

# MUSIC DERIVED FROM OTHER SOURCES

 **CLARENCE BARLOW**

University of California Santa Barbara  
barlow@music.ucsb.edu

## ABSTRACT

One imagines composed music as originating in the mind of an author. Indeed, I have for the last six decades been composing music in this fashion. However, for the last five decades I have also been repeatedly attracted to various methods of deriving music from sources both inside and outside of music, viz. linguistic, acoustic, visual and mathematical as well as other works of music. For most of these operations I have resorted to strict algorithmic means and the use of computer programming. In this paper I will outline the sources mentioned above. For instance the linguistic: I have used text orthography, spectral analyses of human speech, digital recordings of the human voice, and synthetic semantic structures. In the case of the visual, it was the conversion of pixellated photographs, abstract films and geometric models as well as the visualisation of algorithmically generated music that played a central role in the compositional plan. This paper is the most comprehensive text on my work in this field.

Keywords: Linguistics; Recordings; Sonification; Music composition; Harmony; Metre.

## 1. LINGUISTIC SOURCES

The four main sources I will describe in this section are *orthography*, *phonetic composition*, *speech recordings* and *semantic composition*.

### 1.1 ORTHOGRAPHY

In this field, it was the spelling of a text chosen at will that provided the compositional material. My prime example of this usage is the composition *Textmusic* (1971). In its most basic form, this work is a list of instructions to a composer (who could be someone other than myself) to allocate the letters of a text, each of them once only, to a piano keyboard, starting in the middle and moving outwards in a zigzag way. This procedure is to be executed three times, once on the black keys, once on the white, and once disregarding the key colour. Thereafter the text can be ‘played’, to wit, in single letters, or in whole syllables at a time as chords, or similarly as words, phrases and sentences. One can freely move from one syntactic text level as just described to another or from one key-colour system to another between any two successive words. Further aspects such as loudness, length and right pedal depression are also left to the composer’s discretion, to be effected, when desired, between any two successive syllables.

As an example of this method I first cite *Textmusic #6* (1973), based on the text Ping by Samuel Beckett, the opening line of which is “All known all white bare white body fixed one yard legs joined like sewn”. Accordingly the 19 letters ALKNOWHITEBRDYFXGSJ contained in this sentence are allocated in turn to as many black (pentatonic), white (diatonic) and mixed-colour keys (chromatic). Further letters like QUV... are allocated as they appear later in the text. Fig.1 shows the allocation of the first 19 letters in chromatic mode at top left and right as well as the opening notes up to “joined”.

Figure 1: *Textmusic #6* – Letter allocation and beginning of piece

This letter allocation technique can be extended to other than the Latin alphabet, as e.g. Devanagiri, used in Sanskrit, Hindi and other North Indian languages. *Textmusic #10* (1974) stems from various Kathak-bols, spoken rhythms accompanying a major form of North Indian classical dance, Kathak. Fig.2 displays bars 21-27, comprising a bol given to me personally by the renowned dancer Birju Maharaj (b. 1938), based on the numbers one to seven in Hindi and shown in sargam notation, the Indian equivalent of solfège. The Devanagiri letters were allocated to the piano

on the three key-colour levels – pentatonic (black keys), diatonic (white keys) and chromatic (mixed), including the letter for the short sound [a] (the first vowel of the Devanagiri alphabet), also used in words ending silently and invisibly but implicitly with that letter, viz. ék(a), tín(a), chár(a), páñch(a), chhah(a) and sát(a). Also included among the letters is a hyphen [-] showing prolongation in time. The bars are pentatonic, diatonic, chromatic and diatonic in turn. The letter [a] just mentioned is played as a Bb3 in the pentatonic, a C4 in the diatonic and a D4 in the chromatic bars. The rhythms (including prolongations) correspond exactly to those in the bol.

Figure 2: Textmusic #10 (excerpt bars 21-27).

See also references (Barlow, 1998a, 2008, 2009b, 2012).

## 1.2. PHONETIC COMPOSITION

While not strictly representative of composition in the usual musical sense, I cite three text examples of my work in this field. The first and last were put together as texts embedded in a larger context and the one in the middle as a stand-alone phonetic exercise.

