ARCAA: a Framework to Analyse the Artefact Ecology in Computer Music Performance

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ABSTRACT

This paper presents ARCAA (Actors, Role, Context, Activity, Artefacts), a framework that supports designers in understanding the artefact ecology in the music performance scenario, in particular, allowing to frame the role of the different actors. The ARCAA framework is the result of the combination of two different areas of HCI: artefact ecology concept, and design framework for digital musical instruments. The model borrows three categories from MINUET an established design framework and rethinks them from an ecological perspective. In ARCAA, these three categories are used as three lenses to connect each human actor to her artefact ecology. Finally, the framework allows comparing how the various artefacts create connections among the different people involved. The second part of the paper describes a case study that shows a practical adoption of the framework.

CCS CONCEPTS

• Human-centered computing → HCI theory, concepts and models; Interaction design theory, concepts and paradigms; HCI theory, concepts and models.

KEYWORDS

Digital Music Performance, Artefact Ecology, Design Framework

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1 INTRODUCTION

With the transition from second to third wave HCI, the focus of the HCI community gradually shifted from the workplaces to everyday and cultural actives [4]. In parallel, interactive digital technology increasingly became central to many approaches in music. Particularly, novel artefacts contributed to defining new interactive strategies in music performances, with different performers engaging in complex relations with the technology. An example of this tendency is provided by the New Interfaces for Musical Expression (NIME) community and conference.

Emerging technologies have been used to develop new Digital Musical Instruments (DMIs) and augmented instruments, i.e. traditional instruments whose creative potential is enhanced by technological artefacts. The performers of these instruments are “users” in a traditional sense: they directly control and manipulate the technology to perform music. Other new digital musical tools, however, are not precisely used by the performers. With “used” here we refer to the traditional conceptualisation of user as the person who manipulate, use, a piece of interactive technology [1]. Thus the relationship between the human(s) and the technology is open to discussion. A class of tools to which this applies is that of the algorithmic systems that perform alongside human counterparts, engaging in musical dialogues [23, 30]. In these cases, the musician is not using the digital system by operating it, instead she plays her own instrument and engages in a dialogue with forms of digital automata. Another case is represented by performances that adopt screen score systems. Screen score systems manage creation/manipulation of scores in real time; these systems are usually designed targeting traditional instrumentalists who play what is notated on the score with their instruments [18]. In these cases, the instrumentalists do not use the technology, but are influenced by it. Moreover, composers deal with these tools before the performance, in some cases manipulating or using them, in others even coding. We claim that musicians can play different roles performing with musical interfaces, according to different categories of those interfaces. Consequently, there may be many differences in their activities during and before a performance and in their interactions with technology. We argue that there is a lack of research tackling these aspects. More generally, there is a lack of models that enable designers to take into account all these aspects, considering the different roles and actions of the various artefacts and human actors. In this paper we unpack this argument, providing evidence to the fact that these interactive scenarios present novel design challenges from a human-centred perspective. These scenarios introduce new nuances in the concept of using the technology, and as a consequence in the concept of the user itself. The expression human actor echoes the terminology proposed by Bannon [2] within the context of the Human-Centred approach to computing, and supports a more holistic vision of the humans interacting with technology, as opposed to considering them merely factors or user. We also propose the music performance as a scenario composed by many human actors and an ecology of artefacts. We borrow the concept of artefact ecology from Jung, who defines a personal ecology of artefacts as the set of artefacts “that a person owns, has access to, and uses” [22].

We advocate that there is a need of conceptualisation of humans and artefact ecology in a performative scenario. In this paper we interrogate ourselves with the provocative question *“Who are the users we are designing for?”* that can be applied to a comprehensive research issue regarding the use of interactive technologies for music performance as well as other forms of interactive art. This provocative question can be transformed in the following broad research question that this paper addresses: What are the roles played by human actors in a music technology performance, and what kind of activity do human actors perform while engaging with the artefacts in a performance scenario? We address this question proposing ARCAA (Actors, Role, Context Activities, and Artefact), a framework that enables the designer to incorporate different aspects of the interactive performance scenario. The model presented in this paper will support designer and creator of new musical interface to consider those musicians who are not directly interacting with the digital instrument, and create different hierarchies of use. We also present a case study to demonstrate the framework in use.

