Technology-Assisted Performance of Polytemporal Music

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ABSTRACT

This paper is an intermediate report of an ongoing artistic research project on technology-assisted performance practice. It describes the application *Polytempo Network* and some works that were realised using this application in the course of the last two years. The different compositional approaches chosen for every individual work and the experiences gathered during the process of composing, rehearsing and performing these works are discussed. The leading question is to what extent the usage of this technology is aesthetically significant.

1. INTRODUCTION

The application *Polytempo Network* has been developed at the ICST Institute for Computer Music and Sound Technology in Zurich [1]. It facilitates the synchronisation of musicians in polytemporal relations and/or over larger distances that would not allow for direct interaction or visual communication. For this purpose multiple instances of this application run on computers linked in a local area network.

The application displays the score and indicates the tempo by two animated bars at the top and left edge of the screen. The movements of these bars resemble remotely the gestures of a conductor: a downward movement indicates a downbeat, a sideward movement any other beat (Figures 1 and 2). For most musicians a tempo visualisation has several advantages compared to a traditional acoustic click track, for instance, it does not interfere with the musicians hearing sense and the animation allows for a better anticipation of beats and tempo changes. However, if a musician prefers the acoustic click track, the possibility to output an acoustic metronome or to send the beats as Midi note messages is provided as well. Moreover, as the application does not only indicate the tempo on the screen but also displays the score, it lends itself equally well to those aleatoric compositional concepts known as 'open' or 'mobile' form.

The motivation behind the development of this application is the research question, whether the availability of a versatile technology to synchronise performers can possibly lead to novel forms of compositional strategies. Or, expressed as a question put towards composers: how to conceive of a music that exploits the specific potential of such a technology?

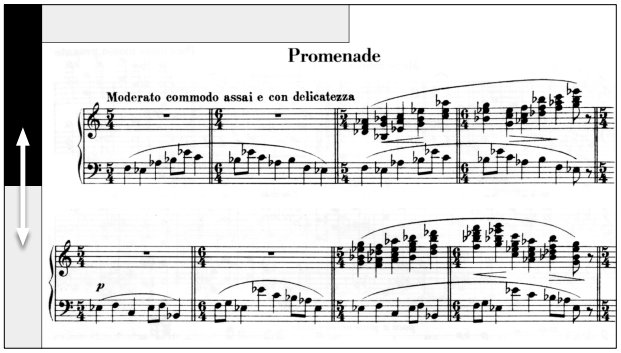

Figure 1. A downbeat is indicated by a bar moving down and up again at the left edge of the screen. This vertical movement is similar to a conductors downbeat.

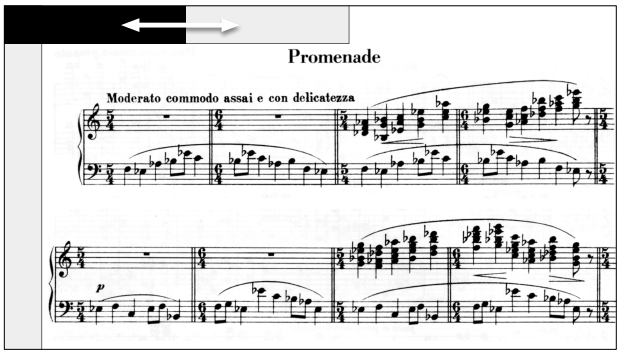

Figure 2. Any other beat is indicated by a horizontal movement of the bar at the top edge of the screen.

2. CONTEXT

2.1 Music History

The first use of technology to synchronise musicians in a performance situation goes back to the middle of the 19th century. For the second edition of his treatise on instrumentation, published in 1855, Hector Berlioz added a chapter on conducting entitled *le chef d'orchestre* [2]. In this chapter he addresses the issue of keeping instrumentalists or singers, which are placed behind the scenes in an opera, in time. He describes an electrical device, the *métronome electrique*, to transmit the conductor's beat to off-stage musicians. Berlioz came across this machine at a

theatre in Brussels and used it again for a monster concert at the Paris Universal Exhibition in 1855 to transmit his beat to five sub-conductors. As this technology-assisted conducting was obviously not compliant with the 19th century notion of musical romanticism, this device disappeared again. In the early 20th century, we find several attempts to synchronise music and imagery in the cinema, for which several visual and acoustical solutions to indicate the tempo were invented [3].