### 1.2.1. Haiku (1968)

This work for baritone and clarinet follows the Japanese Haiku formula of 5+7+5 in its overall form – 5 short pieces for baritone solo, 7 for clarinet solo, then again 5 for baritone solo. Each piece contains 5+7+5 notes of which the 5+7 form a twelve-tone row and the 7+5 the retrograde inversion of this row. The pieces for baritone are sung to ten meaningless palindromes written in the International Phonetic Alphabet consisting of 5+7+5 serial syllables based on English and German phonemes. They are listed here below:

o fyarakule – mæzeniθə θinezəm – eluka ryfo  
 zəhenzɪfə – kəmule sose lumək – aʃɪɾz nəhəz  
 piθɒʃɪləsə – kytof enune foɾyk – asəɪz ʃɒθɪp  
 likaθunəpɾy – ʃɒterəsə seretɒʃ – ɾpɾ nuθakil  
 firozə hēmə – ketz vunuɾnuvətək – ø mēhəzɒrif

ðeʒəmirozə – dubslov ɛ volsbud – azori mæzçð  
 ʃuke zənəli – roha tɔvɪvɪt əhor – ilenəz ekuf  
 roba digezu – lyɒɒzɛnɪz nəzɒlyɪ – uzegɪ dabor  
 tonali kɔme – ɛsəzə ʃɒʃugəzə – eməkɪ lanot  
 veðz nulasi – rytofəm ø mɒfoɾyɾ – isalunəðev

### 1.2.2. *Das Hörspiel* (1970)

The Cologne Courses for New Music were held by Mauricio Kagel from 1969 to 1975. Each course was devoted to a different theme, the one in 1970 to “Hörspiel”, which normally translates as “radio play”. Kagel however meant something different, “neither a literary nor a musical genre, but merely an acoustic genre of indefinite content”, as he wrote in the course brochure in German, English and French. I was inspired to ‘pan’ the three versions from the first through the second to the third. My result, written in the International Phonetic Alphabet as seen below, was printed in a programme for a public concert including my radio play CCU (1980), more about which follows in this paper. As examples of my word-panning, see [jənuf] as a cross between German “genug” [gɛnuk] and its English equivalent “enough” [ənʌf], or [wʲæ̯l], a cross between “well” [wɛl] and its French equivalent “bien” [bjɛ̃].

das 'høʃpɪl ɪst 'vedə aɪnə lɪtə'ræɪʃə nɔx aɪnə muzɪ'kəlɪʃə, zɔndən 'ledɪgɪç aɪnə a'kustɪʃə gatʊŋ  
'ʊnbɛstɪmtən 'ɪnhaltɪs. fə'raʊsɛtsʊŋ ðɪzəs 'uəaɪgənən 'rʊntfʊŋk'zɔ̃rəs ɪz n ybə'traʊŋz'fɛɪçkɑɪt zʌɪʃə  
ɑrt, ðat ði æk'tərə – sprɪkə, 'mju:zɪkə, 'ʃɑ̃smɪ'wɛkəndə – nɛçt hævn tu ak'tɪərən bɪfəð ðen ɔɪjən ðɛs  
hjørəz, ʊm tu mæk ði je'wɑɪliə sɪtu'wɛtʃən 'dɔɪtlɑɪk. dɑ ðə defɪnɪ'tʃənən fən 'mju:zɪk ɔdr 'rɑdʒɔspɪl  
ʃɪm nɛt ləŋgə æpt jənuf tu fə'tsɪlɪtɛt nɔ nɪt dɪs'tɪŋʃn, ɔnt sɪns ði ɪntəprə'teɪʃn ɔf sʌʊnd ənd wɛd hæz ɪn  
lɪðə keɪs bəkɑm kwɛstʃ'nɑbl, 'mju:zɪk ɔz 'rædʒɔfɔnɪk plɛ wəz tʃəʊzn əlz θem fə ðə kə'ləʊnjə 'kʊrsəs  
'nɑɪntɪn'septɪ. ɪt ɪz nɔt ə 'stjɪdɪ dɔv jʊtɪlɪ'zɛʃʃən ɔv mju:zɪk ɪn 'rɑdʒɔθɪ'atə kət wɑn rɪ'sɔɛf dɔ'læʃtəʊŋʃn ɔv  
prə'mʊvɪŋ kɛlkm nɔ'vel rə'sɛt də 'rɪəplɑɪn 'myzɪkəl. wjæ̯l ɔ 'kɔ̃rɛrɪ – ðɛz ɛlɛv kəm'pəʊzərɔ̃ ðə pɪs  
rɑdʒɔfɔ'nɪk ælz a tu, wɪ'sɔ̃'trə ɔblɑɪ'zɛ a 'rɪɔ̃r'sɛ dez akts'jɔ̃s akustɪkə'mɔɪ æsɪfɪ'sɑ̃t ɔ a 'rɪmɪnɛ  
dez ak'sɔ̃'drɑmɑ'tɪk 'dɛzɑ plɑ'sɛ.

