Rethinking 'Open Form'

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Abstract
This paper approaches the idea of a musical work whose polyvalent form is constituted by its randomly generated tempo structure. For this kind of music the original concept of 'open form' is extended by the use of a computer algorithm that not only generates an aleatory collage of prepared fragments, but also calculates an appropriate tempo progression to arrange and overlap these fragments in a musically meaningful way. The author's collaboration with a chamber music trio is presented and the artistic strategies and technical implementations are discussed.

1. Introduction

This is the report of a musical experiment that was carried out in collaboration with a chamber music trio at the *Darmstadt Summer Course for New Music* in August 2016. The aim of these experiments was to explore how the original concept of 'open form' could be extended. It was attempted to find an algorithm to randomly generate not only the succession of score fragments, but also the tempo in which these fragments are to be played. The idea of 'open form' should be combined, as it were, with the idea of 'open tempo'. With the ambition of creating polyphonic chamber music, the random tempos and tempo progressions were individually generated for every single instrument, which lead to an intricate tempo polyphony.

The musicians of the chamber music trio were given a 'mobile score', a music notation that is split up in several fragments. The random arrangement of these fragments was delegated to a computer program. It can be argued that a computer program is the most suitable instrument for this task, as it prevents the preparation of the order of fragments by a biased performer and allows for the utilization of arbitrary complex or constrained aleatory procedures [1].

Two key questions arose in the context of this musical experiment: First, what compositional strategies should be applied in order to prepare a material that not only allows for manifold combinations, but also guarantees that all these combinations are to a certain extent musically meaningful? And second, how should the generative algorithm be designed and implemented that it reasonably arranges the musical material and appropriately calculates the right tempos in order to allow for the music to synchronise in a perceptually stringent and compelling way. Both questions are addressed in this paper.

2. Historical Context

2.1 Chance Based Musical Form

In 1787, Wolfgang Mozart wrote his *Musikalisches Würfelspiel* (“Musical Dice”), a chance based composition consisting of 176 pre-written fragments, one bar each, and some instructions how to combine the fragments randomly by rolling dices. It was only published in 1793, after his death. This early example of aleatory music is not the only of its kind. Musical dice games were quite fashionable in the 18th century in western Europe; Mozart's is just the most well-known. The instructions to this piece include two tables to guide the assembly of fragments and to ensure that the result conforms to the harmonic grammar and the stylistic features of western tonal music of the 18th century (see Fig. 1). In spite of the restrictions imposed by these guidelines, this piece still offers an enormous potential in terms of formal variety. With a length of 16 bars and a choice of 11 possibilities per bar, this piece can take on no less than 11^{16} = 45'949'729'863'572'161 unique forms.

	I	II	III	IV	V	VI	VII	VIII
2	96	22	141	41	105	122	11	30
3	32	6	128	63	146	46	134	81
4	69	95	158	13	153	55	110	24
5	40	17	113	85	161	2	159	100
6	148	74	163	45	80	97	36	107
7	104	157	27	167	154	68	118	91
8	152	60	171	53	99	133	21	127
9	119	84	114	50	140	86	169	94
10	98	142	42	156	75	129	62	123
11	3	87	165	61	135	47	147	33
12	54	130	10	103	28	37	106	5

	I	II	III	IV	V	VI	VII	VIII
2	70	121	26	9	112	49	109	14
3	117	39	126	56	174	18	116	83
4	66	139	15	132	73	58	145	79
5	90	176	7	34	67	160	52	170
6	25	143	64	125	76	136	1	93
7	138	71	150	29	101	162	23	151
8	16	155	57	175	43	168	89	172
9	120	88	48	166	51	115	72	111
10	65	77	19	82	137	38	149	8
11	102	4	31	164	144	59	173	78
12	35	20	108	92	12	124	44	131

Figure 1: The tables of Wolfgang Mozart's 'Musikalisches Würfelspiel'. The roman numerals above the columns refer to the two times eight bars of the piece; the numbers to the left of the rows indicate possible values of two dices; the numbers in the matrix refer to the musical fragments.