As far as tempo polyphony is concerned, there are several works in the 20th century classical music that abandoned the notion of a common tempo for all performers, of which the earliest examples can be found in the oeuvre of Charles Ives. In these works different tempos are assigned to individual instruments or musical layers and in most cases the tempos are precisely indicated by metronome marks. Yet the actual coincidence of musical events remains speculative, since no human is able to hold a given tempo accurately. Hence, these pieces explore primarily the expressive quality of musical stratification *as such,* and, of course, the composers were aware of this and took the appropriate compositional measures.

The possibility to keep all performers in sync even in intricate polytemporal relations, and even when the tempos accelerate or decelerate independently, opens the door for interesting polyphonic strategies. However, it requires a technology-assisted performance practice, i. e. the usage of technical means to keep the tempo to allow for an appropriate timing accuracy. Metronomes or click tracks are commonly used in such situations. The first description of a polytemporal click track was given by Emmanuel Ghent in 1967 [4, 5].

2.2 Related Projects

Networked music performance has been considered since a few decades in contemporary music composition. And it has developed rapidly due to the advance of the enabling technologies [6]. A couple of existing systems provide networked and interactive display of music notation: *Quintet.net* enables an ensemble to share notation and other information across a network of laptops, whether the musicians are in the same room or spread across the world [7]. It is built on top of MaxMSP, and the notation is rendered with *MaxScore* [8]. *INScore* can display images, vector graphics, and symbolic music notation, for which the Guido Music Notation or MusicXML formats are used [9]. It indicates the current position in the (graphical or symbolic) score by a cursor that advances with the appropriate speed. The *Decibel ScorePlayer* is an iOS application that facilitates the presentation and network-synchronised scrolling of graphical scores on multiple iPads [10].

The mentioned projects allow for different forms of non-traditional scores as well as scores generated in real time. However, even though they might support polytemporal music to a certain degree, they are not specifically designed for it. The application *Polytempo Network* fills this gap.

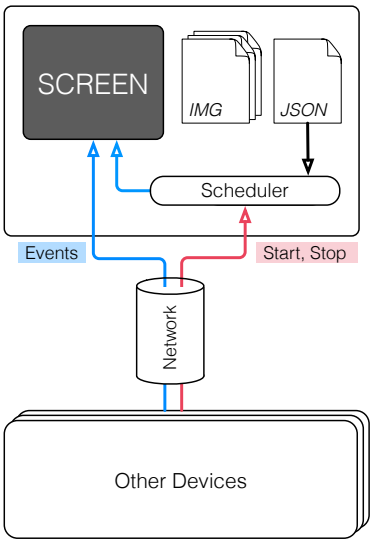

Figure 3. Simplified technical diagram. Events are either read from the JSON-formatted 'electronic score' and processed by the built-in scheduler, or received as OSC messages over the network.

3. TECHNICAL DETAILS

Polytempo Network is a standalone application for Mac OS and Windows available for download from the project's website. [1] Dependent on the tempo structure of the music, and especially on the fact whether the form is predefined or generated in real time, the application can be operated in two different modes: stand-alone and message-driven. The former mode employs a built-in scheduler to play though a given score, and is typically used for compositions with a predetermined tempo and a linear time structure in a traditional fashion. The latter mode requires a central computer to control the flow of time for all instances and is used for music whose tempo and/or form is subject to changes in real time.

3.1 Standalone Operation

For the performance of a composition with a linear, yet possibly polytemporal, time structure the typical procedure is as follows: *Polytempo Network* has to be provided with two types of data, the sheet music stored as image files and an 'electronic score' in JSON format (Fig. 3). The electronic score contains a timestamped lists of events. This list is processed by an built-in scheduler, which executes all the events when they are due. By sending commands over the network to start or stop the scheduler several instances of *Polytempo Network* are kept in sync. An useful feature in rehearsal situations is the possibility to jump to and start from an arbitrary point within the piece. It does not matter if the musicians have to play in different tempos: to resume the music at any given point in time, each instance starts its conducting at the next possible downbeat and, if necessary, with the appropriate time-delay.