The rest of the paper is structured as follows. In Section 2 we describe related works on music technology and artefact ecology in HCI. Section 3 describes the model, and Section 4 presents a case study that we discuss under the lenses of the proposed model. In section 5 we discuss design implications of ARCAA in comparison with other existing frameworks. Section 6 presents conclusions and suggests future directions.

2 RELATED WORKS AND BACKGROUND

This paper is grounded in two main areas: music technology design and human-centred computing. Section 2.1 presents a literature review in computer technologies for music performance. Section 2.2 discusses HCI literature around the topics of human actors, and artefact ecology.

2.1 Interactive Technology for Music Performance

This section presents different types of interactive music technologies organised according to interactive modes. To start with, however, we revise the relations between the two main actors of the Western music tradition: composers and performers. This short description is necessary as this fundamental distinction between composers and performers reverberates in digital music performances.

2.1.1 Composers and Performers in the Western musical tradition. Western music has been characterised by the clear-cut distinction between composition and performance [34]. The composer and the performer mainly differ according to the moment of their involvement: composers write music before a performance, and this music is then played by performers. The composer and the performer can be the same person [35]. An important consideration, at least since the invention of print, is that the composer, the person who writes a piece of music, is considered the author of an artwork that can be reproduced in any moment [36]. Improvisation - i.e. inventing the music at the very moment of her performance - shares characteristics of composing and performing. In fact, in the traditional distinction between composition and performance, the composer is responsible for the creation of the music, and the performer is responsible for playing it. The improviser is responsible for both creating and playing a piece at the same time [32].

2.1.2 Interactive music systems. Interactive music systems introduced aspects in addition to composition, performance, and improvisation: designing and programming interactive musical artefacts. Digital musical artefacts include a variety of technologies, among which: algorithms that compose/improvise music [31], Digital Musical Instruments (DMIs) [21], augmented instruments [26], audiovisual tools [10], and screen score systems [18]. In this context, the process of composing is often subsumed in the design of the technology itself. This idea is well formalised in the concept of the “composed instrument” by Schnell [33]. A composed instrument is an artefact that subsumes aspects of an instrument (it can be played), machine (it can be programmed), and also represents the essence of a musical composition. Composed instruments often overlap the composition with the instrument itself and consequently blur the distinction between and designers and composers [24]. Not all the digital musical tools are composed instruments. Some of them are indeed designed just as new instruments, without embedding any composition in the instrument itself. One example is the Magnetic Resonator Piano [26] as this instrument was used by other composers (e.g. [11]).

Screen score systems [17] represent a set of interactive music technology that is particularly relevant in the scope of this paper. These systems rely on computational elements that generate or manipulate a musical score and visualise it in real-time [18]. These tools share with the composed instruments the property of blurring the distinction between composition and design/development of the technology. For this reason, it has been proposed that such tools can be considered as composed instruments [25]. The type of interaction that occurs during the performance with screen score systems are relevant to the scope of this paper. These musicians are not using in a traditional sense as they are not manipulating the technology. Rather, they use their traditional instrument to respond to the output. Despite not being directly operating the tools, these instrumentalists are important actors in this performance scenario: without them reading the scores, the artefact would have no purpose. To conclude, the recent developments of ubiquitous computing allowed audience participation in the performance: the audience interact with the music or with the performers using mobile apps [29, 37]. In these cases audience members become users and performers.

