Special Issue Música Hodie: Contributions of sound and music computing to current musical and artistic knowledge

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Introduction

The present volume features a selection of works presented at the recent *Brazilian Symposium on Computer Music* held in São Paulo (SBCM 2017). The contents have been expanded and updated from the materials delivered at the conference, highlighting the ongoing exchange taking place between the fields of music, computing, engineering and their contributions to the advancement of artistic practices. Since 1994, the Brazilian computer music symposia have provided a platform for state-of-the-art developments in the fields of computer music, sound and music software and hardware engineering, ubiquitous music, computational musicology, multimedia artistic practices, among a wide variety of technological advances in music making. The 2017 edition emphasized current research in audio open-software resources, ubiquitous music and music information retrieval, featuring contributions both from Latin America and Europe.

This editorial proposes a critical discussion of the contents of this volume, hopefully furnishing an enhanced context for the readers unfamiliar with current discussions in computer music, ubiquitous music, music information retrieval, auditory display, sonic interaction design and technologically oriented artistic practices. All of these fields feature their own concepts and methods, highlighting the intensity and diversity of the influence of information technology on music making and on music research. A long and winding road - and we would venture to say, a whole universe - separates current computer music practices from the pioneering work done by Max Mathews (1963) and by the Australian team at CSIRAC in the early 1950s (DOORNBUSCH, 2004). There are several excellent references that discuss the history of computer music, so we will not repeat here what has already been covered by historians and musicologists. What we would like to propose is a different perspective of the path taken by technologically based music making, highlighting the limitations and opportunities of the resources made available to musicians and amateurs during the last eight decades.

According to the resources being employed, creative technology-based music making can be parsed into three historical stages: centralized, domestic, distributed[1]. An early stage encompasses the pioneering initiatives of the 1950s in Australia, England and the USA that employed room-sized computers to generate simple musical results. During the early days of computing, the majority of the musical output involving technology was produced at large studios which had the means to acquire and maintain expensive equipment. The technical difficulties involved in software coding and in hardware development pushed electroacoustic composers towards the adoption of analogue technology. Until the mid 1960s, electroacoustic music making was bound to the studio. This situation changed with the emergence of portable analogue synthesizers - such as those produced by Robert Moog (1965) and Don Buchla (1969). Voltage-controlled synthesis provided a means to generate sound in real time, thus bypassing the technical difficulties of computer-based sound synthesis and allowing for hands-on exploration of sonic outcomes. It took almost twenty years for computer technology to achieve the portability of the early analogue synthesizers. And yet one more decade would pass before standard desktop computers could execute sound synthesis in real time. By the early nineties, computers were starting to be used outside of university and corporate research centers. With relatively little investment - a good sound card and a MIDI controller - a general-purpose, desktop computer could be turned into a musical workstation. The personal computers of the nineties were fairly portable and had enough computational resources to be taken by musicians to artistic venues and for use at home.

The availability of the personal computer was a key factor in enhancing the potential for home-based creative musical activities. While analogue synthesizers were targeted to a specialized public of technically savvy musicians, personal computers were widely adopted as household appliances[1]. Biologist use the term *exaptation* to describe the features that evolve through natural selection and that are later co-opted for a different purpose (GOULD; VRBA, 1982). We can adapt this concept to the creative reuse of the available technological infrastructure. *Technological exaptation* can be defined as the process of repurposing utilitarian technology to fulfil creative needs. An early example is provided by the proliferation of the music home studios. While throughout the first stage of music-technology development creative activities were almost exclusively carried out in large research centers or corporate facilities, during the second historical stage music making took advantage of technological resources available at home.