Among the events listed in the electronic score the most important are obviously those that represent beats and

[1] polytempo.zhdk.ch

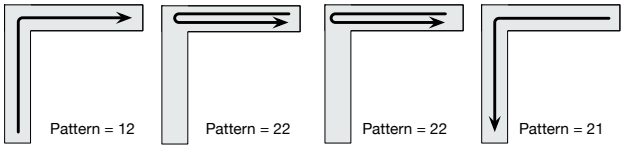

Figure 4. The *pattern* of a beat is a two-digit number that indicates the initial and final position of the bar and hence the direction of movement of the animation. The four beats of a 4/4 bar would have the patterns 12, 22, 22, and 21.

those that indicate that a certain section of an image file has to be shown on the screen. The latter type of event is used to display the music and to automatise the page turning. The former type is defined by the parameters *duration* and *pattern*, both of which influence the rendering of the on-screen animation. The pattern is a two-digit number where the first digit specifies the initial position and the second digit the final position of the animation. The values of these digits are either 1 = bottom left or 2 = top right (Fig. 4).

A JSON object that represents a beat event would, for instance, be written as follows:

```
{"beat":{"time":13.5,"duration": 0.6,
 "pattern":12}}
```

This defines a downbeat (as the pattern 12 indicates) with a duration of 0.6 s and scheduled to be executed 13.5 s after the beginning of the piece.

3.2 Message-driven Operation

In the message-driven operation mode the built-in scheduler remains inactive and all functionalities are controlled by messages received over the network. The communication protocol is Open Sound Control (OSC). Every event that can appear in the electronic score has an equivalent in form of an OSC command.

For this purpose the basic OSC format is adapted in the following way: The address part of the OSC message simply indicates the event's name and the parameters consist of key-value pairs. The same beat event as above would look as follows:

```
/beat duration 0.6 pattern 12
```

As there is no indication, the event's time is 'now' and the animation to indicates a downbeat would be executed on-screen immediately after this message has been received. Thus, the flow of the music can entirely be controlled in real time from any external OSC capable application (e. g. SuperCollider or MaxMSP). This allows for compositional strategies that employ non-linear, real-time generated or interactive forms.

4. WORKS

This section describes five works by the author and other composers that were realised during the last two years. This list is not exhaustive, it only covers those works that made the most substantial use of the application *Polytempo Network*.

Figure 5. Performance of *Trails 1*. Three musicians are synchronised to an audiovisual playback.

4.1 Trails I (2011)

The composition *Trails I* by the author in collaboration with Daniel Bisig exemplifies a straightforward usage of the application *Polytempo Network*: the synchronisation of performers to an audiovisual playback (Fig. 5). Of course, this does not draw on the full potential of the application, as there is no tempo polyphony involved whatsoever. Still, as this was one of the earliest pieces realised with this application, it gave the opportunity to address some fundamental questions about its practicality. For the premiere of this piece in 2011 a prototype programmed in MaxMSP was used. It was only for a restaging in the fall of 2015 when this prototype could be exchanged with the standalone application.

The realisation of this piece gave rise to the question whether such an automated conducting feels awkward to the musicians. In this kind of technology-assisted performance practice, the musicians are required to follow the beat as it is given by a machine, which possibly renders the music lifeless and mechanical. But these worries were proved wrong: until now, *Trails I* has been performed by four different ensembles and none of the musicians ever complained. In general, musicians specialised in contemporary music are familiar with the fact that a conductor does not convey emotions but rather 'organise' the music by soberly beating the tempo. Therefore, they did not feel hindered by the electronic conductor. On the contrary, the performers expressed their appreciation for the beat being so clear and unambiguous, which they found helpful for the performance of rhythmically complex music.

4.2 Quadrat (2015)

The piece *Quadrat* for two trumpets and two trombones was written by the author with the intent to explore the application's facility to enable tempo polyphony and independent tempo progressions. Furthermore, in order to emphasise the independency of the parts, the brass players were positioned at the four corners of the auditorium, that

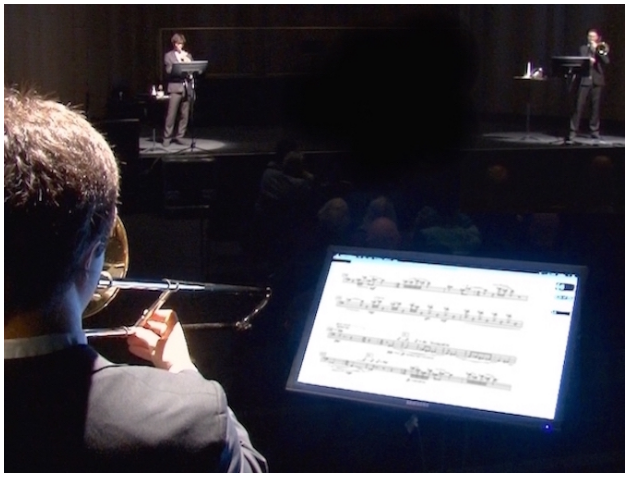

Figure 6. Performance of *Quadrat*. The musicians are positioned at the four corners of the auditorium, approximately 20 m apart.

