Goldsmiths
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PhD Upgrade

Music Composition for Networked Ensembles

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Abstract

This research project consists of two components: the software development of ZScore and a portfolio of compositions written for the ZScore system.

In its present form, ZScore is a collection of third-party and newly-developed components aiming to provide solutions for complex notation authoring, reliable score data distribution over a network to heterogeneous clients, precise performance scheduling and dynamic rendering of interactive stave-based scores. The system specifications for ZScore have been drawn from the analysis of existing networked notation systems and state of the art solutions from other industries where high-throughput, low-latency systems have been successfully implemented.

The current state of ZScore development was presented at Tenor 2018, an International Conference on Music Notation and Representation [23]. Both the presentation and the paper itself received positive feedback and drew significant interest within the music notation community. The presented paper "ZScore: A Distributed System for Integrated Mixed Music Composition and Performance" is attached to the upgrade materials. The paper explains the background and technical aspects of the system. Download links for the paper, portfolio scores and all other additional materials are available in Appendix B.

The attached upgrade portfolio includes two compositions (*Ukodus* and *Vexilla*) written for and performed over the ZScore system. The third upgrade portfolio composition *Red Mass*, written at the very start of my research project, was composed conventionally and performed from a paper score. However, all three pieces share the same compositional approach explained in the upgrade portfolio commentary chapter.

The underlying ambition behind this project is to blur and thereby call into question the traditional boundaries between the roles of a composer, performer, conductor and audience through the effective utilization of cutting-edge technology. The hope is that this might open new possibilities in music making and lead to authentic composition and performance practice.

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Description	Work Required	Completion Date
Notation layout improvements, mixed stave space optimisation, consistent display per information type, collection of feedback from as many different instrumentalists as possible	Composition	Ongoing Sep 2020
Interactive real-time composition flow control where each participant can trigger composition control events	Software development	Nov 2018
Nonlinear interactive composition flow piece	Composition	Jan 2019
Reliable UDP multicast implementation for OSC protocol	Software dev	Mar 2019
Implementation of cross-platform notation front end (Symbolist or browser)	Software dev	Jun 2019
Composition for cross-platform front ends (Symbolist or browser)	Composition	Sep 2019
Real-time conductor gesture capture and visualisation, Wekinator integration	Software dev	Dec 2019
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Integrated audience participation composition	Composition	Jun 2020
Large scale composition (15 – 20 parts), system scalability test, might need significant funding	Composition	Dec 2020
Thesis draft	Writing up	Jan 2021
Completion Status from Jan 2021	Writing up	Jun 2021
Final Submission	Submission	Jun 2021

Chapter 2

Portfolio Commentary

2.1 Upgrade Portfolio

The submitted upgrade portfolio consists of three compositions: *Vexilla*, *Ukodus* and *Red Mass*. The commentary for each of these compositions can be found in the separate chapters below.

The earliest piece *Red Mass* was written at the very beginning of the research process in 2015 before ZScore was available. Therefore, it was composed conventionally in Sibelius and performed from a paper score during the workshop with ensemble Interface in December 2015.

Vexilla and *Ukodus* were written specifically for the ZScore system. *Ukodus* effectively served as the proof of concept piece for ZScore when Moscow Contemporary Music Ensemble (MSMC) performed it during the workshop in March 2017. This score only contained acoustic instrument parts distributed in real-time over a computer network to musicians' screens. ZScore synchronized and displayed the current position and tempo to all musicians through animated cursors, thus alleviating the need for a conductor.

Vexilla additionally included scripting elements embedded directly into the score. These scripts were used in the video projector part to visualise flag elements to the audience. Scoring, distribution and synchronization of the video projector part in ZScore worked

in the same way as for the other acoustic instrument parts. The performance of *Vexilla* in Deptford Town Hall on 1 May 2018 tested the ZScore system under the open public concert conditions for the first time.

Although delivered in a technically different manner, all three upgrade portfolio pieces share the same compositional approach. The first step in the pre-compositional process is to define the conceptual framework and objective structures outlining temporal and material boundaries for each piece. The composition material is then generated through the subjective rational and emotional responses to the given conceptual framework and structure. Likewise, the sound vocabulary is derived from the concepts defined in the pre-composition process. Pitched or unpitched (noise) sound objects are grouped into temporal or vertical harmony groups which are then used in their raw or transformed forms depending on the context and rules defined for each piece.

ZScore opens possibilities for innovative extended playing techniques notation. The portfolio pieces demonstrate gradual changes in the notation style, such as the introduction of mixed clef staves, separation of the means of sound production (hands, breath, bow etc.) and the use of colour in scores.

2.1.1 *Vexilla*

For: Bass Clarinet, Violin, Violoncello and Video Projector

This piece was written for ZScore in early 2018 and was performed on 1 May 2018 at Deptford Town Hall by Heather Roche (Bass Clarinet), Valerie Welbanks (Cello) and Patrick Dawkins (Violin) thanks to Goldsmiths Graduate School and Music Department funding.

Vexilla were flag-like objects used as a military standard by units in the ancient Roman army. Later on, the meaning of the word extended to represent any object such as a relic or icon carried as a standard into battle. This piece explores the emotional and rational responses to various flags I have encountered throughout my lifetime, from fervent teenage patriotism to deep distrust of any ceremony which requires enthusiastic flag waving.

Structurally, the composition is split into three main sections: Yugoslavia (1945 – 1992), Europe (1992 – 2018) and Epilogue. Each main section is then further divided into smaller parts. Section 1 (Yugoslavia) is split into seven parts: six representing former SFR Yugoslavia republic's flag and one for the main SFR Yugoslavia state flag. Section 2 (Europe) is divided into three parts (EU, New Bosnia and UK flags) while the final Section 3 (Epilogue) contains only one part and references all flags used in the piece.

Section 1						
Yugoslavia, childhood, military, communist, nostalgia, friends, love, romantic						
Slovenia	Croatia	Srbija	Macedonia	Montenegro	Bosnia & Hzg	Yugoslavia
1	2	3	4	5	6	7
Section 2						
Europe, family, job, contemporary, capitalism						
EU	New Bosnia	UK				
8	9	10				
Section 3						
Epilogue						
Recap						
11						

FIGURE 2.1: *Vexilla* Structure

Each main section duration is less than a half of the previous section, symbolising the perceived acceleration of the passage of time with age. However, each part duration is the same (35.2 sec), reflecting equal importance (or unimportance) of flags in my life. The original plan was to write a 10 minute piece split into 17 parts of equal duration, therefore, each part duration was set to 35.2 secs. Due to time pressures, the overall number of parts was reduced to 11 but the individual part duration remained the same.

The tempo of Section 1 is set to 90 bpm, being the same as the Yugoslav national anthem used as the source for the compositional material in Part 7. The tempo of Sections 2 and 3 is set to 120 bpm, after the official EU *Anthem to Europe* which in turn is based on Beethoven's 9th Symphony fourth movement (*Ode to Joy*).

