Ambient Intelligence in Electroacoustic Music: Towards a Future of Self-Organising Music

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Abstract

In this article, we discuss the current role of *Ambient Intelligence* (AmI) in electroacoustic music and reflect on its future. AmI refers to the user-centric approach of seamless 'intelligent' environments designed to continuously adapt to the user's needs and intentions. We have previously discussed a contemporary emergent trend in electroacoustic music identified as '*self-organising music'*. This trend is directly related to the technological concepts of AmI: i.e., it includes works able to 'sense' their environment and change their functional structure – self-organise sonically – in response to this environment through decentralised 'intelligent' control processes.

This article continues beyond our original discussion by envisioning an emerging musical tendency, determined by music interfaces using AmI. This consequently poses radically novel technical and aesthetic questions; new principles for creating music as well as for experiencing it - and as a result perceiving/describing/studying it. In other terms, the consideration of the perceptual 'paradigm shift', reflected by implications of AmI. We therefore suggest that it is important to think, not only in terms of technological progress but also in terms of a mental evolution.

1. Introduction

In this article, we discuss the role of AmI in electroacoustic music and reflect on the prospect of a possible future. AmI refers to the user-centric approach of seamless intelligent[1] environments designed to continuously adapt to the user's needs and intentions (Aarts E. et al. 2001, Gunnarsdóttir and Arribas-Ayllon 2011). AmI is an emergent combination of several technological disciplines like human-machine interaction (HMI), artificial intelligence (AI), pervasive-ubiquitous computing, networks and sensors (Augusto and McCullagh 2007).

[1] This article uses the term intelligence for its technological connotations, without its philosophical implications. For a critique of the concept of intelligence in AI, see (Varela 1996).

We have previously discussed a recent emergent trend in electroacoustic music expressed by 'intelligent' sound/music systems, characterised among other features by autonomy,[2] distributed processes[3] and context awareness[4] (Kollias 2017, 2018). By connecting the dots of individual cases of different composers-researchers, with unique yet converging approaches through technological and conceptual similarities, we have identified a technological/aesthetical tendency emerging spontaneously under the umbrella term of *self-organising music*[5] (Kollias 2018).

Interactive electroacoustic music works generated in any given acoustic environment, directly influenced by the given acoustic and social characteristics; works able to digitally perceive their environment and accordingly continuously change their own structure – i.e., sonically self-organise – through decentralised control processes, exposing features of 'intelligence'. Putting aside the central role of the user, what we describe is directly related to the technological concepts of AmI.

Approaches we can include under the term of self-organising music are described by several researchers-composers in several different names:[6] *feedback instruments* (Morris 2007), *audio feedback systems* (Sanfilippo and Valle 2013; Kim, Wakefield and Nam 2016), *feature-feedback systems* (Holopainen 2012), *audible ecosystemic interfaces* (Di Scipio 2003), *autonomous agents* (Collins, 2006), *performance ecosystems* (Waters 2007; 2011), *self-organising works* (Kollias 2008, 2017), *self-organised sound with autonomous instruments* (Holopainen 2012), *adaptive synthesis* (Holopainen 2012), *generative audio systems* (Surges, Smyth and Puckette 2016), *eco-compositions* (Keller and Capasso 2006), *site-responsive sonic art* (Hayes 2019).

In these approaches, the listener is acknowledged as an active participant, in different degrees of importance; however, the listener does not *necessarily* have the central significance a user has in an *AmI* perspective.

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[2] *Autonomy* "means independence of control. This characterization implies that autonomy is a property of the relation between two agents, in the case of robotics, of the relations between the designer and the autonomous robot." (Pfeifer and Scheier 2001)

[3] *distributed system* "is a collection of autonomous computing elements that appears to its users as a single coherent system." (Van Steen and Tanenbaum 2017)

[4] *Context awareness: "*location, identities of nearby people and objects, and changes to those objects" (Schilit and Theimer 1994). "Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" (Dey 2001)

[5] *Self-organising music:* The term 'self-organising' derives from second-order cybernetics acknowledging the existence of a surrounding environment (or *context* as defined in note 4) with which the system is in constant interaction, changing its structure in response to the environment's perturbations, i.e. from the "order from noise" principle (Von Foerster 2003). In this way, a self-organising music system constantly interacts with its (natural or artificial) surrounding environment (or context) while the sound result is the outcome of those interactions (Kollias 2011).

[6] For a discussion on the listed approaches, including the technological and conceptual similarities and differences, see (Kollias 2018).

Other approaches, more technologically than aesthetically driven, yet more directly related in exposing applications of AmI, include: *Embedded intelligent music* (Eacott and d'Inverno 2003), *DigitalBeing* (El-Nasr and Vasilakos 2007) or *Gym Intelligence* (De Prisco et al. 2021).

2. A technological-perceptual paradigm shift

Projecting towards the future, we can envision an emerging musical tendency determined by music interfaces using AmI, which consequently pose radically novel technical and aesthetic questions; new principles for creating music as well as for experiencing it, perceiving/describing/studying it. Therefore, we would like to stretch out the importance to think, not only in terms of technological progress but also in terms of mental evolution. That is, a perceptual 'paradigm shift' reflected by implications of the AmI concept.

