term *meaningful* should not be interpreted from a technical point of view, but rather in relation to the type of perceptual result we want to achieve.

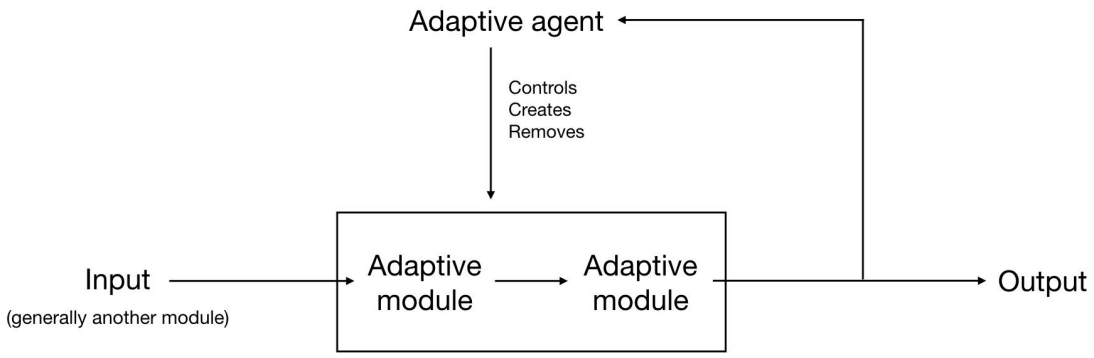
7.2.3 Adaptive agent

Adaptive agents use machine listening to keep track of a set of features extrapolated from an audio signal. These features are stored and subsequently used by the system both to obtain information on its behavior on large time windows and to perform some actions accordingly. While the main purpose of adaptive sound modules is to give immediate response to changes in sound, the role of

adaptive agents is to allow the system to 'remember' what has already happened. The actions performed by an adaptive agent aim to modify the behavior of an adaptive sound process. These actions include: instantiating or removing the module from the audio server, changing which signal the module is analyzing or changing its parameters. Unlike adaptive sound modules, adaptive agents are not rigidly mapped to the control of real-time sound processes, but act on the software configuration. In other words, they give the software the ability to modify itself. So far the two explored strategies for storing data extracted from the analysis performed by adaptive agents are 'sound slicing' and 'signal integration'. Sound slicing uses algorithms like onset detection (Stowell and Plumblet 2007) to perceive changes in the signal and divide it into segments. The algorithm then stores the average values of some chosen descriptors for each given segment of audio. In this way it is possible to have both a perception of the density of the signal – given by how many segments are detected in a specific time frame – and to have a discrete representation of the signal features through a multidimensional array. Signal integration uses a different approach. In it, the values analyzed by the adaptive agent are accumulated as an audio signal using a leaky integrator[19]. This allows for a continuous accumulation – as continuous as it can be in the digital domain – of the values analyzed by the descriptor and to take an action when this value overcomes a given threshold. The accumulation of the signal is generally preceded by a logical operation that opens or closes a gate, thus allowing the signal to be accumulated only if a condition is met, such as being greater than a certain threshold. Another interesting strategy is to accumulate the rate of change of a given descriptor by putting a two point differentiator and a leaky integrator in series. In addition to the data extrapolated from audio signal analysis, adaptive agents keep also track of the changes to

[19] A leaky integrator implements a differential equation that calculates the integral of its input and gradually leaks a small amount over time. It can be achieved using a filter that implements the formula out(0) = in(0) + (coef * out(-1)). See also the Integrator UGen in Supercollider.

the system they perform. This is done by storing the number of adaptive sound processes that have been instantiated or removed by the adaptive agent in a certain period of time. Additionally, the adaptive agent keeps track of which adaptive sound process it acted on. This can be useful to prevent some unwanted behavior, like for example to instance the same adaptive sound process multiple times in a row.