As a starting point, I wrote down immediate factual and emotional responses to each section and part description (as displayed in Figure 2.1). It was instantly apparent that responses to the first section were more about memories and nostalgia while the second section gravitated towards the realities of living, survival and the daily grind of life. I also used associative memory to note the first song or melody that came to my

mind when thinking about a particular flag. Extracts from these songs and melodies were used to construct compositional material for each part.

The common overarching thread across all composition parts is a personal reflection on the processes of othering, belonging and separation. The process of othering is frequently used in political discourse where 'others' are defined as different to 'us', representing a physical or economic threat to be feared. Almost invariably othering rhetoric involves mythology and symbology, including flags, serving to define 'us' as different to 'others'.

Another important process utilised in the compositional material generation is the decomposition of flags into graphical facets and their mapping to sound categories and gestures. For example, the SFR Yugoslavia tricolour flag was made up of red, blue and white stripes with the socialist red star in the middle (Appendix A). These flag features are mapped to sound categories as shown in Figure 2.2.

Flag visual feature	**Sound category**
Red colour	Warm, fully pitched sound
Blue colour	Cold, harmonic and multiphonic sounds
White colour	Air noise, percussive non-pitched sounds
Star	Pointillist glissandi gestures resembling the shape of a star

FIGURE 2.2: Flag feature mapping to sound

Also, the position of individual stripes on the flag is mapped to the instrument range in a vertical order; e.g. the bottom stripe is mapped to the lower instrument register and so on. Angled lines on flags are mapped to the pitch movement, so if a line is sloping downwards when looking left to right, the sound starts at a higher register and gradually slides down to a lower register.

Figure 2.4 illustrates the principles of the generation of compositional material in this piece. Part 1 represents the flag of Slovenia (Figure 2.1). Following the associative memory approach described above, the first song I could recall when thinking about Slovenia was the simple traditional folk melody *Na Planincah* (Figure 2.3), being one of the first melodies I learned to play as a child on the piano.

The time signature for Part 1 of *Vexilla* was therefore set to $\frac{3}{4}$, as in the selected folk song. From the length of the part (35.2 sec) and the preset tempo (90 bpm) it was

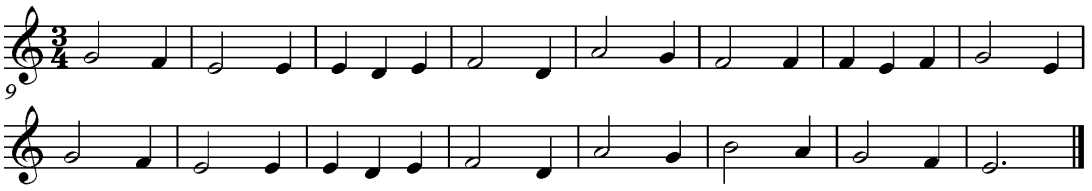

FIGURE 2.3: *Na Planincah*, traditional folk song from Slovenia

calculated that there should be 53 beats in the part. The bar structure of the part was then constructed from the calculated number of beats as:

$$(16 \times \tfrac{3}{4})\ \text{bars} + (1 \times \tfrac{5}{4})\ \text{bars} = 17\ \text{bars}$$

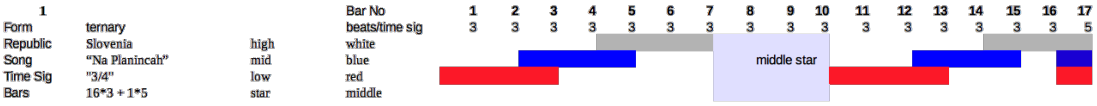

FIGURE 2.4: *Vexilla* Part 1 Structure

This bar structure was then presented in tabular form as shown in Figure 2.4. Visual features of the Slovenian flag (Appendix A) were mapped into the structural tables serving as a meta data for musical content generation.

The common feature appearing on all flags used in Section 1 is a red star. It was mapped to a recognisable musical gesture and repeated in all structural parts, albeit in slightly different form. In Part 1, the star gesture (Figure 2.6) is placed in the middle of the temporal structure (Figure 2.4).

On either side of the star gesture, the flag's coloured stripes are laid out in vertical order and mapped to a sound category as described in Figure 2.2. This creates a ternary form also used in other parts with a similar flag layout.

The *Na Planincah* melody inspired compositional material for all instruments. Excerpts from the Cello part shown in Figure 2.5 are the most recognisable.

Other parts were constructed in similar way to the process described above. The tabular structure representation of parts in Section 1 is shown in Figure 2.9 while Sections 2 and 3 parts structure is shown in Figure 2.10.

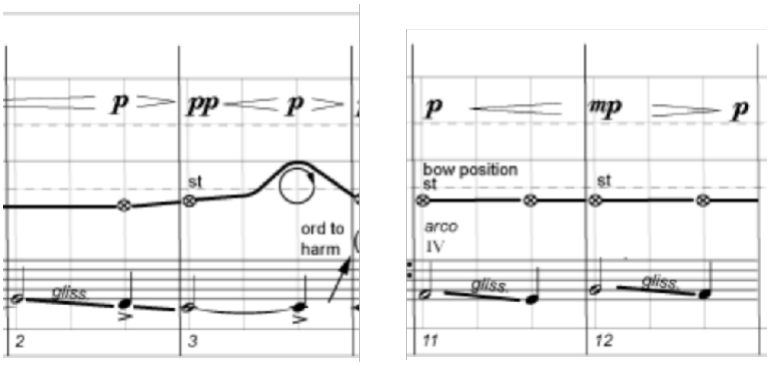

FIGURE 2.5: *Vexilla* Cello part excerpts using *Na Planincah* melody elements

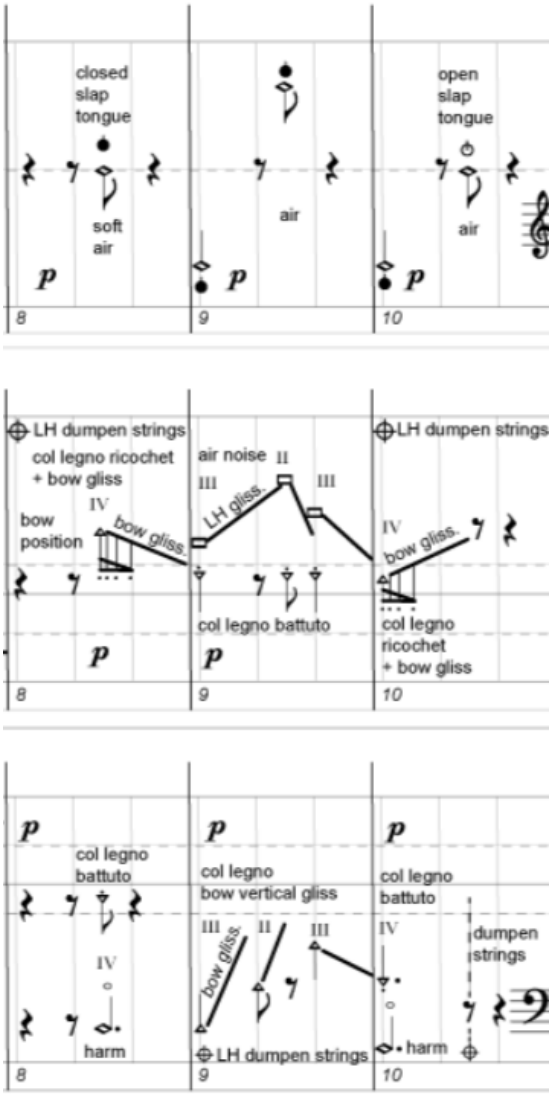

FIGURE 2.6: *Vexilla* Part 1 star gesture

The video part material was created from the deconstructed flag elements as a series of graphical files. In order to ensure the synchronisation of visual and audio output