2.1.3 Design frameworks for interactive music systems. Numerous design frameworks have been presented to investigate the design of interactive music systems. Most of the studies on the design space of musical interface restricted their investigation to DMIs [19] and categorised musical interfaces on the basis of the interaction modalities: instrumental (the musician controls every aspect of the music), ornamental (the system has some level of control) and conversational (shared control). Other studies tried to specifically pinpoint different factors that come into play when designing a new musical interface. For instance, Jorda [20] discusses issues of balance between simplicity and complexity, playability, learning curve, and instrument efficiency; Birnbaum et al. [3] base their design framework on a number of dimensions, among which: required expertise, musical control, feedback modalities, and degrees of freedom. Whereas most of these frameworks are centred on technological aspects, Morreale et al. [27] propose a design framework (MINUET) for musical interfaces centred on the experience of the player. MINUET is a design process structured into two stages: the first one analyses the goals of the interface; the second stage specifies how to practically achieve these goals. The goals are articulated around three main elements: People, Context and Activity. As opposed to other frameworks, MINUET proposes a precise temporal unfolding rather than a set of heuristics. In all these attempts, there is a lack of design models that consider the complex scenarios in which the music performances take place. Specifically, no previous work has tried to identify the ways in which different human actors are involved in the performance when they are not user, in the sense that they are not directly operating the technology, nor are there frameworks that consider the different artefact ecologies in music performance.

2.2 Human Actors and Artefact Ecologies in HCI

In the last decades, the stratification of the HCI domain in many aspects of human life gradually led to the rise of a human-centred computing perspective [2]. This slow paradigm-shifting process came along with the idea that people are much more complex than merely system users. In particular, they have broader motivations, values, goals and interests. All these aspects cannot be fragmented into sets of independent system components, rather they all contribute to complete the design equation. For this reason, Bannon [1] claimed that to avoid transforming human beings into just another system component, it was necessary to reach a more holistic vision and proposed to move from the concept of human factors to human actors. Designing for people without taking into account that they are many other things other than users operating a system may lead to misunderstandings. In the very same way, considering just the interactions of a person with a single artefact may not even be sufficient to understand her relationship with the overall scenario that is taken into consideration [22]. The concept of artefacts ecology is extremely useful to investigate what we can find beyond the interaction of a person with a single artefact.

The word ecology used to conceptualise the artefact ecologies [5, 22] is borrowed from Gibson [13]. Gibson advocates that our physical ecology defines our (visual) perception and they cannot, therefore, be analysed in isolation. The ecology of a single subject is part of the complex physical world. Following Gibson's conceptualisation of ecologies, Jung et al. propose that a person's ecology of artefacts can be defined as the artefacts that a person owns, interacts with and uses [22]. Possibly because this concept is relatively new and still not widely adopted, its definition and use can vary. Jung [22] refers exclusively to the digital artefacts, while Bødker theoretically considers both digital and non-digital artefacts [5] although in empirical cases she focuses only on the digital ones [6,7,8]. On the spatial dimension, Jung et al. [22] adopt a more inclusive perspective, considering all the digital artefacts their participants own and use, while Bødker in some cases proposes to consider as artefact ecologies groups of artefact that are determined by "looking at the empirical situation" [5]. Within this context, Bødker developed the human-artefact model. This model is a framework composed of a set of questions, whose purpose is to understand the artefact ecology of a single person. The studies more strongly centred on the concept and definition of artefact ecology tend to have a strong focus on single individuals using a multiplicity of artefacts [5, 22]. Nevertheless, most of the empirical studies connect this individual usage to broader contexts such as interactions between people in a community environment [6, 7, 8]. Although this broader context is taken into consideration, the kind of relationship between actors involved in the common usage of artefacts seems to be quite loose.

Related to sound, recently Erkut and Serafin [12] proposed the idea of sonic artefact ecologies to analyse the relation of sounds in computational objects. To conclude, the idea of ecology has been adopted in the context of the music performance by Gurevich and Treviño [14]. The authors advocate that considering the relationships among the different persons on the stage is beneficial in order to understand the overall musical context. They discuss their proposal using several examples from music technology and HCI but do not conceptualise any design framework to assist designers in framing the stage pragmatically.

3 THE FRAMEWORK: ARCAA - ACTORS, ROLE, CONTEXTS, ACTIVITY AND ARTEFACTS

ARCAA is our proposed conceptual framework for understanding the roles and the actions of the different human actors involved in an interactive music scenario, within their ecology of artefacts. ARCAA aims to help designers understanding the characteristic of the different human actors. In particular, ARCAA focuses on how each different human actor is related to her ecology of artefacts in the performance scenario.