A third historical stage - characterized by the use of distributed resources - starts to take shape in the early 2000. Two features of current technology seem to push the boundaries of creative music making: massive connectivity and enhanced portability. Network-based musical performances were tackled since the late seventies through custom-made software and hardware (BISCHOFF et al., 1978). With the emergence of the internet - from the local area networks that were used exclusively for research in the early sixties to the global deployment of infrastructure, including the commercial expansion that starts in the mid nineties - there was an explosion in the potential for remote interaction and collaborative music making. A key feature of musical experiences is the intense interaction amongst the stakeholders. This exchange involves a process of decision making which - given the right conditions - does not need to enforce hierarchical or synchronous exchanges (KELLER, 2000; LEWIS, 2000). Hence, the traditional models for the social organization of musical performance - such as the orchestra or the band - do not fit well within the context of current collaborative musical practices. Massive connectivity involves asynchronous forms of interaction and exchanges of resources without the need of face-to-face encounters. Paradoxically, while the network infrastructure promotes collaboration without demanding co-presence, an increased miniaturization of the personal electronic devices affords music making in places that previously were not available for creative group initiatives fostering more frequent face-to-face musical activities. This enhanced portability is a necessary feature of technology for music making in everyday settings. Both massive connectivity and enhanced portability foster new forms of creative manifestations by targeting everyday contexts and by providing access to distributed resources. Before the emergence of the internet and before the popularization of personal devices, collaborating with other musicians or making music outside of studio settings demanded a long period of training to deal with an acoustic instrument. Today, music-making resources are available to almost everybody, almost everywhere (PIMENTA et al., 2014). Despite the qualitative leap afforded by the widespread access to technology, creative music making is not guaranteed by reproducing the mechanics of the acoustic instruments on the digital realm. Music making has become available to many people in a wide variety of places. But *creative* music making is still a challenging goal to be attained.

Creative practices and musical interaction

To understand the difficulties encountered in supporting creative musical activities, it may be useful to provide a panorama of the current technologically oriented creative-practice proposals (see KELLER; BUDASZ, 2010 for a complementary approach). According to a literature review published by Keller (2013), musical creativity practices follow three trends:

1. *Approaches centered on acoustic-instrumental aspects*. Rooted on the nineteenth-century tradition of instrumental music, this perspective focuses on professional and eminent creativity. This view has been adopted by the majority of proposals in digital musical instrument development (see the *New Instruments for Musical Expression* conference for multiple examples). During the 1980s, this trend provided new impulse to the expansion of the musical application of information technologies. Nevertheless, the limitations of this long-standing paradigm can be seen in the massive temporal investment demanded by tools based on musical notation and by the difficulties encountered by casual users when faced with the demands of professionally oriented performance systems. The methods are centered on the needs of professional musicians and rely on symbolic representations that have steep learning curves.

An illustrative example of these methods is provided by Rossetti et alii (this volume). The authors discuss the elaboration of the piece *Desdobramentos do contínuo* for violoncello and live electronics. They applied instrumental extended techniques, a fixed-support soundtrack and synchronous sound processing. Rossetti and coauthors employ a compositional strategy based on computer-aided musical analysis to obtain various timbre manipulations. The analytical results are used to assess the effectiveness of the compositional premises. Their proposal is related to the musical information retrieval techniques discussed in the section *Algorithmic approaches and music information retrieval* of this editorial. More specifically, they employ audio descriptors as tools to inform compositional and performative choices. The paper is accompanied by musical excerpts that hint at the sonic possibilities backed by their analytical approach.

2. *Approaches centered on algorithmic aspects*. This trend is grounded on the early work on artificial intelligence and has had a heavy influence on computer music practices (MCCORMACK; D'INVERNO, 2012; NIERHAUS, 2009). Current proposals have moved beyond the early attempts to reproduce stylistic characteristics of instrumental music - exemplified in the pioneering work by Hiller and Isaacson (1959) and in the multiple style-oriented studies produced by Cope (2004). An interesting development of the last decade is the application of machine-learning techniques to deal with generative creative approaches. This method is exemplified in Sinclair´s work (this volume), discussed in the section *Algorithmic approaches and music information retrieval*.