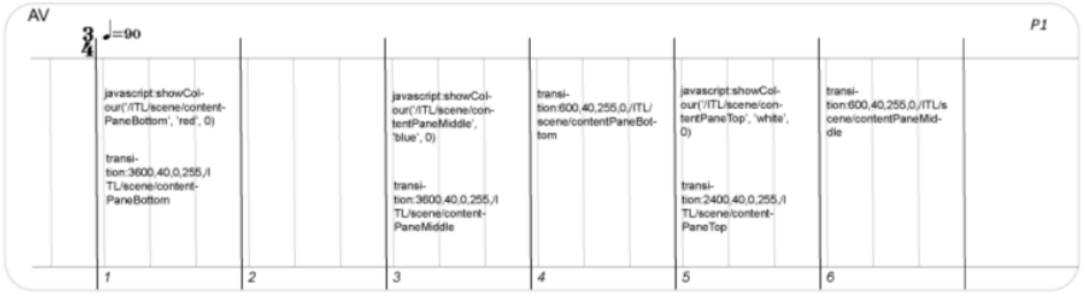

FIGURE 2.7: *Vexilla* score video elements scripting

during the performance, visualisation of the flag elements was performed through the scripts directly embedded into the score as shown in Figure 2.7. Video elements composition was based on the tabular structure (Figure 2.4).

The additional experimentation was done with the use of colour in a graphic score as shown in Figure 2.8. The idea here was to associate a colour with the specific playing technique in order to increase the player's score reading and comprehension speed compared to standard symbolic notation. In this instance, Bass Clarinet multiphonics are associated to the colour blue. Although the idea received a positive feedback, it was concluded that the colour should be used sparingly and might be better suited to dynamics visualisation.