Even though this early example of aleatory music might seem trivial, we can learn some important basic strategies from it. On the level of details, the music is determined; all fragments are precisely formulated and unchangeable. On the level of form, the music is indeterminate; the succession of fragments is variable as the action of putting them together (in the sense of the latin *componere)* is delegated to a chance based algorithm. However, there are constraints to guide the random choice in order to guarantee a meaningful musical grammar – whatever 'meaningful' may mean in a particular musical style.

It was only in the 20th century when composers started to significantly use aleatory features in their music. The term 'open form' was coined to describe a musical form where the sequence of elements or sections of a notated work is indeterminate or left up to the performer. This type of form can also be characterised as kind of collage but without the use of external material. An early examples of 'open form' music in the 20th century is the *Mosaic Quartet* composed by the American composer Henry Cowell in 1934. In this string quartet the players are allowed to arrange and even repeat the five short movements of this piece at their discretion. A well-known European example is Karlheinz Stockhausen's *Klavierstück XI* from 1956, which consists of nineteen fragments spread out on a large sheet of paper. The performer plays these fragments in random order by looking on the sheet without any intention and taking any fragment “that catches his eye” (see Fig. 2).

Figure 2: A detail of Karlheinz Stockhausen's 'Klavierstück XI', the performer is required to randomly choose from nineteen fragments layed out on a large sheet of paper (53 x 93 cm).

The artistic interest in the use of random based systems lays not only in its unpredictability, but also in the extension of the creative scope. A work that includes elements of chance rejects the notion of a definitive, concluded form and multiplies its possibilities of realisations. Furthermore, the use of random procedures sheds a different light on traditional conceptions of creativity and authorship. But despite the fact that the composer liberates some aspects of the work from being under control, this does not just lead to unlimited freedom. Because of the determined details on the one hand, and a chance algorithm that is guided by constraints on the other, the work never allows the performer or the listener to completely step outside the area of the composer's intention. A notion closely related to the concept of an open work posited by Umberto Eco in the early 1960s [2].

2.2 Simultaneity of Different Tempos

'Playing together' in a common tempo is a fundamental principle of music making. This might be the reason why there exist rather few compositions that break this principle. Most novel compositional techniques that emerged in the early 20th century tried to overcome the rigid structure of musical metre, which had been dominating western music for many centuries. Only few composers attempted to negate not only the traditional concept of metre, but also the notion of a common tempo. Early examples of music organised in several layers to be played in different tempos can be found among the works of Charles Ives, e.g. in his *Symphony No. 4* composed in the 1920s (see Fig. 3).

