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Real-Time Composition: Its Applications and Educational Potential

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Abstract

In this paper, the notion of Real-Time Composition (RTC) is discussed as a practice that has emerged and being consolidated with the increasing use of computationally controllable real-time generative music algorithms. RTC was developed through the use of interactive music systems and is nowadays more or less ubiquitous. The principle of RTC can be also be employed in a performance involving just humans, and parallels between RTC and musical practices involving improvisation—namely Jazz, Hindustani and Carnatic music practices. By looking at the relationship between RTC and instrumental improvisation, I will provide an ontology that situates RTC apart from instrumental improvisation, and how that can be helpful in finding applications uses of RTC in an educational framework. Finally, I will discuss how RTC systems can be used as educational tools that have the potential to educate and enculturate users in different musical styles in innovative ways. I will discuss some past work I did in this area as well as more recent work within the research done by the Music and Sound Cultures research (MaSC) group at New York University Abu Dhabi. CaMel, a generative model for percussive sequences in Carnatic style will be presented, and aspects pertaining its development will be discussed, namely in terms of how a data-driven approach combined with domain knowledge about Carnatic music has been implemented in order to make the application generate sequences on this style. The successes and failures in the development of CaMel will be shown as well as how this combined approach has generated new interesting questions on the implementation of computational knowledge about Carnatic music percussion. This hybrid approach is also being used in other projects within MaSC as a means to obtain a deeper understanding of the computational understanding of non-Eurogenetic music.

Keywords: *Carnatic music, computational knowledge, music algorithms, real-time composition (RTC)*

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INTRODUCTION: THE CONCEPT OF REAL-TIME COMPOSITION

I define real-time composition (RTC) as a "*Compositional practice utilizing interactive music systems in which generative algorithms with a non-deterministic behavior are manipulated by a user during the performance"* [1]. This is a practice I define as a possibility of making music with computers, which emerged recently from the fact that computers became fast enough to allow real-time interaction with generative algorithms. Real-time composition *systems* are computational applications that enable real-time composition.

There is a myriad of situations where one can find RTC systems in operation nowadays: (1) the emergence of software applications for smartphones or portable game consoles employing generative music algorithms whose behavior is controllable by users; (2) the appearance of sequencing software that allows non-linear sequencing and its control in real-time (e.g. Ableton Live); as well as (3) generative music modules in commercial sequencing software that allows the control of music by specifying certain high-level parameters (e.g. Logic's Drummer) denote pertinent changes in the practice of computer-generated electronic music. If we add to this the current resurgence of modular, voltage-controlled instruments in what it seems to be a return of the live electronic music from the 1960s now enriched by the digital revolution, one notices that there is a newly established way of making music with computers, and that computers are increasingly seen as companions in music-making.

The revolution computers operated on musical practices have created substantial breaches with the concepts and definitions of the pre-electronic/computer music practice. Notions of what constitutes a musical instrument, what is performing, composing, and improvising, have been shaken to a point that new definitions, re-definitions, and taxonomies are emerging to address these basic notions [2]. Departing from an initial intimate relation to traditional music concepts to describe computer music constructs such as "score," "orchestra," "instrument," "player;" using interaction metaphors such as "soloist with accompaniment," "conductor with orchestra," "Jazz combo," the field of computer music has expanded in ways that originated different avenues of musical expression as well as new concepts, such as real-time composition.

As mentioned in the opening paragraph, the real-time composition is possible through the use of real-time composition systems. Essentially, an RTC system is a peculiar combination between digital musical instrument design, algorithmic composition approaches, and interactive music systems.

Digital musical instruments have moved away from the traditional idea of the instrument as a resonant body that when excited physically produces some sort of sound. Digital musical instruments decouple the sound-producing action from the sound they produce, and often times there is a layer that establishes a more complex relationship between gesture and the produced sound, which is more than mere transduction of physical activity into one sound[2]. Thor Magnuson [3] advances the idea that many digital instruments could be seen as extensions of the mind rather than of the body (as in the case of traditional instruments). This is precise because of the possibility they afford of using computational music systems to build expressive intelligent sonic outputs. In his comparison between acoustic and digital instruments, Magnusson states that the "primary body of the digital instrument is that of symbolic instructions written for the meta-machine, the computer. As opposed to the body of the acoustic instrument, the digital instrument does not resonate" (p. 168). The use of computational techniques such as generative algorithms "and their theoretical implications unavoidably involve an explicit systemic representation of music as a rule-based field or a creative search space" ([4] qtd. In [3], p. 169).

The use of real-time generative algorithms in RTC provides navigable musical spaces that can be explored interactively. This navigable space is typical of algorithmic composition with computers and was identified by Iannis Xenakis [5] on his famous account of his first experience with the computer in 1962. The control/alteration of parameters in algorithmic computer music provides the possibilities for navigation of a musical space whose limits are defined by the ranges of values in the parameters. This brings us to an important aspect, that of the metalevel representation of a composition in which all possible results of composition are already present in the algorithm [6]. It is the user's interaction with the generative algorithm that will create a piece in real-time.