### 1.2.3. *Ode to St. Cecilia* (1988)

This text specifying misuses of music forms part of Fruitti d’Amore for cello and electronics. The piece was written for Frances-Marie Uitti, who recites the text at the beginning. The stanzas of verse were so written that every stressed syllable of one line phonetically resembles the corresponding syllable of another, a technique I call “omniproxonance” as opposed to “finæquisonance” for the final perfect rhyme; all spoken lines were also recorded, synchronised and used as sound material rendered electronically near the end of the entire piece. Fig.3 arranges the phonetically similar syllables vertically, e.g. the second syllable of each line: “view – through – su – mu – you – thu – few – mu – you – beau” (“qui” in the penultimate line is an exception, of which there are many).

The	view	se-	cure,	in	flight	a-	bove	the	lawn /	A	haugh-	ty	fea-	thered	friend	of	mu-	sic	be	
And	through	this	song-	ster's	throat	(but	not	for	long) /	Be-	fore	it's	caged	and	braised,	a	me-	lo-	dy.	
A	su-	per-	mar-	ket	oo-	zing	gen-	tle	sound /	Sees	for-	tunes	spent	with	grey	ra-	pi-	di-	ty.	
Be	mu-	sic	but	a	fruit	of	love,	pay	on! /	And	more	we	serve	this	fair	com-	mo-	di-	ty.	
(If	you	think	"can't	af-	ford	e-	nough",	be-	gone) /	And	more	we	serve	this	fair	com-	mo-	di-	ty.	
En-	thu-	si-	ast?	Be-	fud-	dled?	But	you're	one! /	It's	Form	where-	with	so	sheer	con-	ten-	ty	we	be.
A	few	would	fain	be-	lieve,	o-	bey,	be-	long... /											
Here	mu-	sic	(just	the	thing	to	hull	the	throng!) /	Lets	dou-	blers	yield	to	hap-	py	sa-	ni-	ty.	
With	you,	O	bu-	gle	bright,	men	rise	at	dawn; /	Their	chore,	to	e-	du-	cate	an	e-	ne-	my,	
In-	qui-	si-	tors,	be	full	of	lus-	ty	song, /	A	jaun-	ty	march	to	spur	their	jol-	li-	ty.	
Thus	beau-	te-	ous	is	mu-	sic... /				And	tor-	tured	yells	dis-	perse	in-	au-	di-	bly.	
										And	more	we	serve	this	fair	com-	mo-	di-	ty.	

Figure 3: *Ode to St. Cecilia* with syllables separated into individual phonetically homogenous columns.

See also references (Barlow, 2008, 2009b).

### 1.3. SPEECH RECORDINGS

As examples of using speech recordings for composition, I will outline three techniques I developed, *synthrummentation* (1981), *sound wave surfing* (1987) and *spectastics* (1994).

#### 1.3.1. Synthrummentation

I invented this term – from “synthesis through instrumentation” – to denote the following technique. A spectral analysis of a recording, typically of spoken language, adapted to a fundamental, which can move as compositionally desired, is rendered as a series of short chords comprising ‘telescoped’ Fourier time windows represented as a MIDI data file, which is then ‘calmed’: harmonic partials, the MIDI velocities of which fall near multiples of a set tolerance value, are rounded to those multiples and made continuous, i.e. the interruption between a partial in a chord and the same frequency in the next chord is removed. The resulting MIDI file sounds remarkably like the original sound recording. This technique was used in my ensemble piece *Im Januar am Nil* (1984), the orchestra piece *Orchideæ Ordinariæ* (1989) and other works like *Felle Hymnus Van Verre* (2001) and *Septima de facto* (2006).