The framework considers the musical scenario of the performance from a holistic perspective, considering all the actors and the artefacts. Rather than limiting the investigation to the physical space of the performance, this model includes those situations that anticipate the performance itself. Such situations might include compositional aspects, but also the design of the technology itself if the technology is ad-hoc developed for a specific performance.

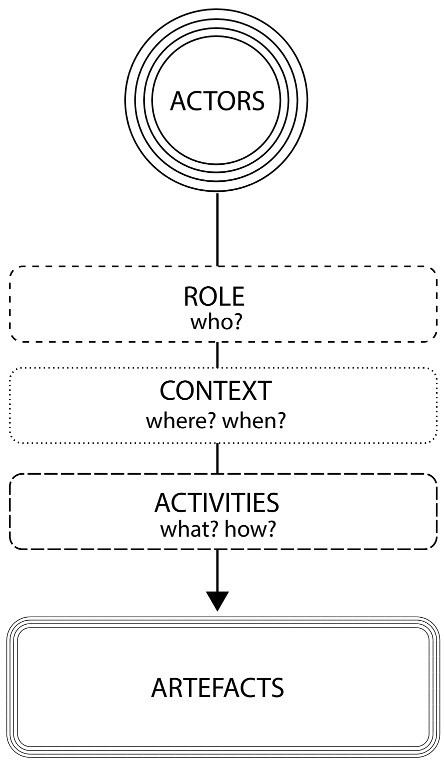

Figure 1: Structure of the framework: ARCAA (Actors, Role, Context, Activity, Artefacts). The framework connects all the actors (top in the scheme) to all the artefacts (bottom in the scheme) throughout the three levels: Role, Context, Activities. Each Level proposes different questions related to the actors: Who is involved, and in which role? – Where and when is the actor involved: In which context is each actor involved? Is the actor engaged in the real-time interaction? – What kind of activity is the actors performing? How is the actor manipulating or interacting with the artefacts?

From this perspective, the set of human actors that are considered, do not only include the actors who are physically operating the technology, but also those performing alongside the technology, composers, designers, developers, and so on. Even if the primary purpose of ARCAA is to support digital technology designers, our model also takes into consideration also the non-digital artefacts as part of the scenario. Therefore, the scenario may include acoustic instruments and scores.

The structure of ARCAA is borrowed from the top level interactive dimensions identified by MINUET [27]. We decided to rely on MINUET, given its focus on humans and their needs. ARCAA proposes three levels of analysis that mirror the three dimensions proposed by MINUET when defining the goals of a musical interface: People, Context, and Activities. In ARCAA, we change the word people to Role as the same person can play more role, while Context and Activities maintained the same terminology. Role aims at framing the role played by the actors involved in the interaction; Context distinguishes between actions that are carried out during the live interaction from those that are carried out before; Activities probes into the specific activities performed by the different human actors in relation to the different artefacts. The objective of this model is to analyse the role of each actor through different levels and gradually define the different connections that they have with the technological artefacts at play. The overall structure of ARCAA is shown in Figure 1.

An innovative aspect of ARCAA, compared to other DMIs design frameworks, is to look at the artefact ecologies of those actors that are not actually using the technology, but whose role is essential to, and whose activities are affected by, the interactive digital artefacts. Another novel aspect of this model is the inclusion of non-digital artefacts, such as traditional instruments.

3.1 First Level: People Role

The first level focuses on identifying the role of the human actors involved in the scenario. The actors include the users in the traditional sense, those who use the artefact, but also other human actors whose presence is relevant in the music performance. In this sense, it is worth specifying all the subjects who engage with the interface, thus considering the term engage from a broader perspective. Summarising, the first level proposes this question:

Who *is involved, and in which* ***role****?*

The following list shows the most typical roles. This list is not meant to be comprehensive of all the possible roles in music performance. Rather, we support that these categories depict the main distinctions in the roles and can offer key concepts to be fine-tuned for each specific scenario.