3. *Approaches centered on human aspects*. This perspective gathers contributions from information technology creative practices (MITCHELL et al., 2003), interaction aesthetics (KELLER et al., 2015b; LÖWGREN, 2009) and ecologically grounded creative practices (KELLER, 2012; KELLER; CAPASSO, 2006; KELLER; LAZZARINI, 2017a). An interesting expansion of the human-centered approach to design is laid out in the humanity-centered Danish Designers' Manifesto (GRØNBECH; VALADE, 2010). The editors Grønbech and Valade suggest that design has moved from a tangible answer to a design brief, toward domains involving large and complex challenges. Therefore, designers work in close collaboration with all kinds of other professional disciplines (GRØNBECH; VALADE, 2010, p. 5). The impact of the design of computer systems on music making and the impact of musical knowledge on the development of new information technologies are illustrative examples of the intricacies of knowledge construction through close collaboration.

The three perspectives laid out in (KELLER, 2013) furnish concepts, methods and tools for music making. But their specific contributions to theoretically driven research on creative practice are still unclear. There are at least two aspects to be considered. Firstly, despite the complex relationships between the models and the data-analysis procedures - theoretical proposals require validation through actual deployments. A tight bond between a model and the data gathering and analytical processes increases the weight of the theory. Ideally, a model should be falsifiable and replicable. It should also be possible to establish the range of potential applications. Finally, and probably the most important requirement for creative practice usage, it should be possible to avoid bad choices. Creativity studies deal with elusive objects, precluding clear-cut boundaries. Therefore, falsifiability and replicability are difficult to attain in creative endeavors. Furthermore, creative practice yields products and processes that cannot be defined a priori. For example, the validity of a theory cannot be circumscribed by the extant musical repertoire. Creativity-oriented tools should support new ways of music making. When musical models are turned into prescriptive tools, the artistic results may be satisfactory. But more often than not, they turn out not being creative.

Another aspect to be considered is the relationship between the domain-specific (musical) knowledge and the broader approaches to creativity (LIMA et al., 2012). The dialogue between musically oriented creativity theorizing and the field of creativity studies has been scant. It could be argued that the methods employed in areas prone to formalization - such as engineering - are not easily translatable to the artistic realm. A common mistake is the use of problem-solving recipes to approach fuzzy creativity domains (NEWELL et al., 1958). Problem-solving demands a clear specification of a goal at an initial stage of the creative cycle. While some forms of music making - such as rule-based instrumental counterpoint writing - are amenable to teleological methods, most twenty-first century musical practices resist explicit formalization.

More generally, current discussions in creativity theory try to untangle domain-specific and general creativity factors (BAER, 2015; KAUFMAN; BAER, 2005). With few exceptions (KATZ; GARDNER, 2012), this issue has been ignored in music theorizing. For example, the acoustic-instrumental approach takes as a given that all forms of music making adopt simplified forms of sonic parameter manipulations: usage of discrete pitches (preferably following the standard temperament), time parsed into discrete durations (ideally represented as notes within a meter-based representation) and employing a fixed set of timbres (usually emulating acoustic instrumental sources). Furthermore, almost all forms of musical interaction within this perspective are based on bodily gestures. While the latter constraint is well suited for technologies closely linked to the use of acoustic musical instruments (see

Souza and Freire, this volume), the emergent methods based on technological or on environmental resources for creative music making may not be amenable to heavily anthropocentric views on creativity (cf. Aliel et al.; and Keller, this volume, for alternative proposals).

Algorithmic approaches and music information retrieval

Most music information retrieval (MIR) proposals have targeted feature-extraction and classification of previously produced musical content. The obvious usage of this functionality is searching, browsing and retrieval of items in large databases, accessible through web-based tools. The ability to retrieve specific information within sonic and multimedia files has fostered a variety of applications involving the usage of musical and meta-musical information that goes beyond the intent of MIR-oriented proposals. This volume features an example of MIR-centered usage of acoustic and metadata information (in this case provided by listeners) to deal with a long-standing problem in music recommendation. According to Borges and Queiroz, automatic music recommendation involves suggesting potentially interesting pieces that bear no obvious relationships to a user listening history. Their paper addresses the problem of the “cold start”, in which musical content with no user listening history is added to a dataset. The authors propose a probabilistic model based on acoustic content and implicit listening feedback to infer the users’ listening interests. They report experiments using a dataset of selected Brazilian popular music, concluding that the proposed method performs significantly better than the alternative extant models.

