Enactive framework for design of Digital Music Interfaces

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Abstract. This paper presents a theoretical framework focused on how some principles of Enaction can contribute to the design of Digital Music Interfaces (DMIs). Enaction comprises cognition as an emergent property resulting from the structural coupling of the organism and its environment. As opposed to the representationalist perspective, the knowledge for Enactivism is not based on a mental mirroring of nature but on the embodied experience of the subject that emerges from a peculiar view of the world on which he actuates. Through a systemic perspective, we present some principles of Enactive Interfaces and how it is reflected in the design of DMIs. The enactive approach is established from a bilateral recursion between system components through ontologies that can be dynamically adapted and restructured so that their behaviors can emerge from their interaction. Performers and interfaces are immersed in a shared autonomy system, so both co-evolve from the experience of interaction. Finally, we discuss how this approach brings relevant aspects of interaction with DMIs, primarily related to embodiment, autonomy, and agency.

Keywords. Digital Luthery; Digital Music Interfaces (DMI); Enaction; Music Cognition;

1 Introduction

The emergence of Digital Music Interfaces (DMIs) in last decades proposed new ways of thinking about technical and technological mediation of musical experience. While acoustical instruments provide direct interaction between the humans' sensorimotor contingencies and the environment, the interaction in DMIs is established through a mediation system. The separation of the gestural control and sound generation systems in DMIs represents, on the one hand, an expansion of the expressive potentialities of instrumental interaction and, on the other, a potential weakening of the engagement and presence sensations [1] [2]. This is mainly due to the discontinuity between the performer's actions and the DMI resulting behaviors (i.e. sound and images). The discontinuity between them is negotiated by a mediation system that translates the physical domain information into the digital domain and vice-versa [3] [4].

The mediation systems of our everyday technological artifacts are impregnated of cultural and scientific models that comprise a peculiar perspective about the environment around us. Considering the epistemic nature of DMIs, Magnusson [4] arguments that our interaction with it occurs through symbolic channels, i.e., require the existence of a mediation system that arbitrarily translates the performer's actions to a system that is responsible for the vibration of the sound bodies. While the construction of acoustic instruments is based on tacit forms of knowledge acquired through direct experimentation with physical materials, the Digital Lutherie operates under kind of "meta-machine". A "meta-machine" is a set of instructions that is converted to in binary information, which in turn are converted to analog current and transmitted to the speakers.

The affordances [5] of acoustic instruments are explicitly manifested by their physical and mechanical nature. Even with deliberate practice, the performer becomes able to explore new possibilities for action, as the knowledge is established through a *bottom-up* operation of human sensorimotor contingencies related to the physical object. In DMIs, despite the action potentialities highlighted in their physical control interfaces, the interaction is based on symbolic exchanges between the performer and computer. Its affordances are established by mental representations of instrument parameters and their modes of transformation. As a violin luthier enables affordances to manipulate the wood, the digital luthier defines the affordances and constraints of DMIs through mediation strategies employed between the physical energy channel of gestural interfaces and symbolic mechanisms present on epistemic tools [4].

While acoustic instruments may be regarded as extensions of our body, DMIs could be considered as cognitive extensions. As opposed to the more rigidity of action possibilities in acoustical context, DMIs can comprise more flexible and plastic range of actions possibilities. Their mediation system can be modified over time considering especially the consolidated habits through human experience with the interface [6].

Thus, an enactive perspective can be usefull both in understanding of cognitive tools that underlie the human interaction with DMIs as well as guidance on the interface design based on the principles of *agency*, *adaptivity,* and *embodiment*. Our goal is to find a theoretical framework that supports the design of DMIs whose ontologies can be dynamically adapted and restructured to extend the human sense-making through interaction. We believe that this approach can assign more plasticity to the DMI design, especially considering the human experience as base for dynamic and adaptive machine architectures.

First, we will briefly present some concepts related to Enaction, how it is reflected on the Enactive System design, and how this approach brings significant aspects of interaction with DMIs. Finally, we propose a model that agents (both human and machines) are immersed in a shared autonomy system that becomes more "opaque" and "translucent" as more congruent are its interactions with the environment.