7.3.4 Overall considerations

Adaptive sound process and Adaptive agents are meant to jointly govern the evolution of a system creating behaviors on different time scales. In the context of the time scales in the perception of music (Roads 2004), adaptive sound processes would mainly operate on a micro time scale, creating pitch, rhythmic, and timbral variations, while adaptive agents would be more suited for the meso time scale, creating phrase structures and grouping sound transformations. However, it is also possible to create adaptive sound processes exhibiting behaviors on larger time scales, or to force an adaptive agent to work on shorter time intervals. In any case, the functioning of one of

these two components can only be fully understood when related to the other, since they both influence each other's behavior and model the same phenomenon from different temporal perspectives. Some sound examples of these behaviors are described below.

7.3 Adapt *Études*

Adapt Études consist of a series of short compositions realized during the early developments of *Adapt*, and were focused on exploring possible developments of the results obtained in *Time Debris*. The strategy adopted consisted of creating networks of adaptive sound processes based on sound analysis, focusing on the emergent behaviors exhibited by the system. The compositional approach for the realization of the works was to live code the software until an interesting sound behavior occurred and to record it without manually changing the configuration. From this material I selected 5 recordings that I found most interesting and from each recording I selected a start and end point. The *Ètudes* have not undergone any other transformations beyond these, except for a compression to slightly reduce their dynamic range and bring the loudness to a level appropriate for listening and an equalization to attenuate some resonances in the middle frequency range which were at times unpleasant to hear.

The works use 4 types of elements:

-Short percussive sounds driven by a randomized pattern controlled by the performer and used to excite the system;

-A variety of adaptive sound processes creating sound textures of various kinds;

-An adaptive real-time granulator analyzing the audio produced by the system and developing granulation layers from a circular buffer containing the last two seconds of sound produced by the system;

-An onset detection meant to measure the density of the output and control the adaptive sound processes.

01

Short percussive sounds are processed with some comb filters. An onset detection of the resulting sound is then used to activate and deactivate textures of adaptive parallel processing (00:25 00:31 00:40). A maximum of 3 textures are activated simultaneously in relation to the event density of the pattern and influence one another. In this recording, I also experimented using a gate with a very low threshold to process the master output (for example around second 4 the effect of the gate on the noise is clearly audible). This suggests that interesting details could be added using creative dynamic processing on the various adaptive processes.

02

In this excerpt, I increased the maximum amount of possible concurrent textures. I also added new textures making rich low-frequency sounds that sometimes saturate, feedback loops that develop harmonic materials from the input, and reverberated textures processed with a tremolo-like amp modulation effect. Overlapping of more differentiated automatic textures seems to yield richer, more organic results, but the logic by which they are activated is still primitive. Some moments in the recording suggested that particular pairings between these textures give better results than

others, and that a mechanism could be implemented to prevent the same combinations from recurring.

03

Here I changed the settings of the granulators so that the density would react to the RMS of the adaptive textures. This develops some interesting micro-rhythms that counterpoint the movements of the textures. Using the feedback based texture introduced in the previous example, I added a system meant to randomize their spectral content each time they are activated.

04

In this recording I further experimented with the parameters of the granulator by adding a fill factor that relates the density to the grain duration. When the fill factor is greater than 1 an overlapping between the grains occurs. The interaction of this behavior with the adaptive textures creates some compelling behaviors, e.g., at 00:27.

05

In this recording, I made the pattern of short percussive sound extremely sparse to favor static configurations in the system. The sound in the first minute is given by the interaction of the granulator and the automatic textures but no onset is detected and there is no change in the configuration. When at 00:57 some percussive sounds are played, new textures are started and the balance of the system shifts into another configuration.