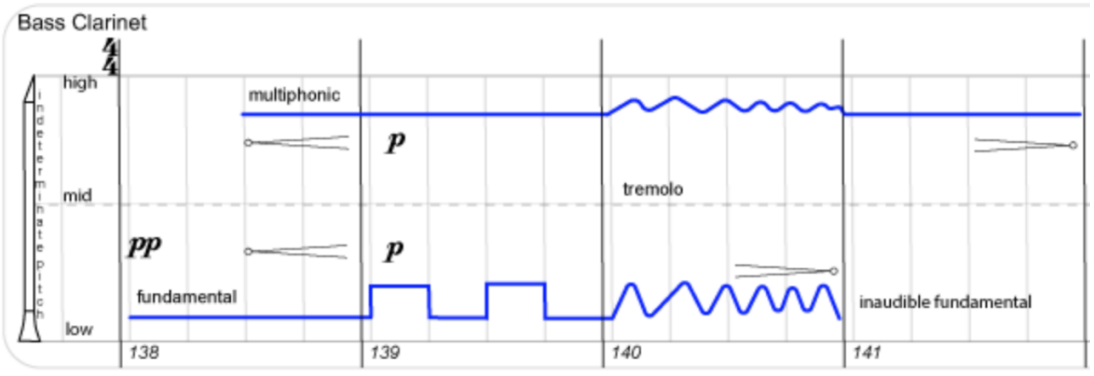

FIGURE 2.8: Use of colour in *Vexilla* score

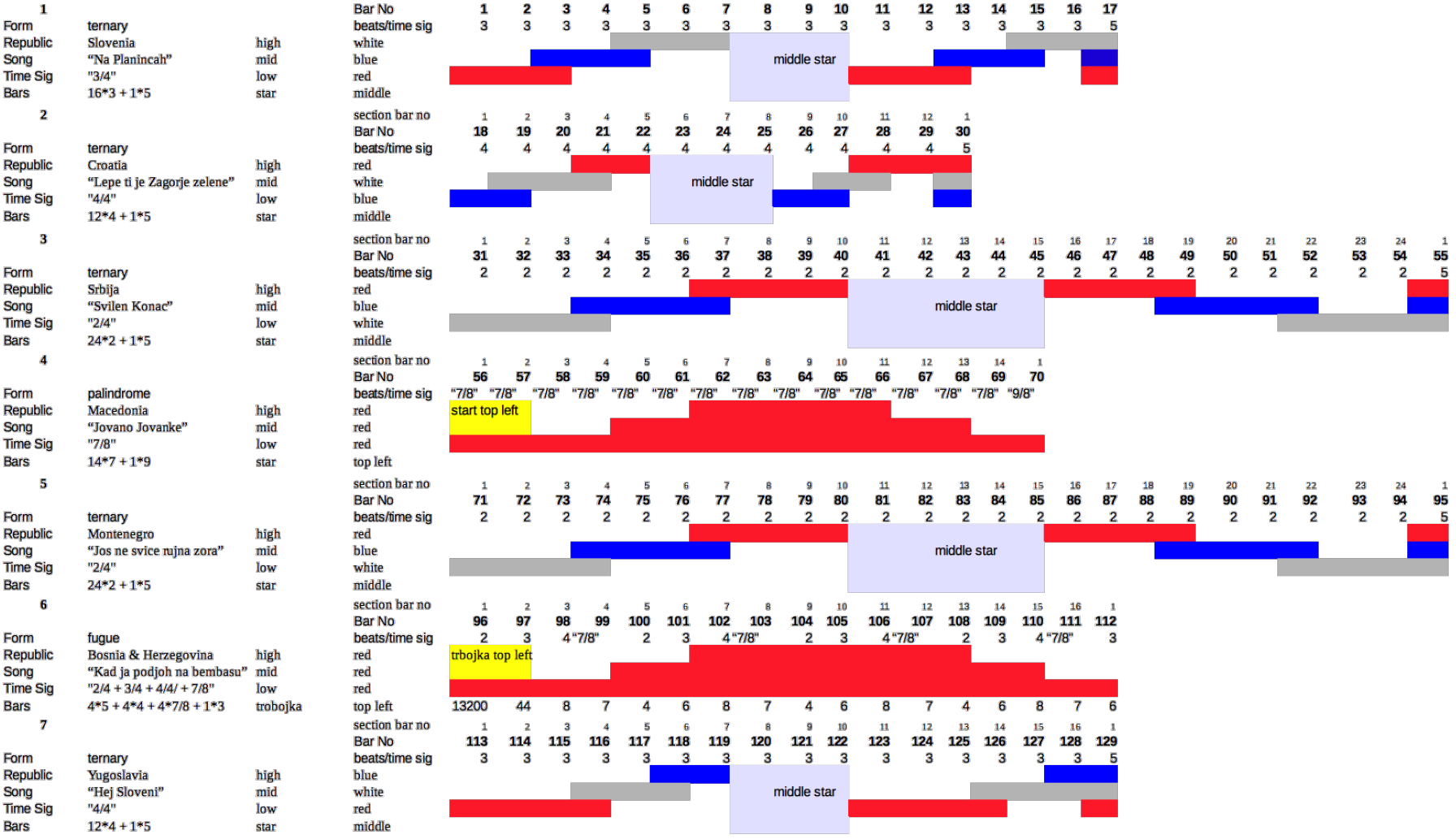

FIGURE 2.9: *Vexilla* Section 1 Parts structure

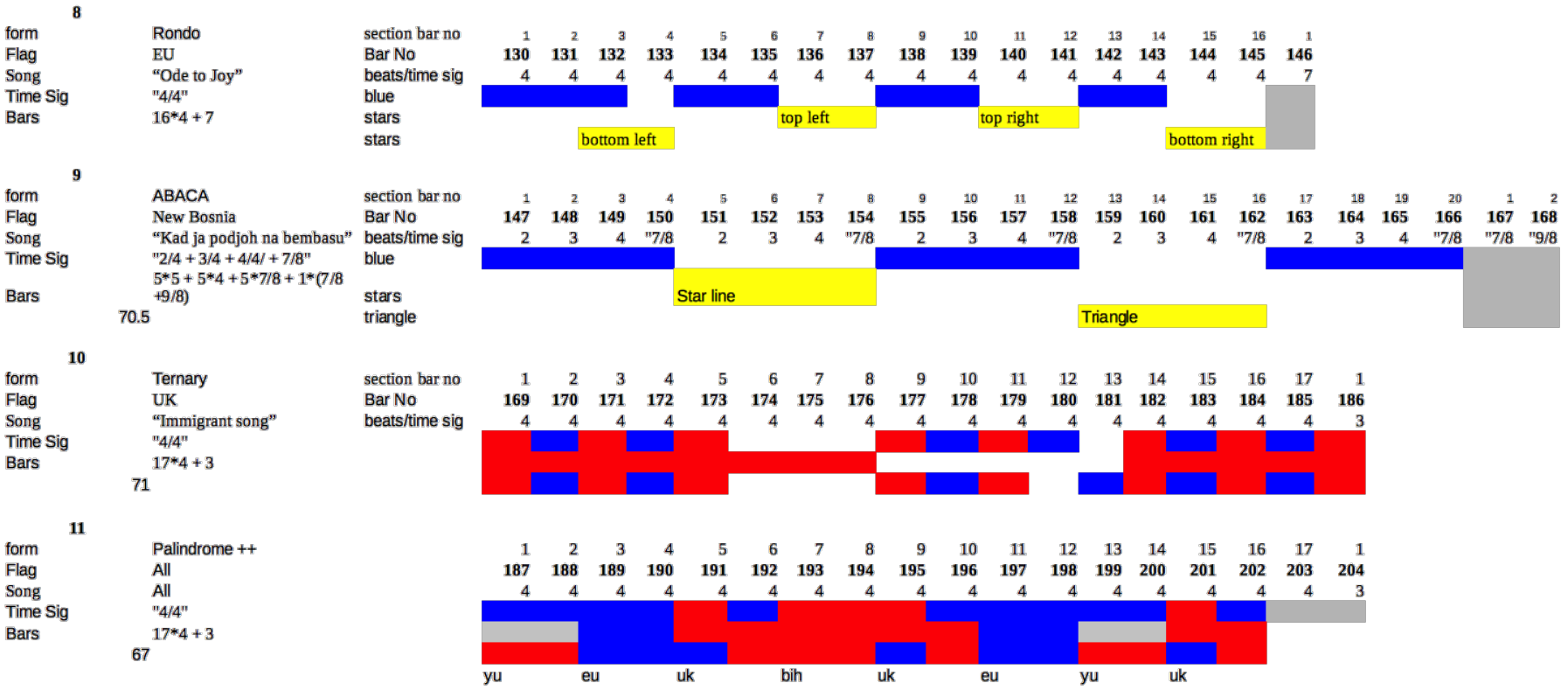

FIGURE 2.10: *Vexilla* Sections 2 and 3 parts structure

2.1.2 *Ukodus*

For: C Flute, Bb Clarinet, Cello and Piano

This piece was written in March 2017 for a workshop with Moscow Contemporary Music Ensemble (MCME). *Ukodus* was the first composition written for ZScore so the MCME workshop served as the system's proof of concept. The inspiration came from a particular Sudoku puzzle with visually and numerically interesting symmetrical structures including multiple lines of symmetry. The name of the piece is the word Sudoku reversed.

Sudoku is a logic-based, combinatorial number-placement puzzle. The objective is to fill a 9×9 grid with digits so that each column, each row, and each of the nine sub-grids contain all of the digits from 1 to 9. The puzzle used for the composition structure of *Ukodus* is visualised in Figure 2.11.

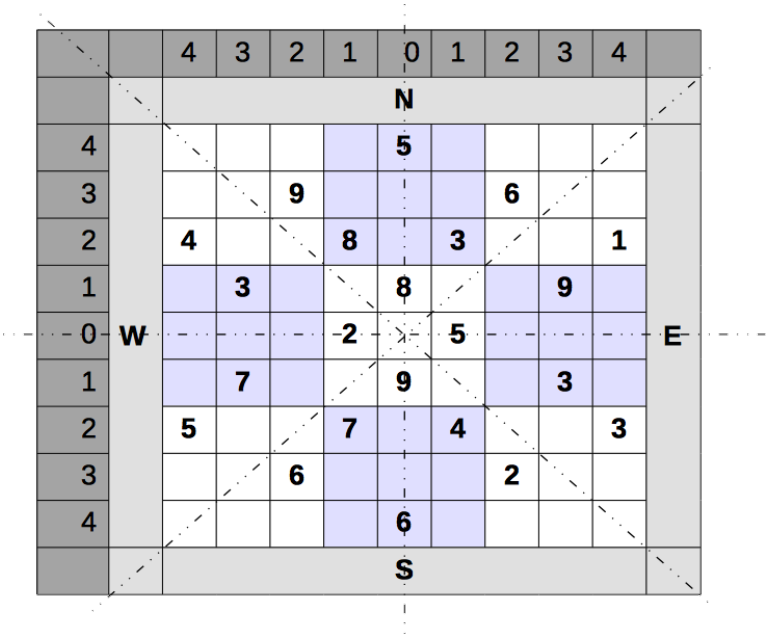

FIGURE 2.11: Sudoku puzzle used in *Ukodus* composition material

It can be noted from Figure 2.11 that the initial setup for this particular puzzle contains symmetrical positioning of numerical values in both the horizontal and vertical direction. I attempted to define relationships between visual and numerical elements of this puzzle as a basis for the compositional structure of this piece.

