Polytempo Network: A System for Technology-Assisted Conducting

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ABSTRACT

This paper describes the current development of a system designed for the synchronization of musicians in polytempic music. In order to convey the tempo, an animation is used that resembles the gestures of a conductor, which is believed to be particularly comprehensible for musicians. This system offers an alternative to the use of a click track which is still the most common means for the purpose of synchronization. The possibility to combine several devices in a network allows for the synchronization of several players in ensemble music. It is hoped that this system promotes the creation and performance of music that exhibit ambitious tempo polyphony as well as spatial distribution of the musicians.

1. INTRODUCTION

1.1 Polytempic Music

Polytempic music is a music whose parts are based on different tempi. Creating polytempic music means to apply the compositional techniques and concepts of polyphony (i.e. the independence of parts) also to the parameter of tempo. Historical examples can be found in the music of the 14th and 15th century (for example mensural canons) and then again in the 20th century. In his seminal book *New Musical Resources,* Henry Cowell relates rhythmic values to the ratios of frequencies [1]. Such ideas have later been embraced by several other composers, for instance Karlheinz Stockhausen [2]. Conlon Nancarrow's *Studies for Player Piano* are well known for exploiting the simultaneity of musical parts in different tempi, however, this music avoids the human performer and replaces them with a machine [3]. Useful information about polytempic music can be found on John Greschak's website which provides an annotated bibliography [1] .

The performance of polytempic music always raises the question of synchronization. If we think of a kind of polytempic music that requires an accurate simultaneity (i.e. its parts are more than just "freely" coordinated) and if we further assume that the different tempi are related to one another in intricate ratios or may even speed up or slow down independently, it becomes evident that this music is almost impossible (or at least very difficult) to perform for an ensemble without the help of technical means.

1.2 Technology-Assisted Conducting

The use of technology to convey a tempo goes back to the beginning of the 19th century when the mechanical metronome was invented. With such a device at hand it became possible to quantify musical tempo rather than rely on traditional knowledge or the musicians' judgement. Technology-based conducting systems are a most important tool to enable the coordinated performance of polytempic music. Moreover, they lend themselves also to any performance scenarios where there is no sufficient visual communication between conductor and players (for instance because of long distances, complete darkness etc.)

Most technology-based conducting systems transmit their cue signals acoustically; the old familiar click track is still common practice. However, there are alternatives: some systems convey the tempo visually and – especially in more recent systems – also tactilely. In the case of acoustic systems musicians are provided with earphones through which they perceive a click track and possibly other information as well. An early description of such a system can be found in Emmanuel Ghent's article *Programmed Signal to Performers: A New Compositional Resource* from 1967 [4]. The most basic visual solution consists of the flashing LED of a metronome or a blinking spot on a computer screen. More elaborate solutions emulate the gestures and indications of a conductor as, for example, the *Virtual Conductor* proposed by Raquel Baez et al [5]. In order to perceive beats with one's tactile sense it is necessary to attach actuators to the musicians' bodies. There exist commercial tactile metronomes (for instance the Peterson BodyBeat Sync [2]), but such devices fall short of supporting complex polytempic music. One can find, of course, non-commercial systems which are more sophisticated yet often either experimental or highly specialized (see for example [6]).

2. TECHNOLOGY

The following section describes the technology-based conducting system the author has developed. The system consists of a number of identical devices, each of which

[1] http://www.greschak.com/polytempo/ptbib.htm (accessed: 25. March 2014)

[2] https://www.petersontuners.com/index.cfm?category=163 (accessed: 25. March 2014)

combines an "electronic music stand" (a 24" flat screen mounted on a microphone stand, see Figure 1) and a computer. These devices are synchronized among each other via network connection. For rehearsals and practice, a smaller setup consisting of only laptops can be used as well. The software consists of several components which will be explained hereafter.

Figure 1. An electronic music stand consisting of a 24" screen mounted on a microphone stand.