7.4 Live coding with Adapt

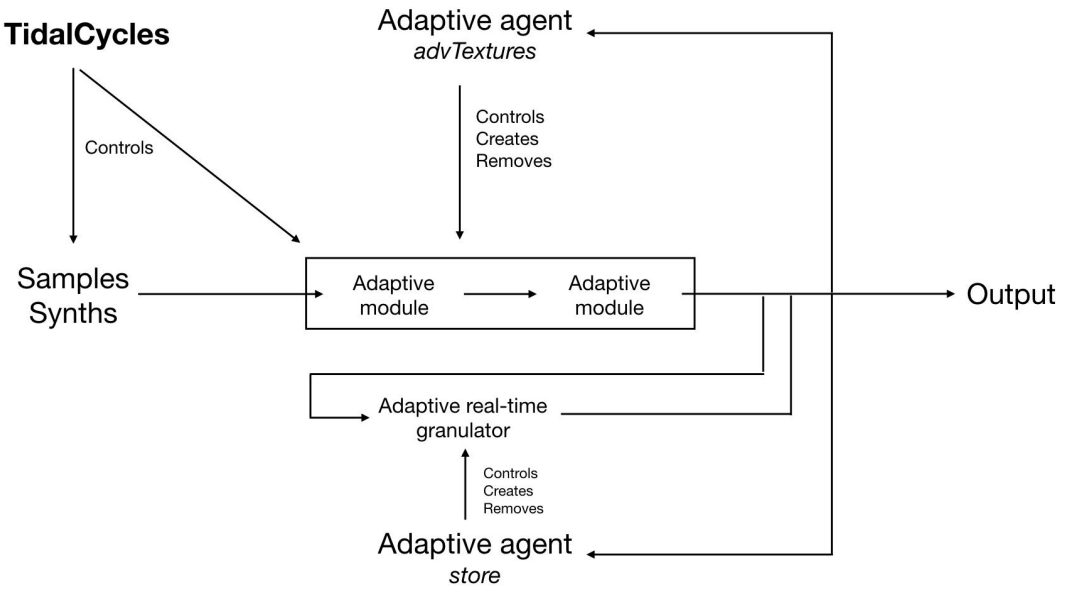
Live Coding with Adapt (Corvi 2022a) is a performance that was presented as part of the ICFP 2022[20]. The performance was a 20 minute audiovisual live coded from scratch improvisation building on top of some prepared abstractions. A full video of the performance is available for online streaming[21], and a video in high quality is available for download with open access[22].

The performance uses adaptive sound processes as the main source of sound generation and processing. These are sequenced using Tidalcycles (McLean 2014). In some parts the performer also used some audio samples making them interact with the adaptive sound processes and other traditional sound effects (mainly reverb and distortion). During the performance, the patterns created with Tidalcycles were used to instantiate and remove various adaptive sound processes on the audio server and to control which audio source the modules were analyzing. In addition, the performer had the ability to activate two adaptive agents. The first one was called *advTextures* and could instantiate a series of adaptive sound processes that used various synthesis techniques. The second was called *store* and recorded the sound of the analyzed signal in a circular buffer, then reading the buffers through granulators whose parameters were controlled by descriptors extracted from the analyzed signal. Both these two agents analyzed an audio signal detecting onsets, and instantiating new adaptive sound processes in a parallel chain for every specific number of detected onsets. Once deactivated, the adaptive agent would delete all the adaptive sound processes it created after a fade out.

[20] The International Conference on Functional Programming held in Ljubljana on 11-16 September 2022.

[21] https://www.youtube.com/watch?v=83yBrlRiOFE

[22] https://zenodo.org/record/7443687#.Y58AxuzMJn4



The main purpose of Live coding with Adapt was to combine the expressive possibilities of sequences and patterns with aspects such as timbre and Spectromorphology (Smalley 1997)[23]. In this sense, having interconnected content-aware components led to more organic transitions between various configurations of the software by establishing relationships between the evolution of simultaneous sound processes. Moreover, *Adapt*'s logic stimulates emergent behaviors in the software that can be used to stimulate the performer's inspiration and suggest new ideas during performance. These behaviors are not simply random, as in the case of an aleatoric sequence. They react to the performer's inputs, having a considerable impact on the embodiment that the artist can develop with the system and on the kind of interplay that is generated between man and machine.

[23] See section 11.3 for a practical example.