- *The Designer/programmer* should be considered only if the design process occurred in parallel to the creation of the performance; this can be the case of many new DMIs.

- *The Composer* is responsible for writing the piece, in a way that the core characteristics of the piece are not bound to a single performance, and, at least to some extents, repeatable.
- *The Performer* of a digital instrument is the traditional user, she is the actor that directly manipulates the technology.
- *The Instrumentalist* is a performer that plays a traditional musical instrument.
- *The audience performer* in case of audience participation

3.2 Second Level: Context

The second level aims at specifying the context in which each actor is involved. We refer to context as the actual moment in time and space in which the actor is involved. In the first level, we specified that a single actor might play different roles: such roles could be performed in different contexts. Therefore, we argue that it is essential to consider each different role while analysing the context to fine-tuning the roles.

The context mainly distinguishes between on-stage and off-stage and reflects the classic dyad composer/performer (described in section 2.1). Stage refers to the place in which the performance occurs, but not necessarily in the traditional sense. In the on-stage context, the actor is usually involved in a real-time interaction, whereas this usually is not the case in the on-stage context. Summarising, the second level addressed this question:

***Where** and **when** is the actor involved: In which context is each actor involved? Is the actor engaged in the real-time interaction?*

Where:
- *On-stage:* in this context, the actor engages live in real-time interactions in the same location. Rehearsals usually occur at on-stage context as they typically rely in real-time interactions.
- *On a control desk,* or in a control room, for those interaction that occur in relation to what happen on-stage, but in a different physical space.
- *Off-stage:* in this context, the actor is preparing the performance (e.g. designing the instrument, composing the piece) thus does not engage in live interaction.

When:
- *In real-time*: the interactions have a real-time impact on the performance; usually, the on-stage context implies the real-time interaction.
- *Not in Real-time*: the interactions do not have a real-time impact on the performance; usually, off-stage interactions do not occur in real-time.

3.3 Third Level: Activities

The third level connects the actors to all the artefacts. In this level, the artefact ecology of each actor emerges. The connection between the actors and the artefacts is expressed through the typologies of activities that involve them. Different actors might simultaneously perform different actions. For instance, an acoustic instrumentalist may be playing the flute while reading a score from a screen score system; or a DMI improviser may be manipulating some knobs on the instrument while listening to an algorithmic agent. The question that this level poses is:

***What kind** of activity is the actors performing? **How** is the actor manipulating or interacting with the artefacts?*

The following list presents some of the most common activities performed in music scenarios:
- *Designing* a digital artefact specifically for one performance.
- *Playing* a DMI (using the interface in the traditional sense).
- *Coding* or *providing data* for an algorithmic system
- *Performing alongside* a system that algorithmically generates music based on musical input.
- *Playing* a traditional instrument.
- *Composing* a piece, this may include compose scores or produce samples.
- *Reading* a score.

3.4 Artefact Ecologies of the Different Human Actors in the same Scenario

ARCAA connects all the actors with all the artefacts. The framework can be beneficial for the design and evaluation processes and can support practitioners to use new artefacts. By analysing the different human actors through these three levels, a designer can visualise the different artefact ecologies of each human actor. The framework highlights essential aspects of the actors: each level adds a layer of details. ARCAA also helps understanding how different persons and ecologies are connected, and how the same artefacts are involved in different activities with different actors.

4 CASE STUDY

In this section, we present a case study in which we used ARCAA to analyse a music performance for a trumpet and Chimney, a DMI previously developed. The performance took place in Trento, during the 12th International Conference on the Design of Cooperative Systems (figure 2). A complete description of the design of the instrument and the performance can be found in [28].