In order to quantify positions of the puzzle's initial numerical values, each row and column in the puzzle was given a sequence id ($0 \rightarrow 4$) visible in the top row and the first column in Figure 2.11. Sequence id 0 was assigned to the central row and column. The upper contour of the puzzle in the West $\rightarrow$ East (W $\rightarrow$ E) direction was then extracted as a graph (Figure 2.12). Vertical values in the graph indicate the distance from the central row.

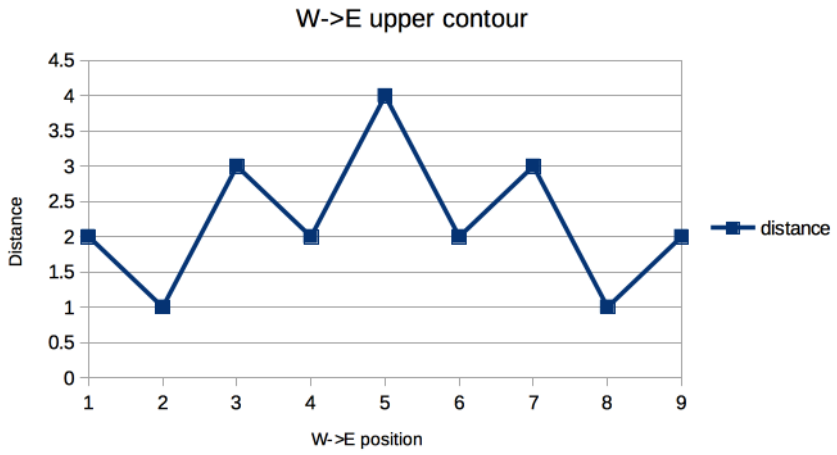

FIGURE 2.12: Sudoku puzzle W $\rightarrow$ E upper contour

Actual numerical values of the puzzle's upper area in the W $\rightarrow$ E direction were also plotted as a graph in Figure 2.13. As the upper area columns can contain up to two numerical values, separate curves were defined for the inner and outer numerical values.

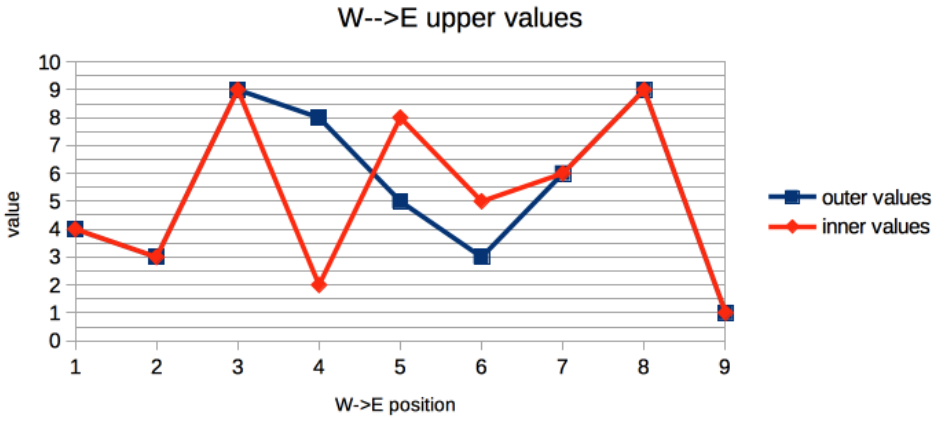

FIGURE 2.13: Sudoku puzzle W $\rightarrow$ E upper values

Due to the horizontal symmetry, the lower area of the puzzle in the W → E direction has the same outer contour as the upper area. However, the actual numerical values are different, as displayed in Figure 2.14.

FIGURE 2.14: Sudoku puzzle W → E lower values

Following the same approach, graphs for the vertical contour in the North → South (N → S) direction and the corresponding numerical value graphs were extracted and plotted.

The basic structure of the piece was derived from the obtained graphs and resulting data sets (Figure 2.15). The composition was split into nine sections reflecting sudoku's intrinsic divisions. The tempo and the length of each section was calculated from the upper contour values (Figure 2.12). The starting tempo value was set to 100 bpm while the vertical unit value was set to 20 bpm. As can be deducted from the graph (Figure 2.12), the vertical contour value in the W → E direction decreases by one unit from position 1 to position 2. Therefore, the section 2 tempo can be calculated as:

$$100_{\text{ starting tempo}} - 1_{\text{ direction}}[1_{\text{ number of steps}} * 20_{\text{ tempo unit value}}] = 80 \text{ bpm}$$

The tempo and number of beat units for each section were then calculated by using the formula above. Pitch range for each section was selected to reflect the same contour curve, starting with the mid-range for each instrument.

By following similar rules, each section was split into nine parts. The length of each part was calculated from the section length and the upper contour (W → E) value for

section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
tempo bpm	100	80	120	100	140	100	120	80	100
beats (8ths)	100	80	120	100	140	100	120	80	100
range	mid	low	high	mid	very high	mid	high	low	mid
material	air/noise	pitch/noise	pitch	air/pitch	harm/mphon	air/pitch	pitch	pitch/noise	air/noise

FIGURE 2.15: *Ukodus* basic structure

each step. Therefore, the part's length is relative to the contour value for the equivalent position; the higher the contour value, the longer the part, and vice versa. The structure of Section 1 is displayed in Figure 2.16. Here, each part is defined by its length in terms of a number of beat units (1/8), a division of beat units into bars and a number of musical events based on W $\rightarrow$ E upper values graph (Figure 2.13).

Distance sum	20								
part	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
distance/bars	2	1	3	2	4	2	3	1	2
Section 1	**register**	mid	**material**	air/noise	W->E upper val				
beats	10	5	15	10	20	10	15	5	10
divisions	5+5	5	5+5+5	5+5	5+5+5+5	5+5	5+5+5	5	5+5
no events inner	4	3	9	2	8	5	6	9	1
no events outer	4	3	9	8	5	3	6	9	1
bars no	1, 2	3	4, 5, 6	7, 8	9, 10, 11, 12	13, 14	15, 16, 17	18	19, 20

FIGURE 2.16: *Ukodus* Section 1 structure

Other sections were defined in a similar way. The structure of Sections 2 and 3 is displayed in Figure 2.17. All sections use different curves for event and material generation. For example, Section 2 uses the W$\rightarrow$ E lower value graph, while Section 3 uses the W $\rightarrow$ E upper values in retrograde. The number of events in this context represents a guideline for the density of musical material in each part.