8. *Time Debris*

Time Debris is a series of works that aims to question the human perception of time interweaving music, computational processes and improvisation. This ongoing research combines live coding, machine listening, and adaptive systems to generate emergent behaviors arising from the interaction between the performer and computational processes spanning across different time scales.

The title is inspired by a section of the book *The Order of Time* (Rovelli 2018) written by the physicist and philosopher Carlo Rovelli, where he inquires into the nature of Time and deconstructs the illusory nature of its appearance. My fascination with Rovelli's ideas stems from the intricate connection between music and our comprehension of Time, especially considering its ephemeral and intangible presence, which solely materializes within time itself. The relationship between temporality and music is a particularly stratified and multidimensional concept. As early as 1960, composer Karlheinz Stockhausen posited the idea of Unified Time Structuring, highlighting how the continuum between pitch, rhythm and form can be a territory to be explored by the composer[24] (Stockhausen 1989). Computer music offers a distinctive perspective with which to investigate temporality, since it allows the sound phenomenon to be investigated and organized on a multiplicity of scales[25] that were previously impossible. In 1985 Trevor Wishart criticized the lattice based approach present in much Western music and explained how through the computer he could achieve some of the sound transformation processes he had always dreamed of by composing in the continuum of concrete experience. Many of the technological artifacts used

[24] See his composition *Kontakte* (Stockhausen 1966).
[25] See the definition of Time Scales of Music proposed by Curtis Roads in (2001 Microsound).

today, though more advanced and sophisticated, have partly inherited this lattice based approach. Some examples may be technologies such as the *MIDI* protocol, sequencers in *DAW*s and synths, or the distinction between score and orchestra in languages such as Csound and in language and server in Supercollider (McCartney 2002). The ideas behind *Time Debris* started developing when I realized that although I had a very sophisticated system for sequencing musical events and synthesizing sound, my thinking inherited a lattice based approach where on one hand I had the timbres and on the other I had the events. My curiosity, however, lay in exploring how sound characteristics, which manifest across different temporal scales, interrelate with one another and are mutually constituted. For this purpose, I started designing processes that operate across distinct temporal scales, focusing on how their interaction could create emergent behaviors in timbre, rhythm and form. These ideas were further refined and expanded in my research with *Adapt* and finally led to the creation of adaptive sound modules and adaptive agents.

8.1 *Time Debris* at Sonology Discussion Concert

The first artistic work realized as part of this series was performed on 9th February 2022 in the Amare's Conservatoriumzaal as part of the Sonology Discussion Concert, and later released in digital format on the SUPERPANG label (Corvi 2022b). The performance consisted in a solo live coding improvisation where my aim was to investigate not only how the domain of events and those of timbers could interact and merge, but also how this phenomenon could become the subject of an improvisation. As the researcher progressed, it also explored paths beyond performance, as described in the following section of this work. .

8.2 *Time Debris*: *Superimpositions*

While the previous works focused on live coding performance and real-time processes, *Superimpositions* adopted the form of a first fixed media composition. The piece was created from recordings of various improvisations made at different stages in the development of the live coding environment employed in *Time Debris*. Some legitimate questions that may arise are why produce a fixed media piece, given the interest in ephemerality? Why constrain the music to a specific form rather than leaving it open to the various possibilities of a generative process flow? In my experience working on fixed media compositions using the materials created during the system's development is a critical moment of reflection because it enables exploring the behavior of the system from a different perspective. Frequently, such an approach leads to the discovery interactions that can then be implemented in real-time processes in the future. Other times, it allows to compose sound behaviors that cannot be formalized in a real-time process. As a computer musician, upon observing my work and that of other artists around me, I have noticed that some of the most intriguing artistic outcomes may emerge during the most unstable phases in the development of a system. Unfortunately, these behaviors are sometimes lost because the system takes a different direction. Although an ephemeral approach to software incorporates the possibility of recreating these stages of instability and transition, sometimes it seems impossible to rediscover a specific behavior amidst the infinite possible configurations, particularly if its cause is behind our current understanding of the system. From this perspective, I do not believe that a fixed media composition is necessarily in contrast with an aesthetic of ephemerality. Instead, it can be a means of communicating how the artistic work exists in overlapping temporal frames, as it combines a long term design process with instinctive explorations and a deliberate compositional approach.