Interactive music systems [7] constitute a possible way of designing the contact between gestural interfaces and compositional algorithms in digital musical instruments. Joel Chadabe [8] calls these type of instrument "interactive instruments." Jon Drummond [9] rightly and succinctly asserts that "[i]nteractive systems blur these traditional distinctions between composing, instrument building, systems design and performance." (p. 124). The complexities of relations that can be established with interactive music systems challenge the traditional paradigms in music performance, composition, and instrument design. The reality is that interactive music systems contribute to blur these distinctions, which are often imperceptible when one watches a performance. The performers of a certain system may even not grasp what the system is doing while they're performing it such as in the case of certain games or applications. This makes it hard to really understand where does one establish the boundary between digital instruments that simulate traditional instruments and RTC systems, or other interactive instruments that are not RTC systems. Moreover, if whatever one is doing while interacting with the system should be considered performing, improvising, or composing. In RTC systems digital musical instruments enable the creation of complex mediation spaces between physical gesture and sonic result. Generative algorithms occupy these spaces to mediate interaction [8]. Interactive music systems provide the possibility of modifying the behavior of these algorithms in real-time and enable a metalevel approach to composition through the possibility of interactive and real-time control of the musical generation [7, 10].

IMPROVISATION AND REAL-TIME COMPOSITION

The real-time composition is an improvisatory practice. However, even though it is common for musicians coming from improvised music traditions (e.g. Jazz) say they are composing in real-time, the indeterministic nature of RTC as defined above makes it ontologically different from traditional instrumental improvisation. More than just looking at minutiae between these two situations, it is perhaps worthwhile to look at the differences offered by the situation provided by RTC in relationship to improvising with an instrument.

Composing is different from performing. Composing relates to conceptualization, planning, and to think in music "outside of time." (cf. [5], [11]). Performing relates to executing a plan in time, during the time of the performance. The aspect of real-time is indissociable from performance, be it improvised or not. The real-time composition brings a performative aspect into the composition and real-time interaction with the unexpected. Moreover, since the algorithms do not provide a deterministic approach there is never a complete control over the situation and there are always adjustments that have to be made on the fly. In this sense, RTC could be thought of *improvising while composing*. This is something fairly new in the musical landscape and visible through this particular combination between interactive music systems and generative algorithmic composition in the context of digital musical instrument design.

In his analysis of improvisation from a psychological perspective, Richard Ashley [12], provides interesting insights that may help distinguish the differences between improvisation with musical instruments and improvisation with compositional algorithms. He distinguishes three constraints that operate on the processes of musical (instrumental) improvisation: 1) The body; 2) Real-time; and 3) Limits on what we know.

In instrumental performance, the musicians work with their hands, feet and voices to produce the music. The physical capabilities of the body and the training the body has obtained impose limits on what can be produced musically during the improvisation. The real-time aspect also constitutes an important constraint as there is a complex process of decision-making going on for determining what gets played, and how, as well as its consequences on establishing the musical narrative on the immediate future. Finally, perhaps the most important constraint in this characterization is the limit of what the performer knows while improvising (cf. [13]). Ashley asserts that in the case of improvisation, the knowledge one uses is/should be encoded in procedural (know-how-to) form rather than in declarative (know about) form.

This perspective is perhaps the one that so far provides a clear distinction between instrumental improvisation and RTC. When one is composing in real-time, constraints 1 and 3, respectively the limits of the body and of what we know are substantially extended, if not abolished:

- One is operating an algorithm (or set of algorithms) that can produce musical

results that go beyond the limitations of the body;
- One can rely on declarative knowledge for the musical generation — i.e. know about the effects certain algorithms produce rather than having to know how to produce them — and perform with algorithms that can provide unexpected results.

These assertions provide a clear distinction between real-time composition and instrumental improvisation, which not only is important for establishing an ontological distinction between the two but also for understanding how these differences can be used in performance and in music education. Elsewhere [14, 15], I give an example how the concept of real-time composition can be employed in instrumental music, in a piece for the big band [17] where the differences between RTC and traditional improvisation are put in confrontation. Below, I will explain the educational potential of such systems.