From a technological point of view, the evolution of self-organising music (including AmI music) is intrinsically linked to the evolution of the digital computer and what is vaguely called AI; its intrusive role is spreading more and more to all aspects of life – including the arts – and is becoming ubiquitous in replacing human activities, from simple to complex tasks: predictive algorithms fed by user data suggest what products to buy (ex. Amazon), curate music (ex. Spotify) or films and series (ex. Netflix, IMDB), predict and correct phrases (ex. Google Autocorrect), monitor and assist in healthcare through wearables (ex. Apple Watch), can compete and defeat professional human opponents in complex games such as Go or StarCraft (ex. DeepMind), as well as – partially or entirely – synthesise visual footage with Deepfake technology (ex. de-ageing algorithms used in several films, or celebrity internet deepfakes).

Throughout the history of technological evolution, humans have always found ways of expressing themselves creatively through the new technologies of each era. Whether mental or material innovations, they explore new prospects while incorporating the latest technological means in the cultural domain. For instance, the invention of writing helped significantly with the organisation of language and consequently advanced poetry and literature that were oral forms of expression; accordingly, the invention of electricity made the design of electric instruments possible (such as Theremin, Ondes Martenot, electric guitar).

Today, we are witnessing a computational revolution, for better or for worse, constituted by inevitable and unstoppable developments in AI, perversely in disruptively changing every aspect of society, such as self-driving cars, agricultural robots, autonomous weapons, algorithmic trading, AI legal applications, predictive crime policing, or deepfake political propaganda. However, as artists, we can adopt a critical approach through our compositions, musicological reflections or musical algorithms to show its positive and negative aspects in a socio-cultural context.

3. The evolution of the digital computer and the electroacoustic medium

Let us reconsider the history of the digital computer throughout three main stages (Mossberg 2017). (1) Initially, computers required complicated and counter-intuitive HMI expressed in lines of code. (2) Gradually, they evolved to more intuitive systems equipped with graphical interfaces alongside the development of HMI of mouse and keyboard. (3) Most recently, digital

computers are gradually blending into the human environment, a tendency towards AmI: At home, at the office or in the car, we are equipped with interconnected devices participating in the *Internet of Things* (IoT) with sensors that observe and "understand" us; decentralised computers in our human environment with which we can communicate in an increasingly intuitive way and closer to our natural ways of interacting, i.e. with gestures and voice commands, towards Natural User Interfaces (NUI).

If we make the analogy with electroacoustic music, we can identify three major technological stages accordingly. (1) In the first stage, we can detect a fixed medium constituted by computer music and tape music, controlled by unintuitive lines of code, or by cumbersome tapes that must be edited and processed physically.[7] (2) Then, the evolution of the digital computer and its more intuitive means of interaction made electronic manipulation unimaginably more accessible and created new ways of creating, perceiving and analysing music; for instance, at the beginning of the 90s, Vaggione discusses the advantages of the digital computer and suggests a new compositional framework through Object-Oriented Programming (Vaggione 1991). In addition, developments in HMI were also reflected in the emergence of the new medium of interactive music. (3) More recently, we can identify works that express the new advancement of AI and AmI, where we can point out a musical transformation towards self-organising music, including AmI music systems.[8]

More specifically, considering today's technological equivalent expressed in electroacoustic music:

- where music is dynamically created by contemporary digital means, integrated into the computerised and automated human environment.
- manifested by an intelligent and adaptive sound support, expressed by autonomous musical agents
- produced in real-time and in direct interaction with its environment
- where the listener is an active part and with which she is in direct interaction
- a sound interface without artificial means of interactions (such as mouse and keyboard) but rather where the sound environment becomes the interface in itself – reminding us of Di Scipio's related concept of "sound is the interface" (Di Scipio 2003).

Therefore, we could imagine that the practice of the AmI music work could spread from its narrow academic limits as a contemporary practice to create, listen to, perceive and analyse a broader range of music in new ways. However, it is crucial to underline that any proposal towards new interactive sonic interfaces that constitute AmI music works will remain sterile if not accompanied hand-in-hand by a mental evolution, a perceptual paradigm shift.

[7] To the potential surprise of some, cut and paste originates from cutting a tape and pasting it with glue.

[8] We want to point out that our undeniably linear historical narrative is attempting to outline *a* specific trend – i.e., one of many co-existing trends - and not necessarily *the* only trend of a supposing linear causality.

4. Towards an Ambient Intelligent Music

During the experience of an AmI music medium, the listener – directly and indirectly – determines how the work sounds in the particular listening context; in other words, the work adapts to the listener's needs and intentions. The listener's presence and – intentional or unintentional – actions in the physical space are tracked through audio and visual sensors and analysed through machine learning techniques. In addition, the psychosomatic state of the listener is tracked through biofeedback sensors such as electroencephalography (EEG), heart rate monitor (HRM), respirometer. External context data and user's biometrics are analysed and fed back to the sound production, directly influencing the sonic result, following a user-specific and user-centric plan.