Figure 7. Performance of *Manduria*. The musicians are grouped in small sub-ensembles and distributed in a gallery space.

is, approximately 20 metres apart from each other (Fig. 6).

Especially the first section of this piece exhibits a constant change back and forth between synchronicity and independence. Every few bars, all instruments play a note exactly together. Between these notes they execute rhythmical structures in different tempos or in tempos slowly drifting apart. This structure was well perceivable by the listener as a (tempo-)polyphony interspersed with synchronous chords.

Concerning the performance practice, the musicians had to develop a special (but quickly mastered) skill. Being positioned wide apart, they had to precisely adjust their timing solely to the beats indicated by the application, rather than using their hearing sense to adapt their playing to the other musicians. However, other aspects of musical interaction like control of intonation or dynamic balance remained the same as in traditional musical practice.

One musical texture posed a problem: At some points, the four musicians have to play interlocking rhythms, which should result in a rhythmic pattern of regular semiquavers circling around the audience. In practice, this was not satisfactorily realisable for two reasons: On the one hand, playing a tight interlocking rhythm does not simply need the aid of a metronome but rather a very subtle interaction between the performers, which cannot be established over large distances. On the other hand, the visual animation to indicate the tempo is less precise than the punctual 'beep' of a click track. In most other cases this is a considerable advantage, as it does not give the musicians the feeling that they have to fight against the metronome when they get a litte behind or ahead of the beat. But for the execution of tight rhythms this flexibility is not particularly helpful.

4.3 Manduria (2016)

Without knowledge of the aforementioned piece, the composer Stefan Wirth came up with a similar idea of spatial distribution of the musicians for his piece *Manduria*. Seven groups of one to three musicians each were placed around the audience (Fig. 7). The immersive sound thus produced was very impressive, not only because of its spatial quality but also due to the fact that a dense polyphonic structure or a superimposition of differently characterised musical layers can be segregated more easily if the sound sources are distributed in space.

In accordance with this, it was Wirth's intention to assign an individual characteristic to every instrumental group and to produce a very heterogeneous texture. This lead to the question if in fact spatialisation is musically more effective than tempo polyphony and therefore will turn out to be the primary purpose of the application *Polytempo Network* in the future. Although it is too early to make a final assessment, one can certainly say that spatial effects are more straightforwardly composed than tempo polyphonies, which always involve a great deal of tedious mathematics.

Wirth, being an accomplished composer, relied on his experience and wrote a piece that worked well and was successfully performed, but he did not engage in experiments with complex tempo structures. The tempo polyphony in *Manduria* consists of the superimposition of speeds that can be expressed in notation, e. g. a 4/4 bar in the same time as a 5/4 bar, etc. Furthermore, the basic tempo MM = 72 is present throughout the piece and all other tempos are proportionally related to it. This allowed Wirth to plot his composition in a traditional score with occasionally coinciding bar lines. That way, he could stay in his familiar working environment and maintain his habitual workflow, which eventually was necessary to deliver a piece of high quality and in due time.

4.4 Tempo Studie (2016)

The short composition *Tempo Studie* was the author's attempt to realise a piece with an open form generated in real time. This trio for violin, bass clarinet and accordion utilises a computer algorithm that randomly chooses fragments and presents them to the performers. But not only the succession of fragments is random-based but also the

Figure 8. Rehearsal session of *Tempo Studie*. The musicians play individual tempo progressions that are random generated in real time.

tempo, which is individually calculated for every part. In addition, the tempos never remain static but constantly accelerate and decelerate, which means that the three musicians have to play in different and independently changing tempos throughout the piece. Yet, in order to establish appreciable relations between the parts, prominent features in the musical texture, e. g. a sudden changes in loudness, density, or pitch range are synchronised ever so often. To enable these coincidences, the random algorithm calculates the tempo progressions accordingly [11].