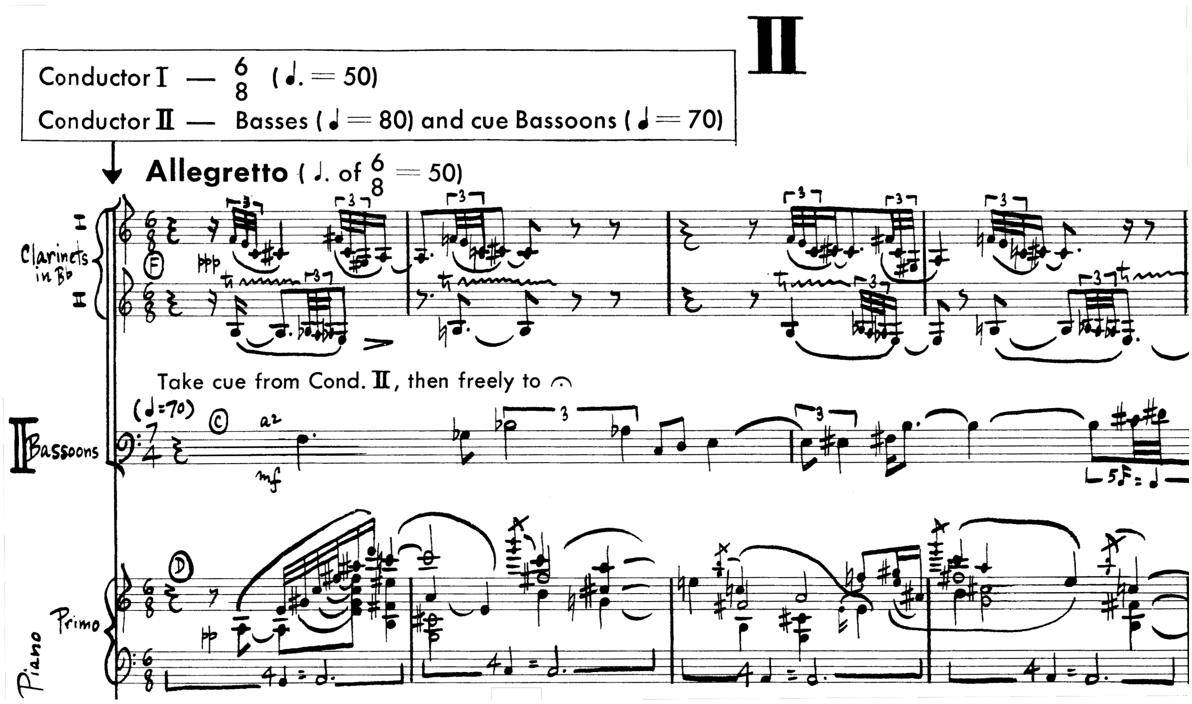

Figure 3: A detail of the first page of the 2nd movement of Charles Ives's 'Symphony No. 4'. The whole orchestra is split in two groups to play under two conductors in two different tempos.

Frustrated by several poor performances of his music, Conlon Nancarrow decided to avoid the human performer and started to compose for a mechanical instrument. Up to the present day, his *Studies for Player Piano* constitute the most substantial corpus of polytemporal music. In these *Studies* one can find not only different tempo-streams played concurrently, but also simultaneous tempo progressions [3]. Because of the use of an mechanical instrument, all these tempo proportions are executed with greatest accuracy, far beyond the precision a human performer could possibly achieve.

The case of Conlon Nancarrow suggests that the performance of polytemporal music could generally benefit from the use of technology. Especially, if the temporal coincidence of all musical events needs to be precisely kept under control. Charles Ives's work mentioned above – several other examples could be found – deals with the stratification of musical layers *as such* and explores the expressive quality of rhythmical independency. However, if a composer is interested in real polyphony, i.e. the precise superposition of the different layers of tempo, it becomes unavoidable to apply mathematical formulae to calculate the synchronisation of musical events and to use either a device that precisely executes these musical events – as Nancarrow did –, or a technological aid to help human musicians to play accurately in time.

3. Concept

It was attempted to realise a piece with a polyvalent form based on the combinatorial possibilities of the succession of fragments as well as on a variable tempo. The most important question was: how to create a musical texture that, rather than sounding like an arbitrary layering of detached instrumental parts, reveals its polyphonic coherence? There are parts played concurrently in different tempos, how to render the relations between these parts perceivable? There were two places to address these issues: in the preparation of the musical material and in the design of the 'open-form algorithm' itself.

3.1 Preparation of the Instrumental Parts

In the preparation of the musical material, two strategies were employed to reach the desired polyphonic coherence: a global control of harmony and the establishment of synchronisation points. To achieve harmonic control a twelve-tone-chord that spans the ambitus of all instruments was defined. This chord is mostly symmetrical: all pitches, apart from the lowest and the two highest, are mirrored around the axis *e*. The pitches for each instrument were individually generated by iterating through cycles of intervals. Whenever a pitch thus generated was found to be one octave apart from a pitch of the twelve-tone-chord or outside a given pitch range, it was adjusted to match the twelve-tone-chord as explained in Fig. 4. Hence, while maintaining the independency of the individual parts, the pitches of the common twelve-tone-chord appear statistically more often and therefore imbue the overall harmony.

Figure 4: The global twelve-tone-chord (left), two iterations of the interval cycle (middle) and the adjustments made according to the global chord and a given pitch range (right).

The second, and probably more important measure to achieve polyphonic coherence concerned the formation of synchronisation points. For this purpose, the fragments were divided into three segments of an almost but not strictly identical length. This division created four synchronisation points: the beginning and end of the fragment, as well as two points in the middle. These two intermediate points were treated as turning points and associated with a perceivable change in the musical texture: either a change in pitch range, from low to high (regarding the instrument's ambitus) or vice versa, or a change in density, from rapid rhythms, trills or tremolos to slow held notes or vice versa. Often, but not always, these turning points were further emphasised by a dynamic gesture: a crescendo followed by a sudden piano (see Fig. 5).