One layer of *Im Januar am Nil* is the synthrummentation of German sentences, made according to phonetic considerations relevant to this piece (plosives and other noise phonemes excluded). Fig.4 shows five stages in the synthrummentation of the spoken words “In Armenien” (= “in Armenia”), starting with the sound file. Its Fourier Analysis – time windows with harmonic partial numbers and amplitudes – is passed into synthrummentation, yielding a MIDI file mapped at centre right as pitch (y-axis) against time (x-axis). When the MIDI file is played, the sound is clearly recognisable as “In Armenien”. This MIDI file was made into the score shown below; played by musicians – bass clarinet, four violins, two cellos and a double bass – its similarity to spoken language is still strongly evident.

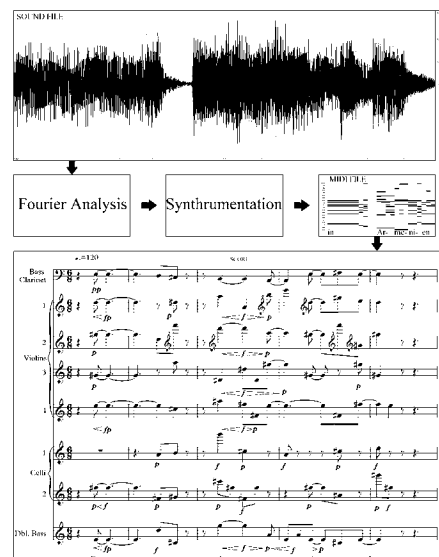


Figure 4: Excerpt “in Armenien” from *Im Januar am Nil* in five synthrummentation stages

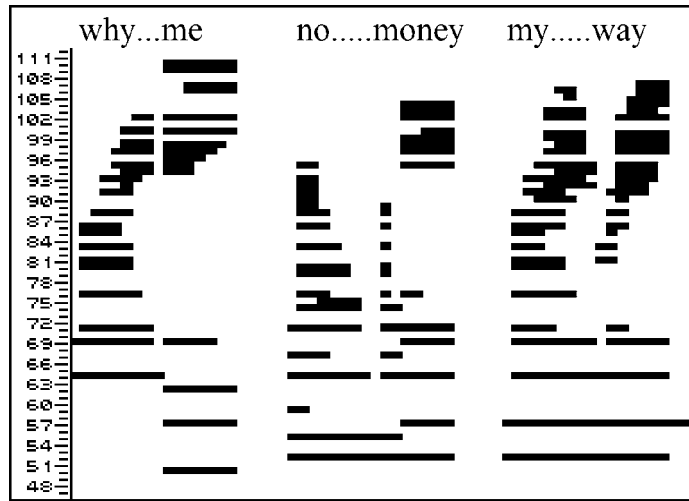


Fig.5 – *Orchideæ Ordinariæ*: MIDI maps of three synthtrumentated phrases in English.

Figure 5 shows MIDI pitch-time maps of three phrases “why me”, “no money” and “my way” in *Orchideæ Ordinariæ*. Against one clarinet and seven strings in *Im Januar*, 50 string players were involved here. The words “no money” are especially well recognisable in performance.

### 1.3.2. Sound Wave Surfing

This technique, one I first used in 1987 in software I named “Samploop” (from “sample loop”), employs forwards and backwards motion, looped if necessary, along the samples of a recorded sound wave. It has three parameters: first and final sample number of a sound wave segment as well as number of iterations of the segment. For backward surfing the final sample number must be lower than that of the first sample. I first used Samploop applied to the spoken words “Herre Gott erbarme dich, Christe erbarme dich, Herre Gott erbarme dich” in *Herre Gott* from my piece *documissa '87* (1987). Here is the input to Samploop, one segment to every line, for the middle section, in which the segment “dich” is repeatedly truncated (see also Fig.6):