Figure 2: Photo of the Performance. Riccardo Terrin (B.) plays the trumpet, Raul Masu (A.) Plays Chimney

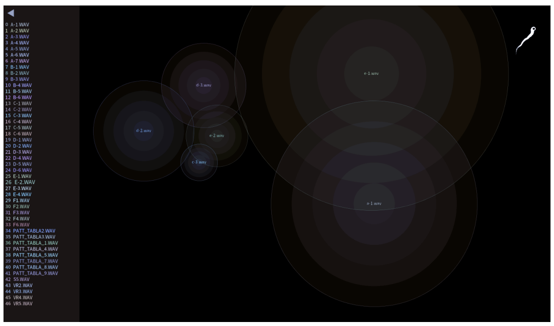

Figure 3: Screenshot of the graphic interface of the DMI

4.1 Description of the Performance Level 1: Activities

Before analysing the artefact ecologies of the actors involved in the performance using ARCAA we briefly describe both the DMI and the performance itself.

4.1.1 The DMI: Chimney. Chimney [28], is an open-source software application developed in Processing. In Chimney, the DMI composer/performer can select the musical patterns to be played during the performance, by uploading them in the software database before the performance. During the performance, the DMI performer has control over the selection of the musical material; and controlling the probability of the patterns to be played temporally close to each other. During the performance, the live musician can position graphical objects corresponding to the patterns on a canvas; an algorithmic random walker roams throughout the selected patterns and decide which pattern is to be reproduced. The canvas is initially blank except for the random walker (figure 3). An adapted version of Perlin Noise [15] was used for the movement of the random walker. The Perlin Noise function generates a succession of numbers that recall a more natural behaviour if compared to that of standard random functions.

4.1.2 The performance. Chimney was adopted for a duo piece, called Alinearity, alongside a trumpet. The piece was performed in Trento. The most important aspect of the compositional process of Alinearity is the composition and production of the sound patterns. The piece is indeed based on the overlapping of the different sound patterns that create different musical outputs. The gamut of these patterns comprises the 20 short monodic musical patterns, in addition a score with the description of these patterns was composed for the trumpeter performer. Each of the 20 short musical patterns is characterised by a specific timbral, melodic, harmonic, and rhythmic characteristic, and was produced using a digital synthesiser. Two actors were involved in the described scenario: A. composed the piece, produced the musical patterns and performed the piece playing Chimney, and B. a trumpeter who performed alongside A., playing his trumpet. We analyse here the two actors, through the lens of ARCAA, passing by the different level of Role, Context and Activity. The result of the analysis is graphically presented in figure 4.

4.2 The First Actor A.

4.2.1 Role. A. plays two different roles as he is responsible of both the compositional and the performative aspects of the piece. Therefore, we assigned to this actor two different roles: composer and performer. As composer A. is responsible for the creation of the identity of the piece, and as performer he is responsible for the performative aspects of the piece.

4.2.2 Context. In this scenario the two roles (composer and performer) played by A. are settled in two different context, respectively off-stage without real-time interactions and on-stage with real-time interactions. In this case, the distinction was clear as this scenario is characterised by a clear difference between a compositional moment and a performative one.

4.2.3 Activity. As a composer A. is responsible for two off-stage activities (i) producing the patterns and loading them in *Chimney*, and (ii) writing a score for the trumpeter. As a performer, A. plays *Chimney*, by placing the musical patterns in the canvas, and at the same time listens to the trumpet. The act of listening to other instruments is an essential component of a performance as it influences many choices on what/how to play. In this case, it affects which pattern to choose.