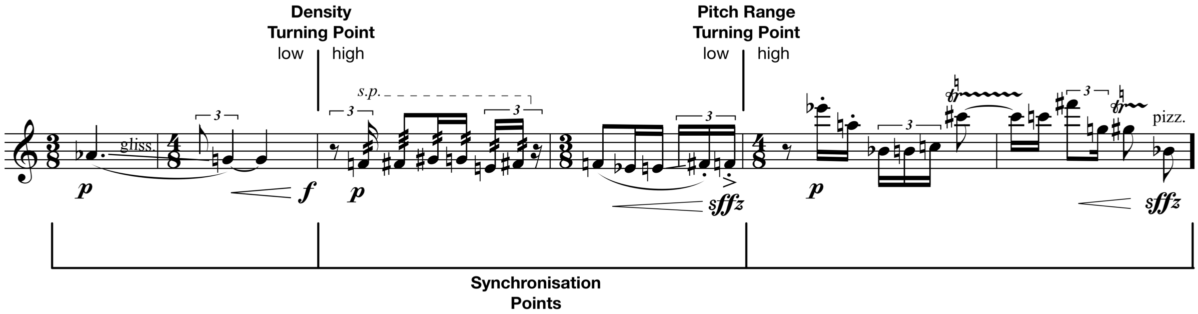

Figure 5: One of the fragments for the violin. It is divided in three segments of two bars length each. The edges between the segments are marked by well perceivable changes in the musical texture.

These synchronisation points provided a number of possibilities how fragments could be aligned with other fragments. Since these points are musically expressed as qualitative changes in pitch and rhythm (two primary musical parameters) they are well perceivable, no matter in what tempo the fragment is played. It was hypothesised, that the temporal coincidence of such synchronisation points between two different instruments immediately induces a relation, as the listeners perception instinctively relates these concurrent events to each other.

Both, the harmonic control and the contrast in the musical texture to create the turning points were formalised and programmed in the algorithmic composition environment *Opus Modus* [4]. The material thus generated was subsequently reworked and the dynamics, the articulations and several instrument specific techniques like glissando, double stop, flutter tongue etc. were informally added. Finally, a total number of eight fragments labelled *a–h* was prepared for each instrument and the music was given to the musicians in advance in order to allow for them to practise.

3.2. The Generative Arrangement of Fragments

This section describes the actual algorithm that carries out the 'open form' process. Every time this algorithm is executed – for instance just before the performance starts – a particular version of the piece is generated. The algorithm randomly chooses fragments and arranges them in time, whereby the fragments that are intended for different instruments are individually stretched or compressed to allow for a variety of different tempos.

The first task of the algorithm is to generate a random time grid that consists of sections of different lengths ranging from two to five seconds. In a second step, the algorithm places the three-segmented fragments onto the time grid. A fragment can span over three to nine sections of the time grid as long as the following conditions are met: the fragments duration remains between five and ten seconds, the change of duration between two adjacent segments of a fragment does not exceed two seconds, fragments for different instruments must not start at the same time, there must be a minimum pause of four seconds between two fragments in order to allow for the musician to prepare for the next fragment (see Fig. 6).