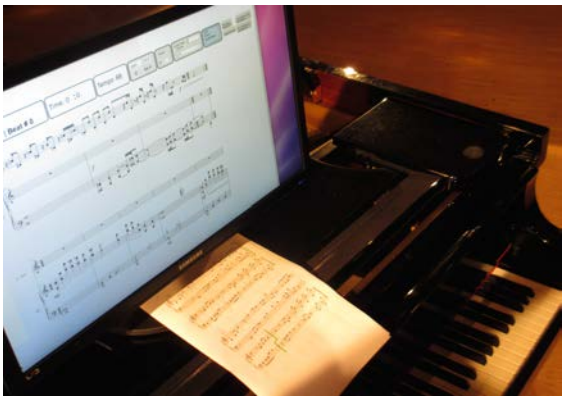

Figure 2. An electronic music stand in the form of an ordinary 24" screen put on top of a grand piano.

2.1 The Virtual Conductor

The proposed system conveys the tempo by visual cues. The beats are indicated by two animated bars which are located on the left and top edges of the screen. The movements of these bars resemble in a simplified manner the gestures of a conductor: a downward movement indicates a downbeat, a sideward movement any other beat (see Figures 3 and 4). If necessary, further subdivisions of the beat can be indicated by the change of the bar's width or colour.

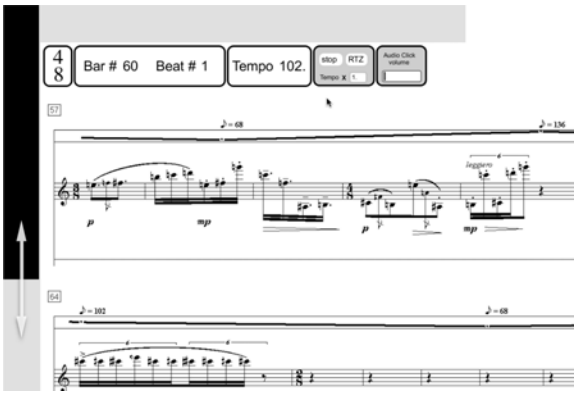

Figure 3. A downbeat is indicated by a vertical movement of the bar at the left edge of the screen.

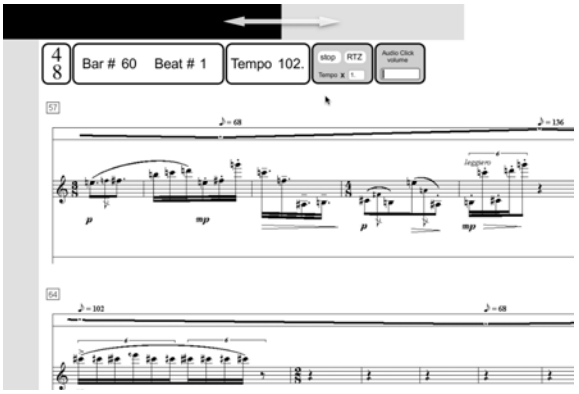

Figure 4. Any other beat is indicated by a horizontal movement of the bar at the top edge of the screen.

It is argued that the proposed visualization method that uses animated bars to indicate the beats has the following beneficial properties:

(1) Visual cues do not interfere with the performer's hearing sense, which should be used solely for primary task of making music, that is, listening to the sound of their own instrument or to the other musicians in the ensemble. In addition, visual cues are silent and therefore, on the one hand, can be perceived by the performers even during very loud passages of the music and, on the other hand, they do not get accidentally overheard by the audience during very soft passages.

(2) The visual sense is a common modality for musicians to receive tempo-related cues, be they gestures from a conductor, the section leader or a chamber music partner. In addition, if the visual cues are similar to a conductor's gestures, the system can benefit from the familiarity of this type of cueing mechanism and musicians will more readily accept it. To a certain extent, the metrical hierarchy of beats is reflected, in that the first beat in a bar is indicated similar to the downward stroke of a conductors baton. Furthermore, the position of the visual cues next to the score

connects to a practice many musicians are quite familiar with: to observe a conductor from the corner of their eyes.