2 An Enactive Approach

2.1 Cognition as Enaction

Enaction proposed by [7] presented cognition as an emergent property that results from the structural coupling of an organism and its environment. Instead Cognitivism and Conexionism approaches, that assumes tacitly variations of cognitive realism, the knowledge of Enaction results from sense-making about the external world through the subject's sensorimotor contingencies. It is not based on a mirroring of nature by the mind but on the embodied experience of the subject that emerges from a peculiar view of the world on which he actuates.

Two complementary fundaments are established about Enaction: (i) the action is perceptually oriented. The sensory and motor processes are inseparable in cognition. As the environment is constantly changing by the action of the subject, the point of interest in perception is no longer a previously conceived world but the sensorimotor structures of the subject-observer; and (ii) the cognitive structures emerge of recurrent sensorimotor *schemas* that determinate how the subject can act and how he is modulated by the environmental events. In other words, the cognition is an embodied action, and it depends on the body's sensorimotor experiences in the physical world.

The embodiment is understood as an enactive instance wherewith we construct meanings, i.e. sense-making, about the world and ourselves. It stresses the dynamic and active nature of cognition: we perceive as we act, and the meanings constructed by this cognition property modulates our modes of action. Cognition does not consist thus of mental representations of the physical world but results from the history of structural coupling of an autonomous, adaptive, and goal-oriented agent and its environment [8] [9].

2.2 Enactive Systems

In last decade, the increase of non-representationalist models has provided greater robustness and flexibility of artificial cognitive systems. [9] considers however that such approach still leaves gaps on the agency and the sense-making compared to lived-cognition. Enactive-Based Artificial Systems (EBAS) must be able to construct meanings that are owned through a sensorimotor coupling with the physical world guided by internally established goals. The authors discuss two premises for the constitution of an EBAS, namely constitutive autonomy and adaptativity.

2.2.1 Constitutive Autonomy

This premise refers to the ability of the system to construct, under a certain level of description, the personal elements that constitute itself. The constitutive autonomy of an agent allows it to obtain a distinct perspective, "a world that has significant-affordances according to the intrinsic goals of the system" [9, p.285]. The enactivist approach aims not only the construction of the agents themselves but also the development of conditions that provide the own agents build the functional and structural attributes that define them. The focus becomes the design of environments that generates agents engaged with its environment and give rise to particular categories of behavior.

2.2.2 Adaptativity

This premise refers to the self-regulatory capacity of the systems to actively adjust their sensorimotor mechanisms related to the constraints and affordances of its environment. The system transformations are not intrinsic to the environment but arise from an active monitoring of agent to maintaining its systemic unity.

Adaptivity implies a certain robustness or tolerance to internal and external changes. For [10], the threshold of the transformation of a system is defined by a viability set that comprises non-fatal events supported without the system's constitutive autonomy loss. The space of viability sets is finite, limited and, generally variable over time. When the actual state of a system approaches the limits of its space of viabilities, the system searches new possible states and puts them into practice depending on whether these will approach or hold off those limits.

The adaptivity can unfold recursive transformations able to change irreversibly the way a system perceives the environment. The structural transformations of the systems are related to sensorimotor loops. The effects produced by the actuators of the agent in the external environment can modify its sensors, changing, in turn, its actuators again. The self-regulating mechanisms are based on evolutionary algorithms [11] [12], in which the targets are externally and extrinsically determined. One of the most notable research fields in artificial cognitive systems focuses on the development of strategies of self-regulation based on internally oriented goals. These strategies assume the arrangement of a perspective that is the system itself and, therefore, different from the designer or an outside observer. On this direction, the biological-inspired artificial system developed by [13] displayed satisfactory results in the creation of narratives based on musical experience [14]. The construction of artificial devices based on biological functions could be a solution to integrate robustness and complexity of machine behaviors.