51660	56652	1	53100	53486	1	53100	53307	1	53100	53211	1
51740	56115	1	53100	53477	1	53100	53302	1	53100	53208	1
51820	55654	1	53100	53468	1	53100	53297	1	53100	53206	1
51900	55260	1	53100	53460	1	53100	53293	1	53100	53203	1
51980	54925	1	53100	53452	1	53100	53288	1	53100	53201	1
52060	54641	1	53100	53444	1	53100	53284	1	53100	53199	1
52140	54402	1	53100	53436	1	53100	53280	1	53100	53196	1
52220	54202	1	53100	53428	1	53100	53276	1	53100	53194	1
52300	54037	1	53100	53420	1	53100	53272	1	53100	53192	1
52380	53902	1	53100	53413	1	53100	53268	1	53100	53190	1
52460	53794	1	53100	53399	1	53100	53264	1	53100	53188	1
52540	53709	1	53100	53392	1	53100	53260	1	53100	53186	1
52620	53645	1	53100	53386	1	53100	53257	1	53100	53184	1
52700	53598	1	53100	53379	1	53100	53253	1	53100	53182	1
52780	53567	1	53100	53373	1	53100	53250	1	53100	53180	1
52860	53550	1	53100	53366	1	53100	53246	1	53100	53178	1
52940	53545	1	53100	53360	1	53100	53243	1	53100	53177	1
53020	53550	1	53100	53354	1	53100	53240	1	53100	53175	1
53100	53564	1	53100	53349	1	53100	53236	1	53100	53173	1
53100	53553	1	53100	53343	1	53100	53233	1	53100	53171	1
53100	53543	1	53100	53337	1	53100	53230	1	53100	53170	1
53100	53533	1	53100	53332	1	53100	53227	1	53100	53168	1
53100	53523	1	53100	53326	1	53100	53221	1	53100	53167	1
53100	53513	1	53100	53322	1	53100	53219	1	53100	53165	1
53100	53504	1	53100	53316	1	53100	53216	1	53100	53164	1
53100	53495	1	53100	53312	1	53100	53213	1	53100	53163	144

The first sample of each segment moves rapidly from #51660 to #53100, staying there until the end of the section. The final sample moves gradually from #56652 to #53163. The segment length is initially 4992 samples (or 113.2 ms at a 44.1 KHz sampling rate) and shortens to a mere 63 samples (1.43 ms). Repeated 144 times, this last segment gives a constant tone of frequency 700 Hz and duration 206 ms with the timbre of the samples in the segment.

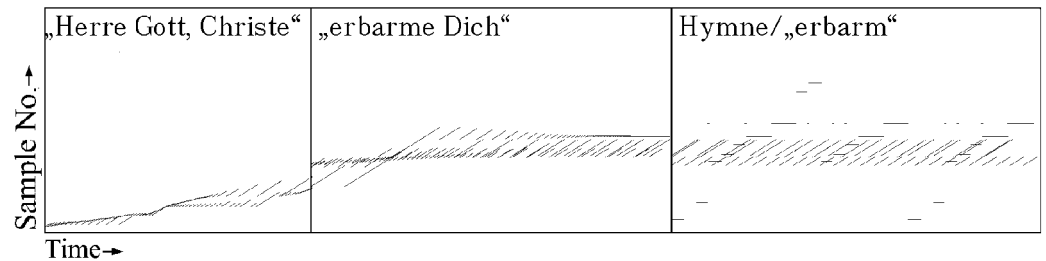


Figure 6: A surf chart for the input sound wave for *Herre Gott*.

Figure 6 is a “surf chart” for *Herre Gott* (1987) – diagonal lines represent sound segments played forwards ‘normally’. Horizontal lines as seen mainly on the right are constant tones caused by short sample segments looped several times: the vertical width of a horizontal loop line (not obvious in the chart) sets the frequency of the perceived tone, the iteration count (horizontal length) its duration, and the inherent timbre is maintained: these tones contain only the input sound wave vowels [ε e o ε α ə i...] from “Herre Gott erbarme dich” etc.

My tape piece *fLvXv\$* (1990) using a further Samploop development uses words spoken by John Cage, taken from a 1988 interview Zygmunt Krauze made with me for Polish television. By gradually shortening the sample segments, the piece organically moves from a form of concrete poetry through rap-like music to electronic clicks and bleeps.