Rather than dealing with musical content, Sinclair (this volume) chooses to focus on the problem of parameter control for sound synthesis. While most work on analysis-synthesis has targeted the use of acoustic information to generate new audio, Sinclair proposes an indirect path as an attempt to reproduce the synthesis parameters rather than the sound itself. Sinclair implements an adversarial autoencoder conditioned on known parameters of a physical-modeling bowed string synthesizer. He describes a real-time system built on a generative, conditioned and regularized neural network, with and without adversarial training. The autoencoder is evaluated for use in parameter estimation and resynthesis tasks. Latent dimensions are added to capture variance not explained by the conditional parameters. The test case features a system capable of copying a user-provided parameter signal. Despite the simplistic application of the proposed method, the development of machine-learning techniques to drive audio synthesis and processing tools may help to pave the way to more effective support for sonic knowledge transfer. Rather than using explicit descriptions - such as “a metallic sound” or “a mellow sound” - stakeholders could furnish sets of samples that exemplify the qualities sought. Machine-learning tools could analyze each of the samples and combine the estimated synthesis parameters to provide sounds that are similar to the composite characteristics of the sample set, yielding something like a Frankenstein sound machine.

Oliveira and Tavares (this volume) investigate the use of algorithmically generated background music as a mean to foster immersion in gaming experiences. The authors used two versions of an obstacles runner game. One of them featured a MIDI sequence written by a composer while the other employed real-time generated melodies based on melodic segments concatenated through Markov-chain based rules. The immersion level was evaluated through user feedback and performance measures of target and ancillary activities, such as solving a puzzle. The results yielded small differences between the test and control groups, indicating that the proposed algorithmic generation procedure could furnish a suitable alternative for background music production.

Since the early days of computing, researchers have used human perception as a benchmark for computer-based performance (TURING, 1950). A basic assumption when comparing human and machine-based creative products is that the ideal algorithmic result is attained when the outcomes are almost human-made. Oliveira and Tavares were careful to choose a well-known musical excerpt to ensure a familiar stimulus for experienced players. In this case, the looped composed melody was used as a reference for an ideal immersive experience. The music generation procedure involved the use of the same melodic source through concatenation of random short excerpts, ensuring a partial familiarity with the materials while introducing novelty. The carefully selected sonic materials unveil an alignment with an anthropocentric view of computational creativity. While it may be true that composed musical sequences and algorithmic melodies provide similar levels of immersion, it is also possible that the sonic materials interact with the local environment to yield emergent properties that impact immersion. As mentioned by the authors, the presence of other participants and the typical noises of a computer lab setting might have been distracting. These same factors might have also fostered a sense of belonging that would be absent if the experience had taken place in the usual videogame settings, at home.

Data sonification and creative practice

Sonification techniques encompass a diverse set of methods that involve mapping data to sound. These techniques have been incorporated in creative music making since the 1960s. Early works include Alvin Lucier's Music for Solo Performer (1965) and Charles Dodge´s Earth's Magnetic Field (1970). As stated by the pioneering auditory-display researcher Gregory Kramer and despite its frequent usage in creative music practices, sonification or auditory display is still an activity that challenges definitions and disciplinary boundaries (KRAMER, 2011). Recent advances indicate two trends. The core of the auditory display production is interested in its utilitarian usage, highlighting the relationships between sonification, scientific visualization and human-computer interaction. An example of this approach is provided by the area of sonic interaction design (FRANINOVIĆ; SERAFIN, 2013). Another trend targets the aesthetic implications of the sonic usage of data, emphasizing the subjective, the emotional or the artistic impact of sonified data within the context of artistic practices (SCHEDEL; WORRALL, 2014). It is interesting to note that the long-standing epistemological tensions within sound art practices are inherited by auditory display. On one hand, the abstract usage of sound - proposed by the acousmatic perspective (SCHAEFFER, 1966; SMALLEY, 1997) - is also applied by some practitioners of auditory display. Contrastingly, situated usage of sonic data has been adopted by the researchers aligned with context-based approaches to creative practice (TRUAX, 2017), such as Opie and Brown (2006), Gomes et al. (2014) and Connors (2015).