3 Bodies en(action): the experience as design

3.1 Gesture Transductions

Cadoz [15] proposes one definition about instrumental gesture based on three determinants of the relationship between human and environment. For him, the instrumental gesture: (i) is generated through a physical energy transduced from human action to sound object (*ergotic*); (ii) enables perception of environment and agent proprioception (*epistemic*); and (iii) transmits an information from agent to the environment (*semiotic*) [15] [16]. Despite the restrictions of this definition, which do not includes non-tangible interfaces in the instrumental domain, for instance, highlights some relevant aspects from Enaction.

The propose of Cadoz emphasizes the reciprocity between the performer's actions and the sensory experience. The *ergotic* channel is established in the instrumental interaction through a coherent and uninterrupted energy chain that transduces the performer's actions to sound behaviors. Although missing or discontinuous in the case of DMIs, the ergotic interaction can be simulated by mapping strategies to create an apparent contiguity between the performer's actions and sound behaviors. [17] and [18] have demonstrated how the investigation of familiar sensorimotor contingencies in sound design can support a more intimate and embodied interaction with DMIs.

3.2 Embodiment and Identity

The embodiment is related to an intimate relationship instantiated in the interaction between humans and the environmental objects. An individual experiences an object firstly through its environmental contingencies, without fixing direct reciprocities between his actions and the perceived behaviors of this object. Along time, he can regulate his sensorimotor contingencies and gradually establish a more direct interaction with that object, anticipating the environmental responses through his actions. Thus, arises a second-order nature, in which the object becomes an instrument and integrates as part of the performer's body. Hence, performer and instrument became a temporary unity in performance situation [19]. From this temporary unity, a new relational space that provides a mediation instance between human and the environment emerge.

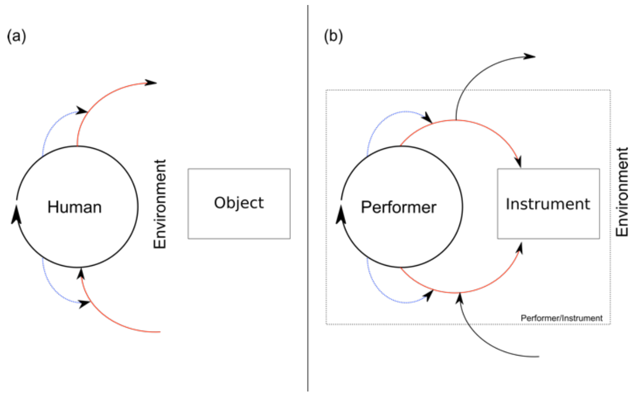

Fig. 1. Relationship between performer and the musical instrument in non-performatic (a) and performatic (b) situations. The transition from (a) to (b) is marked by the embodiment of the instrument that constitutes a temporary unity with the performer.

The instrument becomes part of performer's body as he incorporates the instrument affordances and constraints through the regulation of his perceptual and motor responses. The coupling between the action and the response perception from the object is constituted through a continuous human self-regulation (represented by the blue arrows in Figure 1a and 1b). Nevertheless, this process is not passive by the individual. It arises from an ongoing negotiation between logical consistency founded in the external environment and the flexibility of the individual to adjust his sensorimotor mechanisms [20]. The performer, as a recurrent and autonomous system, modifies his sensorimotor patterns to provide him an expansion of meanings constructed by his experience with the interface.

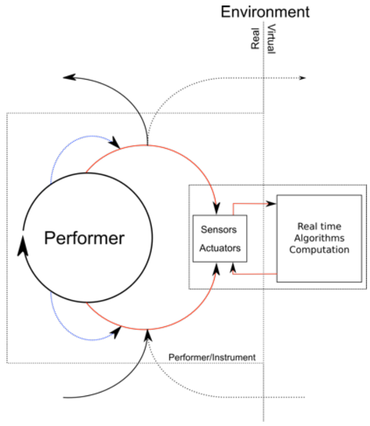

Fig. 2. Coupling between Performer and Digital Music Interfaces constituting a temporary unity that mediates the interaction both in the real and virtual world.

The embodiment in DMIs is related not only to the feedback between action and perception of the performer in the physical world. It is also linked to how this sensorimotor loop is translated to the symbolic domain under which it operates the system control and instrument processing. The congruence between the performer's gesture and sound behaviors produced by DMI will determine the cohesion of the established temporary unity. This interaction allows the performer, therefore, to be recognized as present in another relational space mediated by technological devices and that differ from the physical space occupied by his body [3].