### 1.3.3. Spectastics

30 years ago I invented this term (derived from “Spectral Stochastics”) to denote a technique for converting spectral speech analysis into music. Whereas “synthrummentation” renders the analysis as a ‘calmed’ chord-succession (see §1.3.1 above), “spectastics” generates a rapid succession of single notes: first the spectrum’s amplitudes, calculated for every partial, are interpolated between the partials to give an amplitude value for every chromatic scale degree upwards from the analysis fundamental frequency. These chromatic amplitudes are then used as probability values for the random generation of a rapid melody, ideally 20-200 notes per second: the ‘louder’ a note is during a certain stretch of time in the chromaticized spectrum, the more frequently it will appear in the melody during that stretch. A spectastized melody, as rendered on a synthesizer or a player piano, is remarkably like the original sound recording. My principal use of spectastics was in my composition *Farting Quietly in Church* (1992) for baritone and six computers, performed three times by the late William Pearson (1934-1995). In one part of the piece,

his words were spectastised live and the results sent in real time to an accompanying computer-driven player piano.

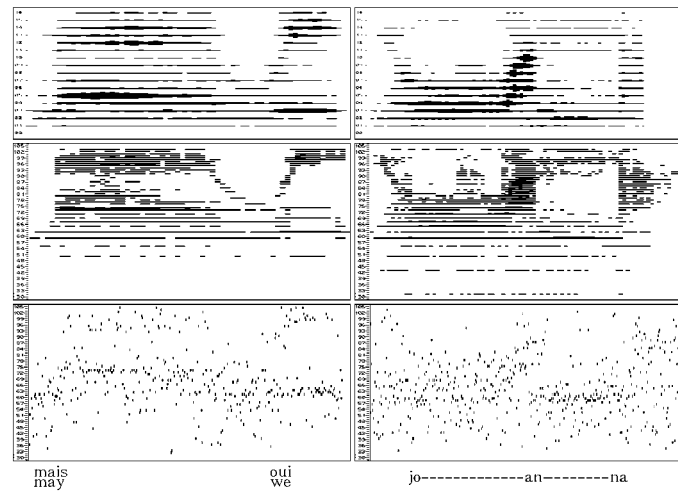


Figure 7: “mais oui, Joanna”: sonogramme (top), MIDI pitch-time maps of synthstrumentation (middle) and spectastisation (bottom).

Figure 7 shows the words “mais oui, Joanna” in three similar-looking forms: a sonogramme, and MIDI-pitch maps of a synthstrumentation and spectastisation of the words. See also references (Barlow, 1996, 2008, 2009b, 2014a).

#### 1.4. SEMANTIC COMPOSITION

I developed this technique for *Progéthal Percussion for the Advanced Beginners* (2003), a piece written – instead of by spectral treatment – in a ‘language’ crafted for several percussion instruments, termed “Progéthal Percussion”: here sentences of a given text are grammatically parsed into parts of speech – nouns, verbs etc. with their attributes – and converted into a music score by a fixed set of rules, using a vocabulary developed with the help of the 1852 Thesaurus by Peter Mark Roget (1779–1869) – hence the name of the language. The piece purports to be a course in the language.

To each of Roget’s thousand categories of meaning I allotted a new five-digit code reflecting – in addition to Roget’s six classes and the sections and divisions therein – shades of meaning such as negation, etc. A text was then taken as source material, parsed into parts of speech and attendant properties e.g. plural, genitive, etc. for nouns; transitive/intransitive, etc. for verbs, etc. After an elaborate process including a comprehensive set of grammatical rules in part inspired by various existing, in part newly devised languages, I wrote a computer program to convert the parsed thesaurally encoded text into a music score. Texts thus translated were Hamlet’s Soliloquy, United Nations resolutions on states in the Middle East, as well as texts on commercial posters with instructions to children as to how and how not to behave properly.