Bodo and Schiavoni (this volume) present techniques for sonification of HTML resources, including textual elements and images. Their work involves finding relationships between web-page contents and potential sound renderings. Their goal is to create a tool that can be used to inspire compositional processes based on the raw materials available on the internet. They also speculate on possible applications of web-content sonification as a strategy to analyze visual layouts or as yet another form of musical score. They present two sonification prototypes, one employing HTML information to drive sound synthesis parameters, and another involving the use of either letters, words or images as raw materials for sonification. Their proposal complements the existing initiatives on the use of browser technology to support music making (KELLER et al., 2011; LAZZARINI et al., 2014a; MILET-

TO et al., 2011; WYSE; SUBRAMANIAN, 2013), pointing to the incorporation of auditory display as a potential strategy for ubiquitous music design. Despite the promising results, this line of inquiry still needs some refinement to provide a useful contribution to creative music making. Truax (2015) points out that not all sounds available on the internet are worthwhile resources for creative musical activities. The same observation applies to potentially sonified data. Data sources need to be clearly specified and documented to provide meaningful materials for artistic endeavors. While sonification for utilitarian purposes - such as finding data patterns or trends - may not demand any type of framing (CHARNLEY et al., 2012) or contextualization, the lack of context in artistic resources imposes a serious limitation on their usefulness. Both computational and general creativity approaches demand contextual information to yield meaningful results.

Arango (this volume) proposes the use of sonification as a strategy to raise environmental awareness. He discusses air pollution as related to artistic practice and reports three practice-based design projects AirQ Jacket, Esmog Data, and the prototype Breathe!. The AirQ Jacket device is a piece of clothing that features an electronic circuit to measure air pollution and temperature levels, rendering the captured information as visual and acoustic stimuli. Arango chose to synthesize only two sounds, one representing the pollution level (correlated to pitch variations) and another signaling an average level. Similarly to Chafe´s Oxygen Flute (CHAFE, 2002), Arango´s Smog Data installation uses CO2 readings to drive sound synthesis parameters. The composer stresses the need to deal with the complete sonic outcome, rather than applying parametric linear mappings. Breath! is a work-in-progress prototype that uses CO2 and NO2 sensors to drive loops of recorded breathing sounds. This proposal has not been publicly deployed, so it is presented as a design brief. The environmental issues that inform these projects, as well as the intensive usage of local resources, align this proposal with ecologically grounded creative practices (KELLER; LAZZARINI, 2017a). Particularly in Breath!, the usage of sounds that are directly related to the mechanics of the installation indicates a path to creative design based on agents-objects interactions which are at the core of the ecologically grounded methods.

Technological support for improvisation

Aliel et alii expand the research on ecological synthesis models through the incorporation of improvisatory practices. They propose a formalization of creative processes in ecologically grounded creative practice targeting comprovisation (ALIEL et al., 2015). To deal with complex adaptive systems from a socio-ecological perspective, they develop a performance experiment, *The Maxwell Demon*. Their observations point to imitation as an important strategy for creative activities in socio-ecological systems. They suggest that improvisation may provide a relevant strategy for ecologically grounded creative practice, enhancing the procedural palette while avoiding hierarchical, centralized or instrumentally oriented perspectives (cf. BAGWHATI, 2014; BOWN et al., 2009; COSTA, 2014; KELLER, 2000; LEWIS, 2000 for critical discussions).