Section 2	**register**	low	**material**	pitch/noise	W->E lower val				
beats	8	4	12	8	16	8	12	4	8
divisions	4+4	4	4+4+4	4+4	4+4+4+4	4+4	4+4+4	4	4+4
no events inner/pitch class	5	7	6	7	6	4	2	3	3
no events outer/pitch class	5	7	6	2	9	5	2	3	3
bars no	21, 22	23	24, 25, 26	27, 28	29, 30,31, 32	33, 34	35, 36, 37	38	39, 40
Section 3	**register**	high	**material**	pitch	W->E upper retrograde				
beats	12	6	18	12	24	12	18	6	12
divisions	3+3+3+3	3+3	6 * 3	4 * 3	8 * 3	4 * 3	6 * 3	3 + 3	4 * 3
no events inner/pitch class	1	9	6	5	8	2	9	3	4
no events outer/pitch class	1	9	6	3	5	8	9	3	4
bars no	41 - 44	45, 46	47 – 52	53 – 56	57 – 64	65 – 68	69 – 74	75,76	77 – 80

FIGURE 2.17: *Ukodus* Sections 2 and 3 structure

The instrumentation of: Flute, Clarinet, Cello and Piano was selected to reflect the symmetrical nature of the material and possibilities for flexible grouping and mirroring. For example, in Section 1 the instruments were split into two groups: Group 1 (Flute and Clarinet) and Group 2 (Cello and Piano). Group 1's event density was extracted from the outer curve while Group 2's event density was obtained from the inner curve.

The beginning of the piece (Section 1, Part 1) for Group 1 (Figure 2.18) illustrates how the extracted data is mapped to musical material. The number of events for Section 1 Part 1 can be looked up from Figure 2.16 and is the number 4 for both Group 1 and Group 2. The material for Section 1 (Figure 2.15) is set to “air/nose”. Therefore, four musical events were created for both instruments in Group 1 (Flute and Clarinet). Internally, instrument lines within the group were constructed as a mirrored response/call while the shape of both gestures resembles the W $\rightarrow$ E upper contour (Figure 2.12).

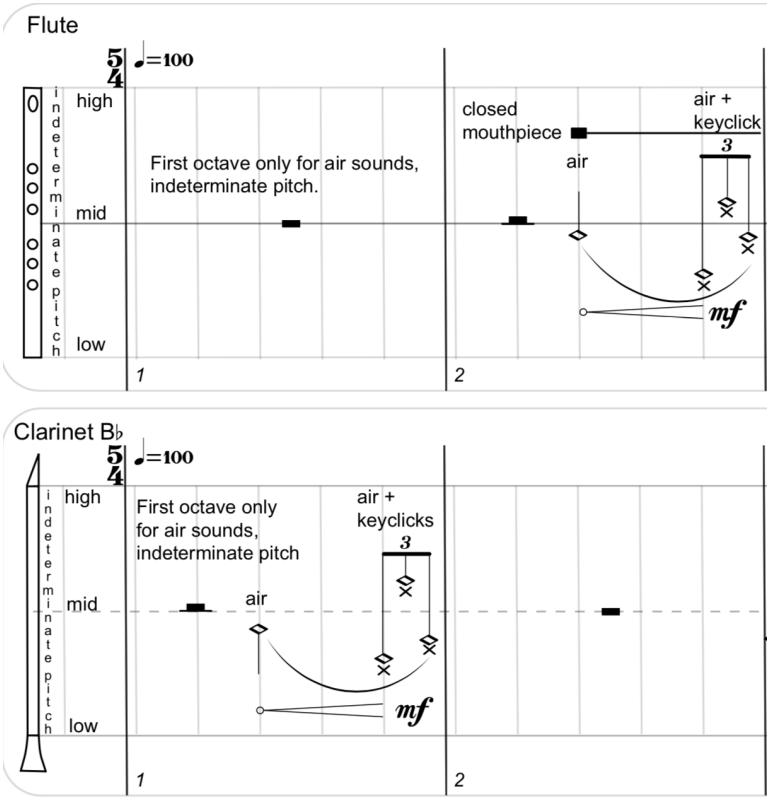

FIGURE 2.18: *Ukodus* Group 1 events in Section 1 Part 1

Likewise, four “air/noise” Group 2 events have been created for each instrument (Cello and Piano) in Section 1 Part 1 as a response/call with a gesture shape reflection internally but also as a symmetrical response to Group 1 (Figure 2.19)).

The rest of the material was created in a similar way to the described procedure. Due to the amount of work required on technical aspects of ZScore software development and Adobe illustrator score authoring, only the first 64 bars of the piece were completed in time for MCME workshop.

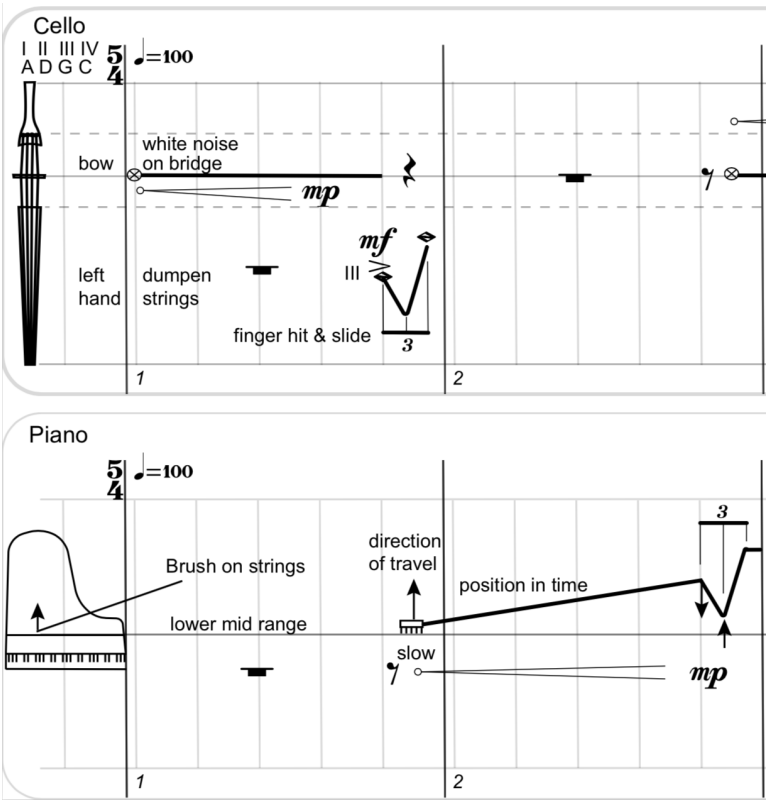

FIGURE 2.19: *Ukodus* Group 1 events in Section 1 Part 1

2.1.3 *Red Mass*

For: Flute (C Flute, Bass Flute and Piccolo), Clarinet (Bb and Bass Clarinet), Percussion (Marimba and Tibetan Bowl), Piano and Violin

Red Mass was written for the workshop with Ensemble Interface in December 2015. It was written with the help of the Sibelius notation software and performed from a paper score in a conventional manner. The inspiration for this composition came from the fact that Interface is a 'Pierrot plus' ensemble (standard quintet + percussion), therefore it prompted me to revisit Schoenberg's seminal work *Pierrot Lunaire* [18]. Schoenberg's composition is a setting of 21 poems from Otto Erich Hartleben's German translation of Albert Giraud's cycle written in French. Therefore, the piece inherited a process of material mapping (language translation) from its inception. The cycle structure split into three groups of seven poems is shown in Figure 2.20.