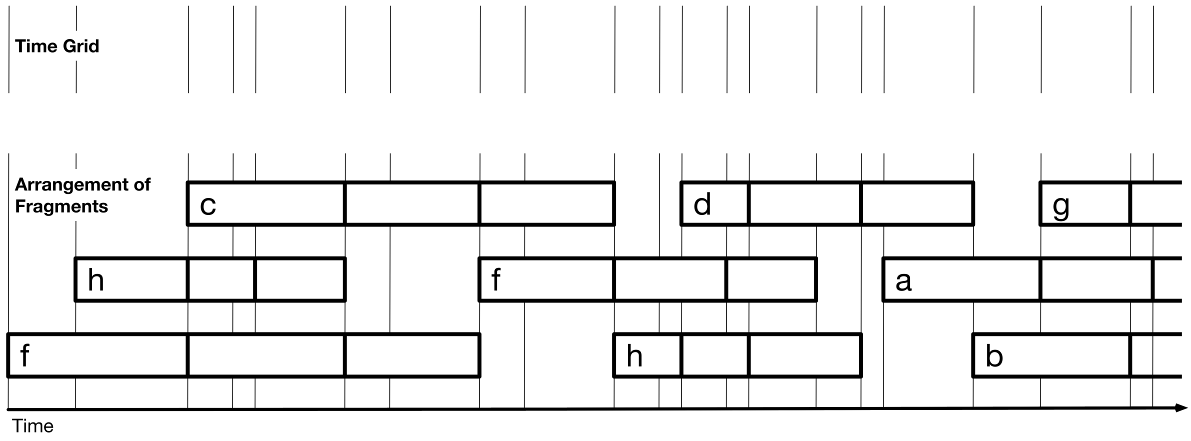

Figure 6: The random time grid that serves as temporal basis for the whole piece (top) and the fitting of fragments onto this time grid (bottom).

In a next step, the appropriate tempo for each fragment is calculated according to its duration. Very often, the three segments of the fragment happen to have different durations, consequently it becomes necessary to change the tempo within one fragment. The steps to calculate the appropriate tempo progression are as follows: first, the the basic tempo for each segment is defined, i.e. the static tempo that matches the fragment's length (measured in note values) to its duration. Subsequently, the average tempos between adjacent basic tempos are calculated and assigned to the two middle synchronisation points. Finally, the tempos to be assigned to the beginning and the end of the fragment are computed by extrapolation (see Fig. 7).

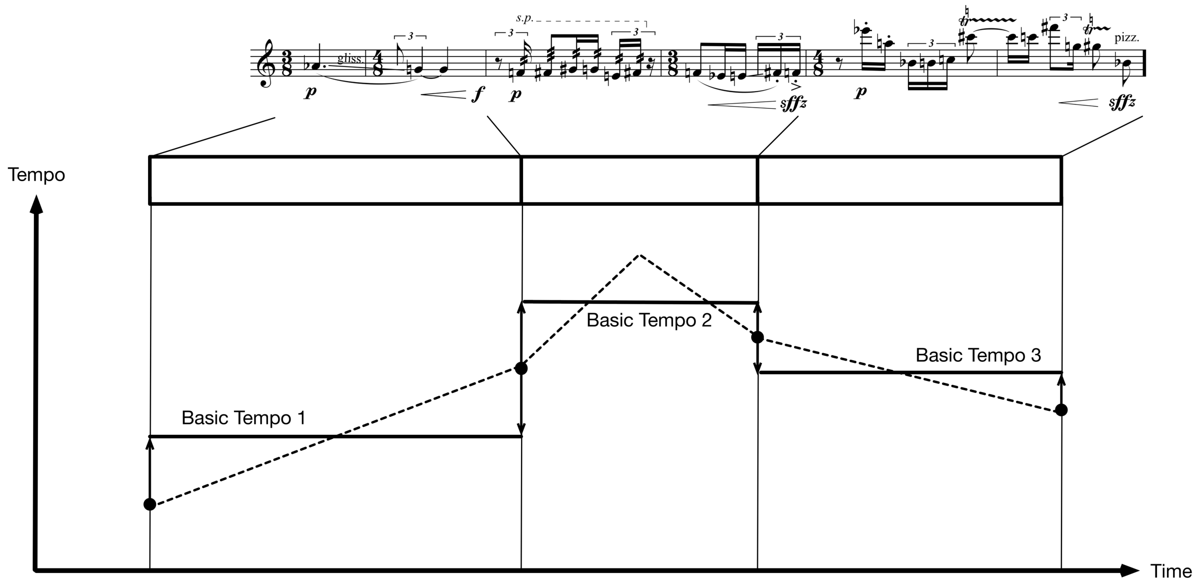

Figure 7: The durations of the three segments of a fragment are variable. Four tempo points are calculated by interpolating between the basic tempos of the segments. The dashed line denotes the expected tempo curve.