Another proposal grounded on improvisatory practice is laid out by Souza and Freire (this volume). They use the analysis of dance gestures as a means to develop methods of segmentation and description of improvised dance, based on preexisting music. Souza and Freire discuss the concept of gesture in music, dance and human-computer interaction applications, targeting the use of motion capture techniques associated with elements from Laban Movement Analysis. Using Max/Msp and Kinect sensors, they implement a process of segmentation through the inspection of zero-crossings and acceleration curves of each body joint. A case study - a dance improvisation based on *Petrushka* excerpts (STRAVINSKY, 1912) - highlights the correlations between the musical pulses and the Laban-based classification of body movements.

Ubiquitous music

Music theory and music analysis have usually been concerned with professional creative practice, giving emphasis to manifestations of eminent creativity. These practices rely heavily on domain-specific knowledge. Consequently, the literature on music theory has mostly been concerned with describing, explaining and supporting activities done by professional musicians. In a recent discussion on the implications of ubimus research on music-theoretical approaches, Keller and Lazzarini (2017b) address the need to expand the horizons of music theory. Three theoretical proposals - the perception-analysis-synthesis model, the in-group, out-group model and the ecologically grounded approach (FERRAZ; KELLER, 2014; KELLER, 2012; KELLER; LAZZARINI, 2017a; KELLER et al., 2014; MANNIS, 2014) - tackle musical creativity as a construct that does not rely exclusively on domain-specific factors. In contrast with the musical interaction approaches that adopt acoustic-instrumental concepts as validation criteria (TANAKA 2009; WESSEL; WRIGHT, 2002), these three perspectives do not depend on simplified representations of musical materials. Hence, they are applicable to instrumental practices, to concert-oriented electroacoustic formats and to other forms of music making - encompassing performance art, multimedia installations and the emergent use of everyday technological devices. Keller and Lazzarini (2017b) present several experimental studies to support a view on ubiquitous music theory that targets musical activities. They address everyday creativity (case 1), professional creativity (case 3) and a mix of professional (*pro-c*) and everyday (*little-c*) modalities (case 2). Case 1 features time tagging - a creativity support strategy applicable to various stakeholders' profiles. This versatility is exemplified by its usage in *pro-c* activities (KELLER et al., 2009) and in *little-c* activities (PINHEIRO DA SILVA et al., 2013). Case 3 deals with knowledge transfer among non-musicians and musicians, employing an opportunistic strategy involving creative surrogates. An example of a musical activity that requires domain-specific knowledge is provided by the improvisational activities featured in case 2. This is a problematic case. On one hand, the instructions need to be sufficiently specific for the participants to establish a common ground for decision making. Preparations for the activity include verbal hints on the type of pitch material and a rhythmic reference laid out as a percussion-based soundtrack. This strategy works well for one session but it is hardly applicable as a general solution for knowledge sharing among musicians and novices. Hence, a pressing problem unveiled by this experiment is how to promote support strategies that simultaneously target the needs of the musically untrained and trained stakeholders.

Ubiquitous music research (ubimus) targets the participation of musically untrained stakeholders, in musical activities that take place outside of artistic venues using resources that previously were not deemed worthy of consideration for artistic goals (KELLER et al., 2014). This new field encompasses recent technological advances that push the limits of what is understood as creative music making highlighting, for example, the manifestations of everyday musical creativity (KELLER; LIMA, 2016; PINHEIRO DA SILVA et al., 2013) and the development of the Internet of Musical Things (KELLER; LAZZARINI, 2017a; TURCHET et al., 2017). Keller´s text (this volume) deals with the challenges of a second decade of ubimus research, highlighting the issues involved in supporting knowledge transfer in musical activities. He documents and exemplifies the concept of metaphor for creative actions while summarizing the results of three studies that use time tagging as an effective strategy for supporting everyday musical creativity. He also reports results of a study employing the stripe metaphor – an extension of time tagging devised for usage of large quantities of sonic resources on mobile devices. Twelve subjects, encompassing musicians and casual participants, realized improvisatory sessions in a non-standard setting – an audio and musical equipment store. The results indicate a promising new avenue of research targeting lay-musician interaction, highlighting emergent issues regarding the strategies adopted for knowledge-transfer support. The paper places the findings within the context of the ongoing ubimus efforts, while addressing four ubimus-specific research targets: everyday musical creativity, lay-musician interaction, design for sustainability and design for distributed creativity.