As can be observed is Figure 20, the poem in the centre of the cycle (poem 4 in Section Two) is *Rote Messe* (English translation: Red Mass). In the original context of the

No/	**Part One**	**Part Two**	**Part Three**
1	*Mondestrunken* (Moondrunk)	*Nacht (Passacaglia)* (Night)	*Heimweh* (Homesickness)
2	*Columbine*	*Gebet an Pierrot* (Prayer to Pierrot)	*Gemeinheit!* (Vulgarity)
3	*Der Dandy* (The Dandy)	*Raub* (Theft)	*Parodie* (Parody)
4	*Eine blasse Wäscherin* (An Ethereal Washerwoman)	*Rote Messe* (Red Mass)	*Der Mondfleck* (The Moonspot)
5	*Valse de Chopin* (Chopin Waltz)	*Galgenlied* (Gallows Song)	*Serenade*
6	*Madonna*	*Enthauptung* (Beheading)	*Heimfahrt (Barcarole)* (Homeward Bound)
7	*Der kranke Mond* (The Sick Moon)	*Die Kreuze* (The Crosses)	*O Alter Duft* (O Ancient Fragrance)

FIGURE 2.20: *Pierrot Lunaire* poems (3 x 7)

poem, the word 'Mass' refers to a religious service ("At gruesome grim communion... Comes to the altar – Pierrot!"). The English word 'mass' is a homonym and can be used to describe a large number of people crowded together. The first response that came to my mind upon hearing the phrase 'Red Mass' was a childhood memory of large communist rallies with workers red flags and youth's red scarves.

I followed the principle of taking the formal (objective) structural elements from the original poem as the basis of the piece, while transforming the material through the compositional process to reflect my personal (subjective) reaction to the original material.

Each *Pierrot Lunaire* poem consists of thirteen lines (two four-line verses followed by a five-line verse). The first line of each poem occurs three times (being repeated as lines eight and thirteen). This poem structure (rondel), visualised in Figure 2.21, is used as the basis for my piece *Red Mass*.

FIGURE 2.21: *Pierrot Lunaire* rondel poem structure

From the poem analysis and the fact that Schoenberg used numerology before the invention of the twelve-note serialism, recurring numbers 3, 7 and 13 were noted as structurally significant. As the first step in the pre-compositional structure definition, the duration of the piece was set to 7 minutes (420 seconds). The overall duration was then divided into 13 sections, each lasting approximately 32.3 seconds. As the poem's

rondel structure is effectively a ternary form, three distinctive composition parts were defined: 'Motion', 'Stillness' and 'Return' as displayed in Figure 2.22.

	"Red Mass" ~ 7 min (420 sec)												
Part	Motion (~ 2:10 min)				Stillness (~ 2:10 min)				Return (~ 2:40 min)				
Section Id	1A	1B	1b	1a	2a	2b	2B	2A	3a	3b	3b2	3a2	3A
Tempo bpm	80	90	110	140	70	70	70	70	140	110	110	140	80

FIGURE 2.22: *Red Mass* Structure

The tempo curve was defined so that in part one ('Motion') the tempo increases in each consecutive section (80, 90, 110, 140 bpm), in part two ('Stillness') the tempo is constant at the lowest value (70 bpm) and in part three ('Return') each section is at the same tempo as the corresponding section from part one. Following the rondel cycle definition, it was decided to use only two basic compositional material types ('A' and 'B'). Materials denoted as lower case 'a' and 'b' were to be derived from the corresponding main material. In subsequent sections where the type letters were repeated the material was transformed and given the version number (eg A1, A2 and A3). Each section was then broken down into individual bars as shown in Figure 2.23. The basic time signature for material A was set to $\frac{7}{8}$ and for material B to $\frac{13}{8}$ (subdivided into $\frac{8}{8}$ + $\frac{5}{8}$).

Section (32.3 sec)	bpm	beats	1/8s	bars	start bar No	end bar No
1A	80	43.0	86	11* 7/8 + 9/8	1	12
1B	90	48.5	97	7 * 8/8 + 7 * 5/8 + 6/8	13	27
1b	110	59.0	118	8 * 8/8 + 8 * 5/8 + 2 * 7/8	28	45
1a	140	75.5	151	21 * 7/8+4/8	46	67
2a	70	37.5	75	10 * 7/8 + 5/8	68	78
2b	70	37.5	75	5 * 8/8+5 * 5/8+7/8 + 4/8	79	90
2B	70	37.5	75	5 * 8/8+5 * 5/8+7/8 + 4/8	91	102
2A	70	37.5	75	10 * 7/8 + 5/8	103	113
3a	140	75.5	151	21 * 7/8+4/8	114	135
3b	110	59.0	118	8 * 8/8 + 8 * 5/8 + 2 * 7/8	136	153
3b2	110	59.0	118	8 * 8/8 + 8 * 5/8 + 2 * 7/8	154	171
3a2	140	75.5	151	21 * 7/8+4/8	172	193
3A	80	43.0	86	11 * 7/8 + 9/8	194	205

FIGURE 2.23: *Red Mass* section info

The material 'A' pitch set (Figure 2.24) was derived from the notes played in the opening beat of Schoenberg's *Rote Messe* by all instruments. The normal form pitch set was constructed according to the pitch set theory [6].

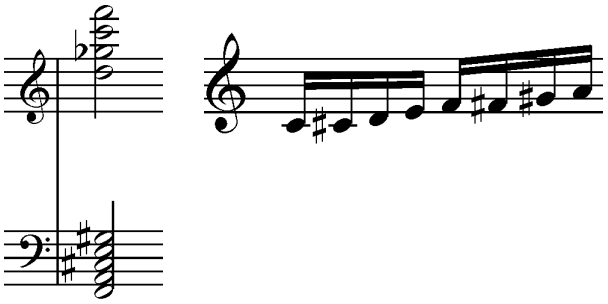

FIGURE 2.24: Pitches used in the first beat of *Red Mass* as a chord and the normal form pitch set

In contrast to the descending opening piano figure in *Rote Messe*, the ascending sequence played by Piccolo and Clarinet was constructed from the defined pitch set and used as the opening in *Red Mass* (Figure 2.25).

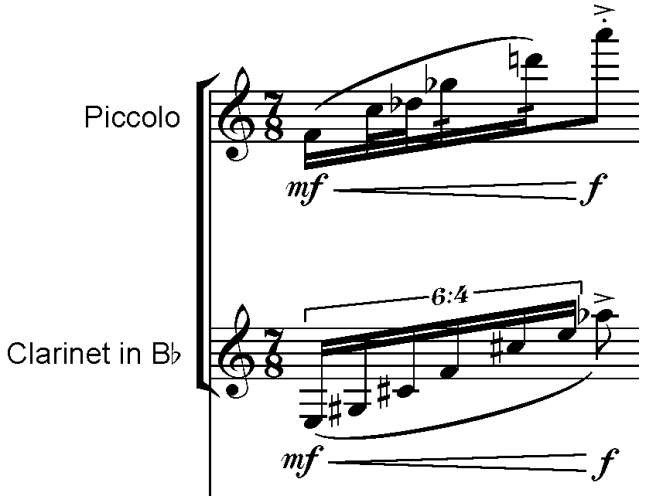

FIGURE 2.25: Opening ascending sequence in *Red Mass*

In the opening sequence all vertical pitches sounding at the same time are either 1 or 2 semitones away from each other in the normalised pitch set form. The idea to use close intervals (minor and major second and their inverted forms) was inspired by the chromatic parallel fifths movement of the Cello part in *Rote Messe* as shown in Figure 2.26.