3.3 Agency and Autonomy

Traditionally, the paradigm of interaction in acoustical context is based on asymmetric relations that performers are conceived as active agents and instruments as passive objects. In the digital domain, new balances became possible, and the stratified roles of performers and machines can be reconsidered. Both can thus act as co-agents, each modulating and being modulated by the other. An enactive approach applied to DMI design comprises users and interfaces immersed in a shared autonomy system, so both co-evolve from the experience of interaction.

The agency refers to the machine ability to regulate its inputs, sometimes unknown and unforeseen, and respond to this through its actuator. Its self-regulation mechanisms must be however consistent with the fundamental goals established by the history of coupling between the agent and its environment. The capacity to make decisions based on intrinsic and not previously established sense of orientation reflects the autonomy of the system. An autonomous DMI is, therefore, an embodied system that satisfies its internal goals through its actions in the environment.

In the model illustrated in Figure 3, interface and performer are coupled through their sensors/actuators (red arrows in Fig. 3) and both regulate their input/output mechanisms considering their goals (blue arrows in Fig. 3). Performer and interface became closed systems capable of modulating their structures to establish a more congruent interaction with the environment.

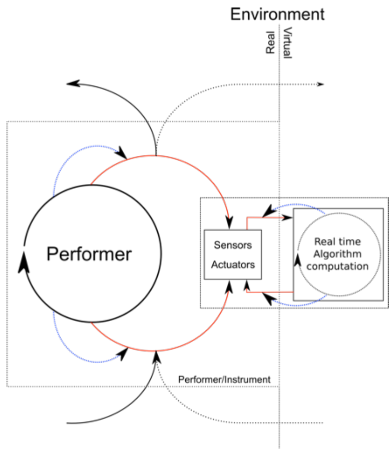

Fig. 3. DMI interactive model based on mutual re-current and self-regulated systems (both human and machine).

The enactive approach is established from a bilateral recursion between parts of the system through ontologies that can be dynamically adapted and restructured so that their behaviors emerge from their interaction. The technology is understood as part of a system with recursive and self-regulating properties, so the role of the interface becomes implicit [21].

While more traditional approaches on HCI are based on "transparency" paradigm, which aims to approximate the handling of interfaces to a situation of direct interaction between agent and environment [22], the enactive approach tends to certain "opacity". The habits emerged through the interaction are iteratively incorporated into the machine sensorimotor mechanisms. The embodiment of these habits will depend on the machine history of sensorimotor coupling with the environment. Thus, the degree of "opacity" or "transparency" of a DMI will vary in relation to the environmental contingencies established on the interaction. The interface will become more permeable to environmental disturbances so far as its sensorimotor contingencies do not guarantee it an adequate interaction with its environment.

4 Final Considerations

The enactive perspective provides new possibilities to design technological interfaces. The fundamental perspective purposed here is that it is possible to conceptually expand the design of DMIs considering the sense-making potential in human interaction with the world. Through this theoretical framework, the interface design comprises mechanisms that modulate the DMI structures considering the environmental contingencies concerning its intrinsic goals.

In traditional paradigm of instrumental music, roles are in general well-defined (or at least temporally dissociated) between its agents (performer, composer, and luthier) and objects (score and instrument). With DMI, new models have been proposed to bring the functionalities of each element as part of the process into play. The distinctions between performer as active agent and instrument as passive object become more fluid to the establishment of bilateral exchanges between them. The typified stability and heteronomy of traditional models of music interaction give way to the autonomy and adaptive capacity of computer systems, able to modify quickly to ensure a more congruent and meaningful interaction.

The Digital Lutherie here is no longer understood as a dissociated and previous process of musical experience. Instead, it can be integrated with the process of creation and musical experimentation. The functions of the interactors (both humans and computers) emerge from their experience and from the discovery process in which each agent outline its history of interactions. Instruments then become mobile structures arising from situated and continuum processes of negotiation between the robustness of the object and the plasticity of the environment.

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