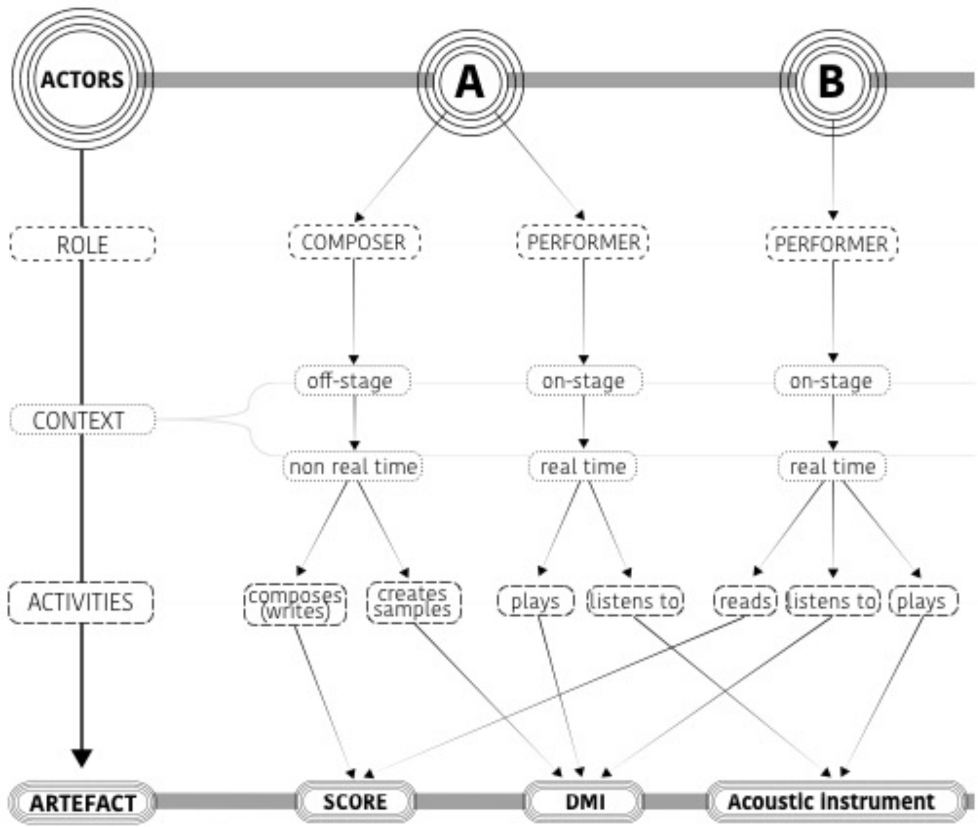

Figure 4: A scheme summarising the ecology of the performance

4.3 The Second Actor B.

4.3.1 Role. B. plays one single role in this scenario, namely he is an instrumentalist, playing a trumpet.

4.3.2 Context. As a performer, B. is involved in the on-stage, real-time scenario. He is not involved in the creation of the piece, nor in the development of the software. All his actions have a real time impact on the performance.

4.3.3 Activity. B. performs many activities in the scenario that connects him with many artefacts on the stage. As a main activity, B plays his trumpet, and at the same time he listens to the output of Chimney, and reads the score.

4.4 Results

The comparison of the two actors' ecologies by using ARCAA allows for some considerations.

- The DMI is central in the performance: all the roles played on by the different actors are connected to the DMI;
- The two performers engage in parallel activities with the trumpet and the DMI, B. plays the trumpet and listens to the DMI, while A. (as a performer) plays the DMI and listens to the trumpet;
- The two roles of A. engage him in different activities, as he performs different activities with different artefacts
- The score connects A. (as a composer) with B.

ARCAA provides support to understand several aspects of the scenario. First, ARCAA highlighted the fact that Chimney has an impact on the action of the trumpeter, even though he is not manipulating it. It showed how the same actor performs different activities, according to the different roles (A. as a composer and A. as a performer). ARCAA also highlighted the centrality of Chimney in the scenario, as this is the only artefact that connects among the roles in the scenario. Finally, the framework showed how the different artefacts create connections between the roles in the different contexts (on-stage and off-stage); for instance, it showed how the score connects actor A., playing the role of the composer, to actor B.

5 DISCUSSION

ARCAA, the framework proposed in this paper, provides support to analyse the artefact ecology of music performance scenarios, as well as to understand the characteristics of the human actors involved. ARCAA is a contribution to two main areas: music technology design and artefact ecology debate.

5.1 Implications for Music Technology Design

ARCAA has two main different design implications. Firstly, it directly contributes to understand the actors and artefact relationships of a specific scenario. Secondly, it contributes to expand the music technology design frameworks. In this sense, we suggest that ARCAA could be used alongside other frameworks.