These four tempo points, which are now defined in time, position in the score and tempo, can equally well be depicted on a time map, where the time and the position are represented by the two axes whereas the tempo is expressed by the momentary slope (the derivative) of the curve. To calculate the exact tempo progression, a Bézier curve is drawn to connect these tempo points. Since a cubic Bézier curve allows for the specification of the slope at its both ends, it is a suitable formalism for this purpose [5]. The exact time of every beat, which it is needed to indicate the tempo to the musicians, can be read from the curve on the tempo map (see Fig. 8).

4. Realisation

The realisation of this music depended to a large extent on technological aids. On the one hand the algorithmically generated succession of musical fragments had to be presented to the musicians, on the other hand the musicians had to be kept synchronised in time. The technical solution used for that purpose was the software *Polytempo Network* [6, 7], which displays the music on screen as well as an animation that resembles the gestures of a conductor (see Fig. 9). Every musician was running an instance of this software on a laptop computer.

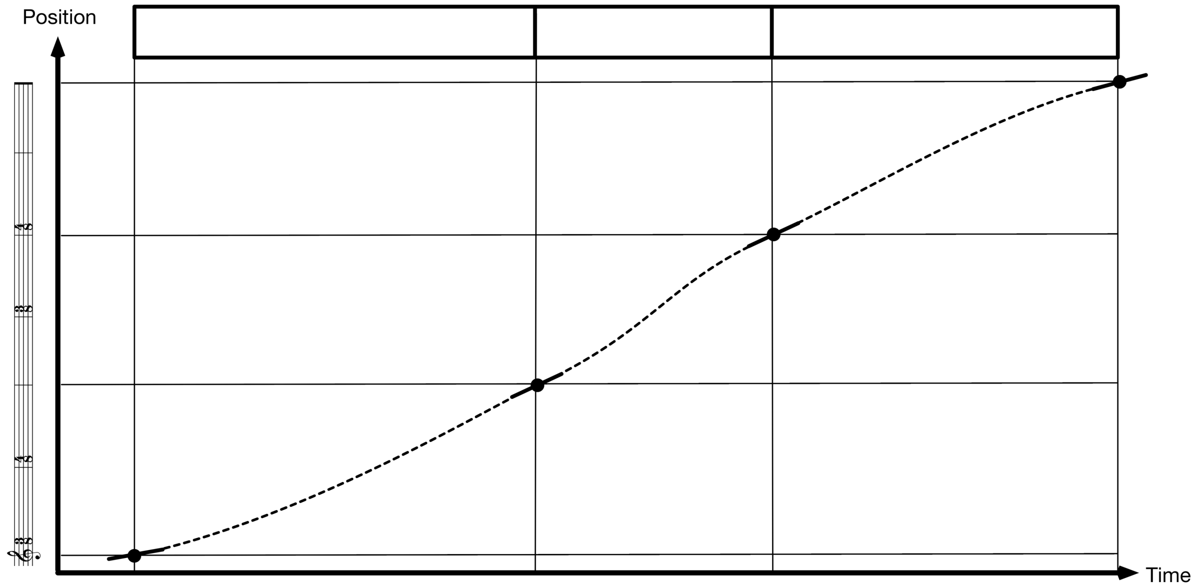

Figure 8: The four tempo points displayed on a time map and connected by cubic Bézier curves. The slope of the curve expresses the tempo.