Ultimately, the focus on temporality in this work is an attempt to blur the boundary between improvisation, composition and instrument design, not only seeking relationships between these three domains, but also exploring the continuity between them and their mutual constitution.

9. The Cross Adaptive Ensemble

The work I was doing with *Adapt* had led me to develop a set of processes with which to engage in dialogue primarily focused on solo performance. However, I had always thought that this approach could be extended across multiple computers and performers. Influenced by actor-network theory and its sociological roots, I was interested in exploring how this approach could be a way to develop not only a form of interplay between myself and the computer, but also between myself and other performers, thus creating a network connecting human and artificial agents. Unlike other collaborative improvisational practices, the ability of performers to listen to each other is expanded with a network of audio analysis connecting the various computers used by each performer. Globally, this creates a system capable of monitoring its own behavior through both human perception and machine listening. From a practical standpoint, this network is much more concrete than one might imagine, as it is made up of analog audio connections that link each performer to all the others. Each patch controlled by a performer has a machine listening system that can both monitor the output of the other performers and influence its own sound output by dynamically relating the expressive features of each other's soundstream. This allows to create a variety of emergent behaviors with great flexibility by modifying on-the-fly the routing structure and the parameters of the machine listening systems.

9.1 Strategies and sound results

In this section I would like to briefly introduce some of the most interesting strategies and musical behaviors that were explored during the works done with the Cross Adaptive Ensemble. These

works consist of collaborative improvisations among three performers using different algorithmic systems including some kind of adaptive processing. They are the result of a collaboration between Giulia Francavilla, Riccardo Ancona, Elif Gülin Soğuksu, Andrejs Poikāns, and Francesco Corvi.

9.1.1 Spatialization

One of the fundamental aspects of this project is the interplay that is created among the various members of the ensemble and the resulting feeling of liveness. The risk involved in the use of algorithmic systems generating sounds not attributable to clear performative gestures is that it can become very hard for the audience to identify which performer is producing which sound. Here spatialization can play a fundamental role , as localizing the sound in the direction of the performer allows the audience to associate a certain flow of sounds with the activity of the performer who is producing it. For this reason, the typical set up used in the ensemble is for each performer to use a mono signal that is output from only one speaker. Thus we have often decided to sacrifice the possibility of creating spatial sound processes using multiple speakers in favor of a clearer sound localization. This choice should not only be interpreted as a compromise for the needs of the audience, but it has also proved to be a good strategy for the members of the ensemble to distinguish their own flow of sounds and identify the activity of other performers. In the future, I believe it would be interesting to further explore this aspect and understand how spatialization could enhance the interplay between musicians being controlled by analysis.

9.1.2 Exchanges

This type of interaction involves the propagation of scattered and impulsive sounds in the analysis network. This type of dynamics is created when performers set up their patch to respond to the envelope of the monitored signal, creating other similar sounds with a variable delay. In this type of configuration, a performer would typically create an initial impulse that is first used to excite the network and then propagates across the various computers.

9.1.3 Canon

A canon behavior can be achieved with a configuration similar to that of exchanges. In this case, a delay of several seconds is applied to the incoming sound of another performer. The canon behavior is clearly evident when using sounds with a longer decay, but it can also be interesting when using continuous textures or shorter sounds. Through the use of a pitch tracker or convolution, it is also possible to transfer the harmonic characteristics between the sound streams of the various performers. The perceptual result can be very interesting because it clearly shows how each patch interprets and modifies the sounds of another patch.