RTC SYSTEMS AS EDUCATIONAL TOOLS

Generative music systems, video games, and virtual worlds are increasingly being regarded as powerful tools for music education and performance [16, 17]). RTC systems are opening new possibilities for musical engagement by non-specialists namely through the use of handheld devices like smartphones. As an example, consider *GimmeDaBlues* [18] in which the user of the app can generate fairly competently[3] a blues on a generative music system in an iOS device, and can interact with and accompany professional Jazz musicians. Also, RTC systems can provide new interesting ways for music sequencing. Consider for example the "drummer" in Logic Pro X or the Max for Live (M4L) device that implements the *kin.rhythmicator* [19]. One can program "behaviors" for these devices instead of copy/pasting and editing drum parts[5]. How can these systems be employed in musical education, namely in helping people getting encultured in unfamiliar musical styles?

If one wants to learn a new musical style there are two conceivable ways of doing this: one can do it passively by buying a book on the subject or by looking at information about that style on the web, etc; or one can do it actively, by learning a new instrument or by learning that style in one's instrument. In the first situation, one will never or experience the performative aspects of the style. In the second situation, it will take a while to learn all the gestural vocabulary and intricacies of that new style in order to perform it competently.

How about learning a musical style by "performing" it in a handheld device or in a computer? RTC systems indeed provide an interesting way for music creation and performance. Due to the nature of their behavior, which is non-deterministic, RTC systems promote interaction and improvisation, as the computer becomes a partner in the musical creation. This requires a deeper understanding of the musical style being played. By guiding a user on how to correctly "perform" a style in the RTC system in order to correctly reproduce it, one would be providing an interesting way for teaching how to learn and get enculturated in that style. The development of such an RTC system would then consist of two essential stages:

1. The modeling of a musical style through (non-deterministic) generative algorithms. This requires understanding the style to a point of devising a rule system that can generate it (as in the case of GimmeDaBlues). Recent work [20] has used a data-driven approach and a generation of the style in direct consultation with a specialist;
2. The creation of supervision mechanisms that can give the user clues about improving their performance. This would require the creation of systems that would compare the current performance of the user to what would be considered a "good" performance. Current developments in machine learning, employing something like real-time regression, could facilitate the comparison of the output of the algorithms as performed by the user to stored representations of correct renderings, and provide guidance to the user on how to obtain these, thus enabling a user to improve their performance.

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The creation of such applications could be very interesting to help to learn unfamiliar musical styles. Or, for example, to help understand what are the relevant features of style by making the users understand which parameters should be manipulated in order to produce their correct rendering. The work of the Music and Sound Cultures (MaSC) at New York University Abu Dhabi is now focusing on this direction. Below I provide a short description of such a (still incomplete) system.

CaMel

CaMel [20] is an RTC system that generates percussive sequences in Carnatic style, where a data-driven approach was used to build a generative music system in straight collaboration with a practitioner of this style, virtuoso percussionist Akshay Anantapadmanabhan. The patterns that are generated were extracted from more than 6 hours of recordings of Carnatic music percussion performed on the mridangam and on the kanjira. The strokes in all this data were annotated, parsed into groups of strokes, and then clustered using the K-means clustering approach. The clusters were then mapped in 2D space using t-SNE [21].

The user interface depicts several dots in different shades of grey. Each dot represents a cluster of patterns, and darker dots represent clusters containing more patterns (Figure 1). The cluster map changes according to the way the user wants to concatenate different possible groupings in Adi tala[6]. When a cluster is selected, the program performs elements of that cluster with a degree of variation that is represented by the radius of the circle around the dot (Figure 2).

During a performance with CaMel, the user can navigate this space of rhythms by selecting a cluster to be performed as well as the degree of variation. Moving within clusters that nearby create smooth variations between the generated rhythms. Moving to more distant clusters will create more audible differences in the rhythms being generated.

Although the generator uses some domain knowledge in order to generate rhythms that resemble those of Carnatic music percussion, the current model is currently being perfected in terms of improving the rhythmic generation idiomatically. In that respect, our recent work [22] is yet another step in that direction. Kaustuv Ganguli is presenting at this conference a more refined approach to adding knowledge constraints to the generation in order to make it more idiomatic.