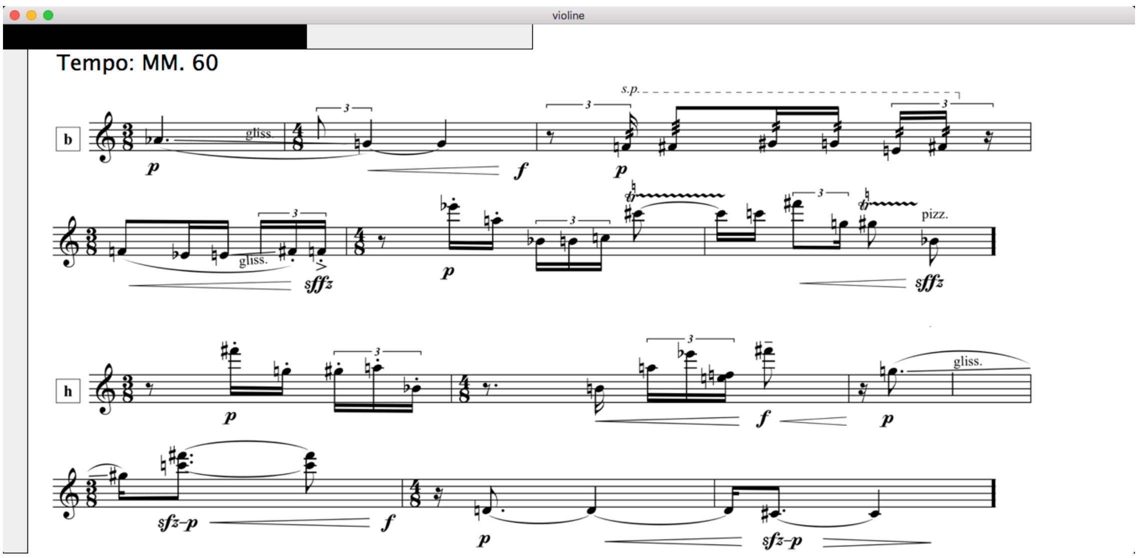

Figure 9: A screenshot of the software 'Polytempo Network', the current (b) and the next (h) fragment are displayed, the rectangles on top and on the left of the screen show an animation to indicate the tempo.

All computers were connected in a network and controlled from a master computer using the programming environment *SuperCollider* [8]. The master computer calculated the arrangement of fragments and the appropriate tempo progressions. Even though the software *Polytempo Network* possesses an own scheduler to display and conduct music autonomously, for our purpose, the built-in scheduler was omitted and all functions were controlled by the master computer in realtime over the network. The Software *Polytempo*

Network is able to receive commands as OSC messages and to perform these commands appropriately, e.g. by displaying a particular section of the score or by executing an animation to indicate a beat.

5. Conclusion

The random form and the varying tempo created a music that sounded liberated and rhythmically flowing. Often the polyphony of tempos even lead to the impression that the performers were improvising along with each other. Yet, the perceivable gestural coincidences that occurred whenever two synchronisation points were aligned added a clear structure. This combination of both qualities, freedom and structure, turned out to be musically very effective.

With a duration of only approximately two and a half minutes for a complete run-through, this piece allowed for several renditions in one session and for an immediate comparison of the different versions. As a consequence of the random durations of the fragments, the same musical material had to be played in different tempos and therefore revealed different gestural qualities. For a listener, the similarity of material and the distinct characteristics of their rendition was well perceivable, but only if the piece was played several times in a row. From a composers point of view it was interesting to prepare a material without having to restrict its gestural potential by determining a particular tempo.

For the performers, it was a challenge to spontaneously and constantly adapt to the indicated tempo in order to bring out the adequate gestural quality. A challenge that the performers found rather inspiring, as it appealed to their expertise as reproducers as well as interpreters or improvisors. Concerning the performance practice, it was important that the performers received a score in advance. Even when they did not know in which succession – and, in our case, in which tempo – they would have to play the fragments, they were able to prepare themselves and practise the music. This, in general, seems to be an crucial factor in ensuring the quality of the rendition, and it allows a composer to write a more detailed and virtuosic score.

Even though it was performed on acoustic instruments, this kind of music required the use of technology. In fact, technology formed an intrinsic part of this music for three reasons: first, the algorithm that generated the 'open form' was a computer program, which allowed for a rather complex constrained random procedure. Second, the score was presented to the performers on a screen, which made it possible to quickly change between fragments without the need to turn pages. And third, for the coordination of the performers, which was a prerequisite for the temporal alignment of synchronisation points, a technical aid to indicate the constantly changing tempo was absolutely necessary.

The piece of music described in this paper was only a short study. However, it seems to be worthwhile to refine the idea of an 'open tempo form' and to use it for works of a larger scale. This would enable to further explore the aesthetics of this particular kind of a technology-assisted composition and performance practice.

6. References

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