(3) A continuous movement (as opposed to the punctual click of a metronome, be it visual or acoustic) enables the musician to anticipate the ictus of a pending beat, as they would predict the time at which the conductor's baton will arrive at its low point. This anticipation of the beat is assumed to be especially advantageous in situation where the tempo changes (accelerando or decelerando).

(4) On the other hand, the exact time at which a beat occurs is less distinct as, say, a metronome click would be. The fact that the precise time of the beat is relatively indistinct gives the player a certain freedom to play slightly ahead of or after the beat. This option to deviate from a mechanical manner of performing music, allows for a more musical and consequently more relaxed performance.

2.2 Further On-Screen Elements

In addition to the indication of the tempo, other visual elements appear on screen. In particular, there is a counter to display the bar and beat number as well as an indication of the current tempo. Other information, appearing in the form of pop-up windows, give verbal prompts to the musician, such as "wait for cue" or "fermata 20 seconds" etc.

The biggest part of the screen is used to display the score. The use of screens allows the musician to play continuously and unhindered by page turns, which are executed automatically. The page turn function is designed to be the least disturbing for the musician. All pages of the score are split into two halves, each of which is replaced at a moment when the musician is currently reading from the other (that is, the upper half is replaced by the content of the next page, when the musician's attention is concentrated on the lower half, and vice versa). Finally, it should be mentioned that the display of music is not restricted to traditional scores. Rather, it is open to any forms of graphical scores or, in fact, anything depictable on a screen [7].

2.3 The Network

In order to facilitate ensemble music and to establish synchronization, the electronic music stands are interconnected in a network. The communication protocol is Open Sound Control (OSC). The network is not hierarchically organized, i.e. there is no master-slave arrangement, all the electronic music stands keep each other informed about the current point in time within the piece by exchanging timestamps and state-messages such as changes in tempo. Not only does this kind of flat hierarchy permit different interactive scenarios, it also ensures that a malfunction of one single component or the interruption of a single connection does not lead to a failure of the whole system. Furthermore, the user can stop the performance at any time, restart at any given bar number, and manually change the overall tempo. This last function is geared towards the fact that the tempo in practice and rehearsals is usually lower and then gradually increased as the musicians get along. It might even be a useful option in performance situations where, for any reason, a different tempo is more adequate. The possibility to jump to and start from any arbitrary point in the piece is a most important feature in rehearsal situations. It requires, especially if the parts are to be played in different tempi, some specific tempo calculations. Based on a desired starting point, the actual starting point has to be calculated in a way that there is at least one bar count in for each instrument. A diagram to illustrate those calculations is shown in Figure 5.

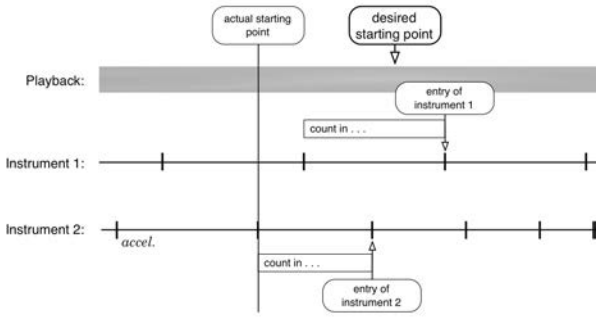

Figure 5. Typical calculations needed in order to find the appropriate starting point in a polytempic context.

2.4 Implementation

Early prototypes of this system were implemented in Max. These prototypes have been used for some artistic projects in the last couple of years (see below) and their successful employment might serve as a proof of concept. Based on the accumulated experience the development of a cross platform standalone application has recently been initiated. The application is written in C++ using the framework JUCE. [3]

3. ARTISTIC PROJECTS

The first composition that employed visual conducting took place in 2010. In the author's composition *Solo für Klarinette,* a clarinetist was to be synchronized to an electronic playback. The fact that the tempo of this piece constantly changes during most of the time was an important inspiration to commence the development of the Polytempo Network.