These are Roget’s first 24 categories in Class I, Sections I-II with my five-digit code at left:



## CLASS I: WORDS EXPRESSING ABSTRACT RELATIONS

SECTION I. EXISTENCE		12110 #10. Irrelation.
1. BEING, IN THE ABSTRACT		12121 #11. Consanguinity.
11111 #1. Existence.		12131 #12. Correlation.
11110 #2. Inexistence.		12141 #13. Identity.
2. BEING, IN THE CONCRETE		12142 #14. Contrariety.
11211 #3. Substantiality.		12140 #15. Difference.
11210 #4. Unsubstantiality.		2. CONTINUOUS RELATION
3. FORMAL EXISTENCE		12211 #16. Uniformity.
i. Internal conditions		12210 #16a. Nonuniformity.
11311 #5. Intrinsicity.		3. PARTIAL RELATION
ii. External conditions		12311 #17. Similarity.
11310 #6. Extrinsicity.		12310 #18. Dissimilarity.
4. MODAL EXISTENCE		12321 #19. Imitation.
i. Absolute		12320 #20. Nonimitation.
11411 #7. State.		12331 #20a. Variation.
ii. Relative		12341 #21. Copy.
11410 #8. Circumstance.		12351 #22. Prototype.
SECTION II. RELATION		4. GENERAL RELATION
1. ABSOLUTE RELATION		12411 #23. Agreement.
12111 #9. Relation.		12410 #24. Disagreement.

Hamlet's lines "To be, or not to be: that is the question: whether 'tis nobler in the mind to suffer the slings and arrows of outrageous fortune, or to take arms against a sea of troubles, and by opposing end them?" are here expressed in a meta-language, parsed and algorithmically converted into a meta-score. My five-digit code is seen near the middle of each line.

1	6	a	<M1---002...--- >	11111	Verb	intrans	inf		existing
2	7	b	<G1--2022...--- >	51161	Conj	coor			or
3	6	a	<M1---002...---0 >	11111	Verb	intrans	inf	Neg!	not existing
4	7	a	<M4-11000...--! >	14432	Pron	demon	sing	subj	that
5	6	a	<M2---220...!- >	12141	Verb	intrans		pres	is
6	8	a	<P1---212...!-- >	41132	Noun	comm	sing	subj	topic
7	6	a	<M2---220...!- >	12141	Verb	intrans	pres		is
8	7	d	<G1--2022...--- >	51161	Conj	subor			whether
9	7		<P1---002...!-- >	41111	Adv.	qual	posit		conceptually
10	7		<S4--1011...!!- >	64321	Adj.	qual	comp		nobler
11	6	a	<M2---220...!- >	12141	Verb	intrans		pres	is
12	6	f	<S2---001...--- >	62110	Verb	tran	inf		bearing
13	7		<G2---201...!-- >	52320	Adj.	qual	posit		outrageous
14	8		<M8---111...!!- >	18131	Noun	comm	figur	gen	fate's
15	8		<G4---121...--! & >	54221	Noun	comm	plur	obj	attacks
16	7	b	<G1--2022...--- >	51161	Conj	coor			or
17	6		<G4---100...--- >	54220	Verb	tran	inf		arming
18	8	a	<G4---021...--- >	54130	Prep				against
19	7	a	<M3---200...--- >	13311	Conj	coor			and
20	6	b	<G4---021...!!- >	54130	Verb	tran	gen		opposing's
21	6	a	<M7---020...--- >	17121	Verb	tran	inf		ending
22	7	b	<M4-11000...--! >	14432	Adj.	demon	def		this
23	8	b	<S2---001...!!- & >	62110	Noun	comm	plur	gen	troubles'
24	8	a	<M4---200...--! >	14311	Noun	comm	sing	obj	sea

Of the above, the code at left e.g. in the first line "1 6 a <M1---002...--- >" (for the first word of the text and the first bar of the music) means:

- 1 the bar number  
 [6 ] the bar length (six beats in this case, see below),  
 [a] the first synonym within category 11111 ( [b] would mean synonym two of six ),  
 [<M1] Metal instrument 1  
 (for Roget's Class I. Abstract Relations; the six classes were so allotted:  
 I. Abstract Relations →Metal, II. Space→Air, III. Matter→Wood,  
 IV. Intellect→Plastic, V. Volition→Glass, VI. Emotion→Skin),  
 [--002] three silent beats followed by three notes with an instrument offset of 0, 0, and 2,  
 [...] three short notes of one beat each, leading to a total duration of six beats for that bar  
 or word; long notes notated as [-] last two beats each,  
 [---] three soft notes (loud="!"). Rhythms and dynamics derive from the parsing.  
 [ >] three-character code preceding ">": " " = no code, "0 " = negative, "& " = plural