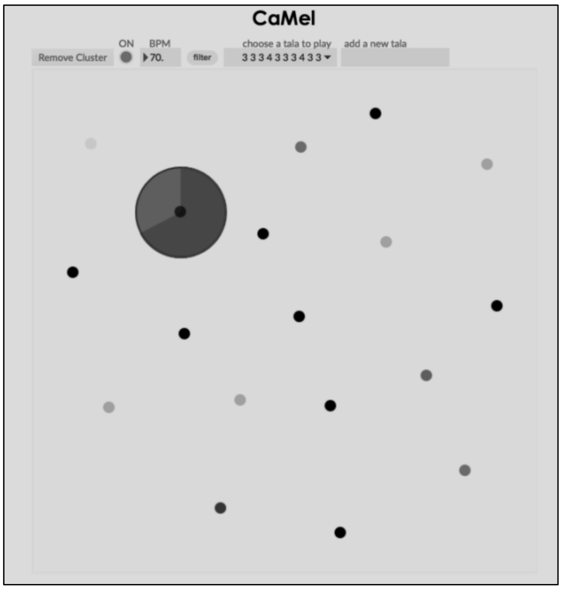

Fig. 1: *The user interface for CaMel.*

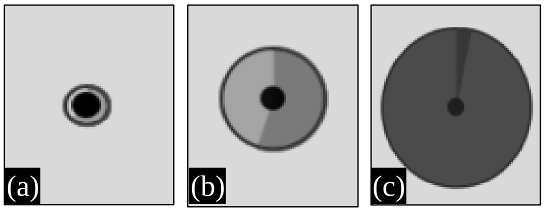

Fig. 2: *Different degrees of variation in the performance of elements from the cluster. 2a) represents no variation, 2b), some variation, and 2c) maximum variation.*

The next step will be to develop the supervision mechanism that will "teach" users to perform idiomatically correct sequences in adi tala so that they acquire the notion of when to start or finish a sequence, to be able to follow the tala and trigger alterations and variations to the performance in idiomatically correct ways while performing the instrument. This aspect is now being addressed and we should have some results by the end of this year.

The revolutionary aspect of the approach presented in section 3 that is being now implemented in CaMel is that, for the first time, one will not need to learn an instrument in order to perform music in a certain style nor will one need to learn all the physical vocabulary that goes with performing a musical instrument for that purpose. This opens possibilities for non-musical experts to engage in rather high-level ensemble music performance (e.g. by each one playing an "instrument"), or playing with experts by engaging in musical collaboration through improvisation. Moreover, we believe this approach provides a novel tool for music education and enculturation using digital portable devices, thus fostering close contact with active music learning.

CONCLUSION

In this paper, I presented an overview of real-time composition, a compositional practice involving the improvisation with generative music algorithms. This practice, although improvisatory is distinguished from traditional instrumental improvisation, although situations mimicking what was defined as RTC can be simulated with groups of musicians, without a computer. However, and through the lens of psychologist Richard Ashley's discussion about improvisation, one can find a clear distinction between RTC and traditional improvisation with instruments. The fact that the limitations of the body can be easily overcome and the ability to use declarative knowledge (i.e. *knowing* about) in RTC allows this practice to facilitate musical performance and expression by non-specialists. Some of the work I was involved within this area was presented, as well as a framework for employing RTC in an educational setting, with the goal of educating lay people in unfamiliar musical styles. I proceeded with a brief presentation of CaMel, a generative model for Carnatic music percussion, that is being developed within the framework that was introduced.

The development of CaMel follows a hybrid methodology that combines machine learning and computational analysis approaches in dialog with a specialist that will provide domain knowledge. This has a goal to better formalize the style as a generative system and in order to better develop the supervision mechanism that will give the lay users the necessary guidance to improve their "performance" in the style. This hybrid methodology is being developed in the Music and Sound Cultures (MaSC) research group, which is a collective of researchers representing a broad spectrum of expertise, including ethnomusicology, machine learning, music composition, performance and improvisation, library science, computational modeling, and the digital humanities. The goal in developing this type of hybrid methodologies is to improve computational knowledge about styles of non-Eurogenetic music that can be used in several applications, namely in helping to familiarize lay people in with the rich styles of music from the Gulf, East Africa, and South India.

End Note

1) *For example, playing a "violin" or a "trumpet" with a keyboard. In this case, the pressing of a key will produce a sound that is "bowed" or "blown."*
2) *For example, the controls of loudness and complexity on Logic's drummer virtual instrument.*
3) *Vimeo. (2019). it's for the iPad… on Vimeo [Online] Available from https://vimeo.com/35743843 [Accessed 2019].*
4) *Vimeo. (2019). GimmeDaBlues Demo on Vimeo [Online] Available from https://vimeo.com/31607650 [Accessed 2019].*
5) *Vimeo. (2019). Rhythmicator on Vimeo [Online] Available from https://vimeo.com/146558971 [Accessed 2019].*
6) *The concept of groupings is a fundamental building block of Carnatic music, be it melody or rhythm. In the vocal percussive form of Konakkol, the language to communicate these rhythms, groupings are also some-times referred to as 'solkattus.' These solkattus at a very basic level are phrases whose sum of syllables map to integer numbers. For example, 'tha ki ta' maps to three, 'tha ka dhi mi' maps*

to four, 'tha ka tha ki ta' maps to five and so on [23]. The mapping however is not one-to-one as the musician is free to play many different n-syllable phrases to represent just one grouping. Assuming, you can fit four syllables per beat, in the eight-beat cycle of adi tala, there is a possibility of thirty-two syllables to fill one cycle. One strategy to perform in this cycle, is to use a series of sollu groupings along with intermittent rests to fill the cycle. Multiple groupings can also be concatenated to form larger musically-relevant groupings.

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