In a second project entitled *Trails I,* an audiovisual composition realized by the author in collaboration with Daniel Bisig in 2011, a small ensemble had to be synchronized to an electronic playback as well as a video. In order to keep the technical gear as simple as possible, we decided not to equip each musician with an individual computer screen. In fact, we used only one single screen and a (human) conductor to transmit the tempo to the ensemble (see Figure 6).

In 2012, the piece *Egregoros* by the Swiss composer Marc Kilchenmann was performed. In this composition each musician of the ensemble plays in a different tempo. Moreover, all the tempi are subjected to a constant change in the shape of a sine function. The realization of this piece promoted the development of the network coordi-

[3] `http://www.juce.com` (accessed: 25. March 2014)

Figure 6. Performance of the piece *Trails I.* The ensemble is led by a conductor who himself reads the tempo from a laptop screen.

nation and synchronization functionality between the devices.

The chamber music piece *FF* by Kilian Deissler, a composition student at the Zurich University of the Arts, poses a challenge to the musicians as the ensemble is divided in two groups whose tempi are just one beat per minute apart (68 and 69 bpm). This composition was performed in 2013.

4. RESULTS AND DISCUSSION

Polytempo Network is part of an ongoing artistic research project in which technological development and artistic practice mutually inform each other. Compositional needs have inspired the implementation of new features and validations have taken place by using the system in performances.

Most of the participating musicians could follow the virtual conductor effortlessly right from their first encounter with the system. The musicians got quickly accustomed to the system and described playing with it as comfortable, even in rhythmically awkward situations like the above mentioned playing one bpm apart. The fact that the system uses visual cues and there is no need to wear earplugs was welcomed by the musicians. Nevertheless, a few people preferred to play to a conventional click track, especially those who were particularly used to it (for example drummers). In general, it turned out to be convenient that the musicians could run the software on their own computers and practice at home without the need for any additional hardware. The rehearsal functions, such as the slowing down of the overall tempo or, particularly, the possibility to enter at arbitrary starting points, proved to be useful and time-saving.

Furthermore, it became clear that the tempi of a piece need to remain within reasonable limits in order to be representable by the virtual conductor. Slow tempi require the indication of subdivisions of the beat and fast tempi necessitate a change to a higher beat-unit, a fact to be considered when arranging a piece for this system. This is, however, not a completely alien practice as it reflects precisely what a human conductor would do.

Future work will include the extension of the existing software, especially by adding a function that allows the musician to annotate the score in rehearsal situations. Furthermore, a production software will be developed to provide tools for composers to sketch, arrange and eventually typeset their music. Finally, more artistic work will be realised, by the author as well as other artists with different aesthetic backgrounds.

5. CONCLUSION

Polytempo Network fits in the history of technology-assisted conducting which started with the invention of the mechanical metronome in the 19th century and later led to the development of different systems using acoustic, visual or tactile cues to indicate the tempo. Similar to its predecessors, the intended goal of Polytempo Network is the implementation of a system that allows musicians to perform a piece of music in the designated tempo with the utmost precision.

The system's network-based synchronization mechanism enables the realization of ambitious polyphonic tempo concepts. Furthermore, the combination of such a precise synchronization with different forms of distributed performance seems particularly interesting for composers, as it allows for a detailed spatial and temporal modeling of every musical event.

As this project is in an early stage, it is likely that there are still many more interesting technological and artistical challenges lying ahead. The author believes that Polytempo Network offers a great potential to be employed by composers and improvisors in a variety of different scenarios. It is hoped that this system stimulates the exploration of novel composition and performance paradigms.

6. REFERENCES

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