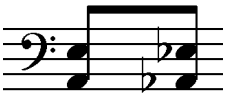

FIGURE 2.26: Cello part opening parallel fifths in *Rote Messe*

The material 'A' piano chord (Figure 2.27) was also derived from the Cello opening dyads (Figure 2.26). Instead of using descending parallel fifths, it was decided to subvert Schoenberg's classical counterpoint subversion and move the base pitch semitone up as shown in Figure 2.27. The resulting chord was split into two augmented fourths intervals and two semitone intervals which were used extensively throughout the score (Figure 2.27).

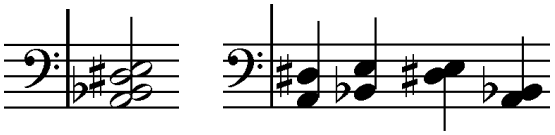

FIGURE 2.27: *Red Mass* material 'A' piano chord and derived intervals

The rest of material 'A' was derived either from the defined pitch set (Figure 2.24) or the piano chord (Figure 2.27). Most of the vertical pitch relationships use either semitone or augmented fourth intervals in the normal form pitch set.

The intention for material 'B' was to create a contrasting musical character to material 'A' by using unstable pitched and unpitched sounds such as multiphonics, air notes, staccato, pizzicato and tremolo. A different pitch set was defined for 'B' material (Figure 2.28) also extracted from *Rote Messe*.

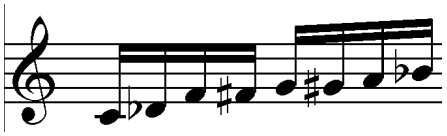

FIGURE 2.28: *Red Mass* material 'B' normal form pitch set

Other important influences in the *Red Mass* compositional process include the Sprechgesang singing technique from *Pierrot Lunaire* [18] and Ganga [20] traditional singing from rural Bosnia and Herzegovina. Video [21] illustrates ganga singing style. Both singing techniques use inflections of either continually rising or falling pitch. In Ganga singing vocal groups of up to five singers follow the lead vocalist by pitching their entry a semitone above or below the lead vocalist. Singers then gradually move between the

semitone and unison with microtonal inflections and individual timings. The glissandi technique is used extensively in *Red Mass* to reflect the Sprechgesang and Ganga microtonal inflections.

2.2 Conclusions and Future Work

ZScore worked well during initial trials and in a live concert situation with no technical issues. Feedback from musicians on its functionality and reliability were both positive and encouraging. The Tenor 2018 presentation was highly rated and several requests have been received from various composers and performers to use ZScore in their work as a result of hearing the presentation.

The mixed notation stave layout did however receive some negative comments during the trials. Further research will explore different ways to achieve better stave space utilisation and notation clarity, including vertical layering by notation type, graphic clef simplifications and hand position animation. This could result in innovations in both conventional and extended playing techniques notation. As an ongoing effort, feedback on ZScore's usability and notation layout will be collected from as many musicians as possible. In order to get useful feedback, short pieces for individual solo instruments may need to be written to aid the process. The musicians' feedback will be analysed and used to improve ZScore's design, functionality and performance when possible.

The conceptual framework and objective forms have brought discipline and clear boundaries to the composition process. However, the musical ideas have not always come across as expected, especially when using mixed unpitched and pitched sound objects and various extended techniques resulting in unsatisfactory tension and release sequences. Further experimentation is required to bring forward the clarity of musical ideas and composition tension curves.

The plan for the additional pieces required to complete the final PhD portfolio is based on the technical features each piece will try to exploit. Currently, implementation of the following additional features are planned:

1. Nonlinear interactive composition flow where each participant (composer, conductor, musician) can send control events to modify composition flow in real-time
2. Composition for cross-platform front-ends (Symbolist or browser), allowing for significantly simpler system setup and wider user front-end choice
3. Composition with real-time conducting integration, including conductor gesture capturing, mapping, distribution and visualisation on musician's screens, Wekinator integration etc.
4. Integrated audience participation where audience members can send/receive compositional control events and generate audio via personal mobile devices
5. Large scale composition (15 – 20 parts), system scalability test which may require a significant funding if performed live

Each feature would require both software development and music composition effort as estimated in the timetable above. An effort will be made to use different instrumentation in each piece, including combinations of digital and acoustic sound sources. Gradual refinement of the compositional voice is expected with every new piece while the consistent approach to composition will be retained.

If a superior networked notation system was to appear in the music notation community in the future it would be evaluated and, if possible, incorporated into this research.

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Appendix A

Flags Used in *Vexilla*

SFR Yugoslavia	
SR Slovenia	
SR Croatia	
SR Serbia	
SR Bosnia & Herzegovina	

SR Montenegro	
SR Macedonia	
EU	
New Bosnia & Herzegovina	

Appendix B

Additional Materials

B.1 ZScore

Composition for Networked Ensembles [https://youtu.be/ioqNP4qg6JQ] video [22]. Explains ZScore system components and workflows.

ZScore: A Distributed System for Integrated Mixed Music Composition and Performance [http://bit.ly/2NAVPMB] TENOR 2018 Conference Paper [23]. Explains background and technical aspects of the ZScore system.

ZScore Software Distribution [http://bit.ly/2MZNVHB] zip file. Contains runnable ZScore version used for *Vexilla* performance. Included ZScoreUserGuide.pdf file explains software requirements and details on how to run the software.

ZScore Source Code [http://bit.ly/2QVSHZO] zip file. Contains Java source code for the ZScore Server and Administration Client. Included README.txt file explains requirements and the code set up.

B.2 Portfolio Scores

Portfolio Scores [http://bit.ly/2Ic3b3g] zip file. Contains all upgrade portfolio scores and related data. Pdf format scores are included for all compositions. However, only *Red Mass* is meant to be performed from the included pdf score versions. ZScore files

required for *Vexilla* and *Ukodus* performance, as well as the pre-composition structural plans and Adobe Illustrator sources are also included in the zip file.

B.3 Portfolio Recordings

Vexilla [https://youtu.be/6pfCLlNxUzU] video recording of the concert on 1 May 2018, performed by Heather Roche (Bass Clarinet), Valerie Welbanks (Cello) and Patrick Dawkins (Violin)

Ukodus [https://youtu.be/ioqNP4qg6JQ?t=444] excerpts from the workshop with Moscow Contemporary Music Ensemble in March 2017.

RedMass [https://youtu.be/zoLrUNkQInw] video recording of the workshop with Ensemble Interface in December 2018, conducted by Hans Kretz. The recording is incomplete as the video tape ran out after approximately 7 minutes.