Aside from Keller´s, two papers featured in the present volume deal with or are closely related to ubimus research: Schiavoni et alii´s; Aliel et alii´s, discussed in the section *Technological support for improvisation*. Schiavoni and coauthors (this volume) present a visual programming environment to implement Web Audio applications, *Mosaicode*. This proposal complements the existing initiatives on the use of browser technology to support music making (KELLER et al., 2011; LAZZARINI et al., 2014a; MILETTO et al., 2011; WYSE; SUBRAMANIAN, 2013). Their system features the typícal functionality of other web-based visual programming tools - such as *Gibberish* (ROBERTS et al., 2015). But rather than targeting audio output, *Mosaicode* yields Javascript applications. Hence, *Mosaicode* is comparable to other digital signal processing systems that generate code for multiple platforms, such as *Faust* (LAZZARINI et al., 2014b; ORLAREY et al., 2004). This functionality sets *Mosaicode* apart from the multiple HTML 5 audio libraries that have been implemented since the inception of the Web Audio API. Given the tight integration of Javascript with current web browsers, there is good potential for usage in fast prototyping of ubiquitous music projects. The preliminary results look promising. But detailed usability studies and careful analysis of the applicability and performance of the audio tools still need to be carried out.

Food for thought

As documented by Doornbusch (2004, p. 24), “the involvement of composers at Bell Labs led to some of the crucially important design decisions that in turn led to the development of current computer music. Lamentably, this did not happen with CSIRAC, perhaps because of its unfortunate isolation [...]”. The gap between the technical knowledge required for the implementation and usage of computer-music tools and the domain-specific knowledge gathered after more than a thousand years of documented music making is still large. Nevertheless, this gap has been reduced significantly since the early computer-music developments.

We have proposed a three-stage historical account of technologically oriented music making, taking as a point of departure the usage and availability of resources for professional and non-professional stakeholders. The first stage encompasses music practice held at large research centers and studios. The second stage involves music making at home or at small-scale facilities. The third and current stage targets both musicians and non-musicians doing musical activities at everyday settings, highlighting the emergent manifestations of distributed creativity. The widespread presence of technology in our everyday life fosters fresh opportunities for creative intervention but at the same time presents challenges that were unknown to pre-internet and pre-embedded computing societies. How should personal behavioral data be handled? What are the ethical implications of collectively sharing individual choices and personal preferences? The massive availability of musical products enabled by the internet is progressively being matched by the enhanced access to creative support platforms by non-musicians. While wide access to musical activities does not necessarily entail a positive social impact, recent ubimus projects have brought together technological development and socially responsible usage.

Part of the proposals included in this volume engage with issues that are specifically linked to the affordances brought by the use of distributed resources and by the increased portability of recent technology. Others adopt views grounded on the long-standing tradition of professional music making, taking advantage of a millennium of accumulated knowledge. We hope that the scientific contributions and the artistic outcomes featured in this volume will help to highlight the fruitful dialogue between artists and scientist that has been a landmark of computer music research for almost eight decades.

Note

1 This constitutes a three-stage, cumulative model of technology-based musical practices according to resource usage: centralized, domestic, distributed.

2 Taking the USA as an example, we see a linear increase in the number of households that own personal computers. Approximately 8% of the families had a personal computer at home in 1984. The percentage grew to 77% by 2010. It is interesting to note that the numbers have dropped in recent years, possibly due to the widespread adoption of portable devices (92% in 2015).

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