9.1.4 Spectral distribution

This strategy can be used when all performers are creating a sound with a rich spectral content. It involves distributing the sounds of the different performers across various portions of the spectrum, such as the low, mid, and high frequencies. Rather than filtering the output sound of one's own patch, this behavior can be achieved by filtering the incoming sound that is being listened to by the patch's analysis system (i.e., the sound of the other performers). In this way, the

analysis algorithm will receive only a portion of the spectrum of the incoming sound and will respond by creating an output that uses only the characteristics present in that range of the spectrum. From a creative perspective, this strategy can be used to transition from a moment in which the performers' sounds merge into a single mass, to moments in which they are perceived as distinct, occupying different parts of the spectrum.

9.2 Remarks

The phenomenological experience of playing with the cross adaptive ensemble is neither one of being in control of something, nor of being in dialogue with an external entity. Rather the sensation could be better described as being encompassed by an ecosystem . In this regard, it fosters a very peculiar form of embodiment where the performers are connected by means of technology creating an evolving network. Through the design of a technological artifact, each member of the ensemble developed a personal vision of a sound. This vision was subsequently shared with others both through a collective experience and through the sharing of ideas. Furthermore, this vision is not conceived in an autonomous, stable and independent way, but rather as something that has to relate and interact with the work of the other members in a continuous process that begins rehearsing in the studio and continues until the performance on stage in front of the audience. The type of result is often surprising, as it is not only given by the sum of individual practices, but emerges from the complexity lying at the intersection of them. From my point of view, working with this ensemble has shown me how technology is not only a medium for individual exploration, but also a way of connecting with other human beings; creating new means of communication; and to express concepts that emerge from a common dialogue.

10. Conclusions

This thesis pivots around three aspects– a philosophical inquiry; a technological development and the creation of artistic works– which I have developed in parallel while at the same time trying to illustrate how each of them affected the others. Upon observing my work, I believe it is impossible to make a clear separation between technique, knowledge, and expression, since my artistic research and its aesthetic values are developed alongside the technological artifacts that I employ. A similar consideration applies to the concepts of theory and practice. Even if these concepts can be distinguished, they cannot be separated, especially if separating them is just an attempt to figure out which comes first and which comes after. In my experience, theory informs practice and practice extends theory, thus creating a virtuous circle in which there is no starting point, let alone a hierarchy. During this process, I have come to understand that exploring the liminal space between concepts is more interesting than attempting to draw conclusions meant to define the essence of something. This prompted me to pursue ephemerality instead of stability, to explore the creative possibilities of such a path and to face the technical challenges it implies. Starting from these conclusions, I can already foresee the multitude of new possible beginnings, and I am convinced that the most exciting part of the journey is still ahead of me.

11. List of sound examples

11.1 Adapt *Études*

For a detailed description of each example see section 7.3.

For 01 see file “adpetudes01.mp3”.

For 02 see file “adpetudes02.mp3”.

For 03 see file “adpetudes03.mp3”.

For 04 see file “adpetudes04.mp3”.

For 05 see file “adpetudes05.mp3”.

11.2 Live coding with Adapt (video)

For an example of how patterns and timbral and spectromorphological exploration can be combined, see the video "LiveCodingWithAdapt_Spectromorphology.mp4".

For an example of hypermediate multimedia experience through the text editor, see the video: “LiveCodingWithAdapt_Hypermediated.mp4”.

For a full video of the performance see https://www.youtube.com/watch?v=83yBrlRiOFE

or download a high quality video at https://zenodo.org/record/7443687#.ZGH1LdZBya4

11.3 Time Debris

Time Debris live at Sonology Discussion Concert see file “Francesco Corvi - Time debris - 01 Time debris.mp3” or https://nesso.bandcamp.com/album/time-debris

11.4 Cross Adaptive Ensemble

These recordings were originally spatialized on three channels. The examples provided here have been reduced to a stereophonic configuration. At the same time, the original spatialization has been preserved to the best possible extent. . For a detailed description of each example see section 9.1 of the present work.

For Exchanges see file "CAEexchanges.mp3".

For Canon see file "CAEcanon.mp3".

For Spectral distribution see file "CAESpectralDistribution.mp3".

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