The realisation of this piece omitted *Polytempo Network's* built-in scheduler and made use of the message-driven operation mode. All events were remotely controlled via OSC: the individual beats to indicate the ever-changing tempos and the display of graphic files i. e. the music of the currently chosen random fragment. All computers were connected in a network and controlled from an additional fourth computer. The calculations to generate the arrangement of fragments and the appropriate tempo progressions were implemented in the programming environment SuperCollider. The overall duration of one complete run-through of this piece is only about two and a half minutes, which allows for several renditions in a row and for an immediate comparison of the different versions.

The musicians were challenged in two ways when performing this piece: first, they had to be able to play the same music in different tempos (the fastest possible tempo being more than twice as fast than the slowest) and adapt to the different gestural qualities thus revealed. Second, they had react quickly and spontaneously to the ever changing tempo indicated on the computer screen. The musicians did not only accept this challenge, but also found it rather inspiring, as it appealed to their expertise as interpreters as well as improvisors. For the listeners, the polyphony of tempos lead to the impression that the performers were improvising along with each other, whereas the perceivable coincidences added a clear structure. This combination of both qualities, freedom and structure, turned out to be musically quite effective.

4.5 The Same (Not) The Same (2017)

The most recent work is the piece *The Same (Not) The Same* for eight instruments by André Meier. This composition takes advantage of technology in several ways: not only to distribute the musicians in space – strings, piano and percussion on stage, woodwinds around the audience – but also to execute several random choices in real time. Some sections of the piece exist in multiple variants and the one to be performed is chosen by a random algorithm. At some points a continuous layer of music is occasionally overlapped with shorter fragments chosen by a random algorithm. Several sections of the piece are to be played in a random tempo chosen from a given range of tempos. The beginning of every overlapping fragment, also played in a random tempo, is placed in such a way that the music of the fragment and the continuous layer coincide at a certain point. To realise these compositional concepts, *Polytempo Network* is used in its message-driven operation mode, controlled from a central computer.

How such a randomisation could be made appreciable for the listener rather than remaining a speculative concept, was one of Meier's main considerations. Hence, one section of the piece consists of one fragment repeated over and over again. As the iterations of this fragment are not completely identical but vary in tempo and some other details, the listener is given the chance to get a vague notion of the pieces underlying concept.

5. CONCLUSION AND OUTLOOK

The experience gained from the performances of the pieces described in this paper was essential, as it provided knowledge about the efficiency of several conceptual ideas when realised in practice. This knowledge is particularly valuable for composers who intend to use *Polytempo Network* for their music in the future.

The case of *Manduria* showed the dialectic relationship between notation and composition. The decision to remain within the conventions of traditional notation provided security but hindered the exploration of new concepts. In order to encourage composers to delve into experimental tempo structures, it seem important to provide the appropriate tools, especially to alleviate the burden of mathematical calculations with which the realisation of complex tempo structures is always associated [12].

There are three aspects where the use of technology is significant, that is, enables aesthetic results that could not be achieved in a performance practice that is not technology-assisted. First, the distribution of musicians in space while keeping them rhythmically synchronised. In fact, spatiality was included in several works, which indicates that composers find it attractive. Second, the simultaneity of musical layers in different tempos, or even different tempo progressions, interspersed with coincidences of salient musical events is effective, as it can be appreciated as a balance between rhythmical freedom or independency and synchronisation. Third, the possibility to generate and perform 'open' form compositions in real time. It is, however, necessary that the whole piece or certain parts of it

are played several times in a row, in order to enable the comparison of the different variants and consequently the appreciation of the random-based form.

The question whether the availability of technology leads to novel forms of compositional strategies, posed at the beginning of this paper, has to be further explored. This requires more composers with different backgrounds to engage with this technology and create works that can serve as application scenarios. It is of particular importance that future works will also involve different genres and styles.

As this is an ongoing project, the application *Polytempo Network* will be further developed and extended. Two features are to be added with high priority: first, the facility to annotate the score, which is much asked for by performers, and second, the possibility for wireless network communication, which would simplify the technical setup for a rehearsal or a concert a great deal.

Acknowledgments

I would like to thank my fellow composers Stefan Wirth and André Meier for their artistic contributions to this research project.

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