Today, we can already identify some traces of self-organising music coupled with the listener's perception, applied to a large audience outside the experimental or academic borders. Let us consider the curative algorithms of music subscription services (like Spotify, Tidal, Apple Music) and the central importance they occupy in the development of those services. Within the subscription ecosystem, the algorithm tracks each listener's habits attempting to understand them while building their music profile of music preferences. The profiling is then used to reflect back to each listener with relevant suggestions of music tracks, familial or novel to some extent.

We suggest that this granularity will progressively become increasingly smaller. Now, the user gets algorithmically curated playlists made out of complete pieces of music. Progressively, future options will put together mashup works made out of familiar (or slightly unfamiliar) sections of existing tracks. Then, collage works made out of increasingly smaller structural elements, from familiar (or slightly unfamiliar) music phrases, motives, sound events, increasingly shrinking down to the degree of sound-grains. In this way, from the current state of a user-centric AI DJ, we are led towards a user-centric AI composer-improviser. All generative music processes take place in real-time, directly connected with prior choices of the user-listener, along with her current physical and psychosomatic state. In addition, increasingly more precise and meaningful analytics of her existing data are applied, along with new ways to measure and acquire those data, like biosensors.

5. Listener-centric paradigm

A kind of approach of this type seems to be technologically advantageous for its direct results and increased convenience. Most importantly however, it demands that the listener becomes aware of her active role. A role that becomes central through the technological medium of *AmI*, including not only the listener's physical presence and physical actions but most significantly also the participation with her active listening.

In other terms, the listener becomes aware that she is no longer a passive receptor of information. Instead, she is the one that chooses the way of constructing the work, choosing the

information to receive and in which way they are used during the constructivist[9] creative process of perception.

During the act of attentive listening, a listener chooses – consciously or less consciously – to switch between several *listening strategies* according to certain expectations on her listening experience (Delalande 1998). Any music work – including a self-organising work – is manifested as a unique entity resulting from the interactions between the listener's imagination and the work's sound materiality (Kollias 2017). Thus, every work is a self-organising work within the space of the listener's imagination and the listener has a central active role in the work's perceptual construction. However, with the actuality of an AmI electroacoustic medium, a past philosophical postulation now becomes a central characteristic of the medium *per se*.

From a sociological perspective, it comes with the realisation of who is in charge of her own music perception. With the help of an AmI music medium, each listener becomes her own master of music perception. Able to dynamically choose the music construction according to her needs, the listener is liberated from the authoritarian chains of imposed percepts, externally dictated musical structures by individualistic composers supported by their curatorial elites.

In addition, it changes our view of AI's involvement in the creation of art and music. Often perceived with suspicion, AI applications can be criticised for sterilising music expression through artificially constructed music of inhuman algorithms. Or AI applications maybe consider taking over the creative expression from humanity's masterminds, from the representatives of our brain elite. On the contrary, we can claim that the machine comes as a liberator of the individualistic and authoritarian regime of the composer. Leading the way towards self-determination in a self-constructed music ecosystem of the listener.

6. Conclusions

We have discussed above the role of AmI in the electroacoustic music medium, reflecting on a possible future. Our proposals are based on interpreting current observations and projecting to a possible future. Although it is impossible to predict any future, there are several benefits from reflecting on it.

The most decisive factors that could determine the future and the social importance of an AmI music medium are the quality of music experiences created and the emergence of an audience. Both factors are interconnected into a coupled self-amplified dance that starts with some music.

Let us consider the type of listener representing the new audience, i.e. someone that will be potentially interested in such an experience: A kind of music lover of contemporary or experimental music open to new musical experiences. Or a certain type of gamer, already accustomed to an art form in which the interactive experience is central. Or perhaps someone familiar with the practice of meditation and mindfulness, accustomed to a perception connected with their contextual surroundings.

[9] *Constructivism* "starts from the assumption that knowledge, no matter how it be defined, is in the heads of persons, and that the thinking subject has no alternative but to construct what he or she knows on the basis of his or her own experience." (Von Glasersfeld 1995).

Moreover, we should consider an 'ideal' context (environment and social setting) for a musical experience of this type: A certain kind of concerts-installations hosted in places designed explicitly for AmI music. Or, thanks to a set of necessary adaptable technological tools, constructed experiences offered in any given context, able to transform any situation into a self-organising musical experience. It can offer the listener a solitary music experience in her own private space. Or a listener may choose to share her experience with others and coordinate with a collective of unique experiences.

In a listener-centric intelligently driven sonic environment, what is the relation of the listener with the work? What is the listener's creative role in the work's creation and how is the role of the composer transformed? What are the limits of authorship and how could it affect the *status quo* of intellectual property? Considering that each specific coupling of work with a listener creates a different experience, what is the work's identity?

What would be the importance of its relationship with technological developments? What does it bring to the musical experience – in addition to what was previously available? During a self-determined experience, can we talk about a new 'listening strategy'? What are the aesthetic interests connected with the new technological medium? In an AmI environment populated by constantly active sensors, what is the future of our privacy? What would be the conditions that would secure safety and privacy in an AmI environment?

All these questions can inspire our thinking and creativity in a new field of AmI electroacoustic music.

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