5.1.1 Actors and Artefact. The primary contribution of ARCAA is to the field of design of interactive music technology. In the case study, we demonstrated how ARCAA provides support to understanding several aspects of the scenario. Generalising the results, we support that ARCAA helps designers to understand the artefact ecology of the musicians involved in the complex scenario of a music performance. In particular, ARCAA provides support in the following points:

(1) Understanding the role(s) that each actor plays and how the role affects her activity with the artefact. Each different role has specific needs for different activities. We argue that all these different needs should be taken into account during a design process to define the software requirements. ARCAA also highlights to the designers that the same actor may play different roles, having therefore different needs.
(2) Take into consideration those actors that are not directly operating the artefact. Understanding the impact that the artefact has on other musicians on stage and include them in the design has a positive effect on both the performer experience and the overall artistic quality of the performance.
(3) Understanding the amount of activities in which each artefact is involved and determining possible hierarchies among them.
(4) Understanding how artefacts mediate the relations of different roles of the actors in the same scenario, for instance how different roles perform different actions on the same artefact.

All the points discussed above contribute to expanding the existing literature on DMIs design frameworks, in particular as it helps the designers to position their artefacts in a more complete understanding of the scenario. Moreover, understanding how the different actors connect with the different artefacts helps to frame the characteristics of the different actors.

Our approach could be particularly beneficial in the design of those digital interactive musical artefacts that are not instruments. As presented in the related work, this category includes screen score systems [16, 18]. ARCAA support designers to frame the profile of those actors who are not using a digital artefact, in the sense of operating it, but instead reading, reacting to what they read or similar activities.

5.1.2 ARCAA and Other Design Frameworks. Compared to other frameworks presented in this paper (section 2.1.3) [3, 20], ARCAA supports a more complete vision of the scenario. In this sense, ARCAA can help music technology designers to broaden their focus to a more comprehensive view of the scenario. On the other hand, being focused on the artefact ecology of different actors, ARCAA does not offer detailed support for technical specification. Summarising, there are advantages and disadvantages:

- *Advantages*: ARCAA includes the ecology of the different actors and helps to understand the needs of all those actors
- *Disadvantages*: ARCAA does not provide the designers with tools to define the more precise technical specification of the system, such as mapping or ergonomics.

For these reasons, we suggest that ARCAA should be used in parallel with other frameworks. In particular, we recommend the use of ARCAA in tandem with MINUET [27]. The structure of ARCAA is explicitly designed to support the coordinated use of the two. The three levels of ARCAA correspond to the three dimensions (People, Context, and Activity) of MINUET. Therefore, we suggest using ARCAA first to understand the overall scenario, and successively report them in MINUET to define the system specification. We suggest that this process may be recursive.

5.2 Ecology of Artefacts

This paper presents a secondary contribution to the literature on artefact ecology. Firstly, ARCAA helps to apply the concept of artefacts ecology in the domain of music performance where this concept is currently overlooked. From this perspective, we argue that this paper will also facilitate designers from other branches of creativity support tools to approach their artefact from an ecological perspective. These areas may include dance and other performative arts.

Secondly, it proposes a model that facilitates the comparison of multiple ecologies of different actors within the same analysis. This possibility expands the Human-Artefact Model proposed by Bødker. This model, indeed, is effective in understanding one person's artefact ecology, but does not provide specific support to analyse multiple actors and their respective ecologies in the same scenario. ARCAA explicitly supports the comparison of the different actors; in particular, it also highlights how the artefacts create connections among the different actors.

6 CONCLUSION

This paper proposes ARCAA, a new framework that can help designers to analyse the artefact ecology in a computer music performance scenario. In addition, this paper presents a case study to demonstrate a possible use of the framework highlighting the benefits of the proposed approach. In the discussion, we highlighted how this work contributes both to the area of DMIs design and to the ecology of artefacts.

Future research will develop two main directions, i) use the model to design, analyse, and evaluate new digital music technology; and ii) investigate other domains of application of this model, including different performing art scenarios or more general interactive contexts.

To conclude: *"Who are the users we are designing for?"*. They can be either the musicians, playing with a new instrument, but also other musicians involved in the performance. Each different musician, is a human actor who plays a different role, in a different context, performing different activities. ARCAA supports designers having a better understanding of these elements and including them in the design process.

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