Compare this necessarily compact description with the 24 bars shown in Fig.8. Also note that the stressed low note (lower staff, for the bass drum) on the fourth pulse of bar 3 means "not": compare this to bar 1 ("To be") – there is no bass drum note there. Shakespeare's text is shown interspersed between the original and the meta version above.

Figure 8: *Progéthal Percussion for the Advanced Beginners*: Hamlet's Soliloquy ( bars 1-24).

See also references (Barlow, 2008, 2009b, 2012).

## 2. ACOUSTIC SOURCES

Here I cite pieces made out of field recordings done with technical equipment in various places. My octaphonic electronic *work CCU* (1980) layers seven of 20 hours of stereo recordings made during three months in the winter of 1977-78 at 60 venues in Calcutta, both in- and outdoors, to form a 48-minute piece reflecting the course of a hypothetical 24-hour day in that city. Here, the main diffusion parameters are *dynamics* (fading the sounds in and out) and *spatialization*: given that the eight loudspeakers are symbolically placed on the city's rim (miniaturized to the bounds of the concert hall), each recording is panned between two of the loudspeakers joined by a line, the midpoint of which corresponds in direction and distance to the place of recording viewed from the city centre. The loudspeaker panning matches the location of the venues, north in front, south behind etc.; the distance of the venue from the city centre determines the separation of the two speakers diffusing the stereo recording – the further the venue from the centre, the closer together the loudspeakers.

Figure 9 shows at left a map of the city in its geographical size of the 1970s. It has an elliptical shape, its major axis tilted clockwise 8 arc minutes from due north-south. The river Hooghly, a Ganges distributary,

curves its way downwards in the upper left of the map. The 60 venues are barely visible as starlike icons (“☼”) placed at their locations. Fig.9 shows at right a series of eight concentric ellipses with loudspeaker positions marked “1” to “8” along the rim of the outermost one. Superimposed slightly tilted on the map at left, these ellipses show a total of  $8 \times 8 = 64$  zones. These adjoin the midpoints of the 28 lines joining the eight loudspeaker positions. In the right half of Fig.9, each midpoint, five seen as large black dots, is adjoined by groups of three conjunct zones. A stereo recording made in one of the three zones would be panned between the loudspeakers at the ends of the line with that midpoint. This type of panning was a very difficult task with pre-digital technology in 1980, given the large number of simultaneously running recordings and was achieved by a team of several persons acting together to achieve the desired result.

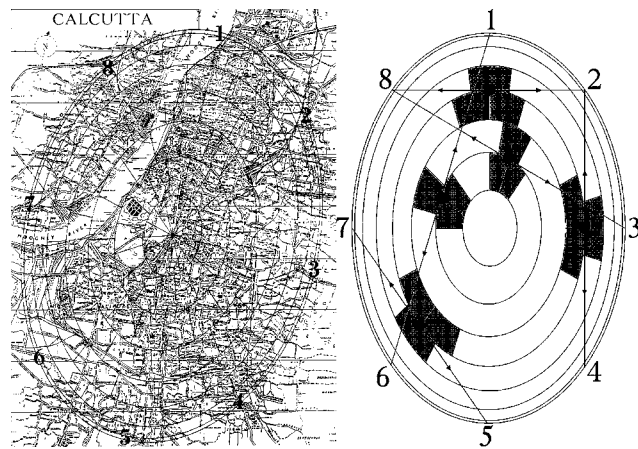


Figure 9: Map (left) of Calcutta in the 1970s and (right) location-based panning exemplified.

On the other hand, the octaphonic 41-minute *Zero Crossing* (2001) contains 83 recordings made daily at the same stellar time in 31 places on a three-month trip around the world in the winter of 1999-2000. Each recording was carefully whittled down to an ‘edition’ lasting exactly two minutes, the central 30 seconds of which (the ‘core’) is played at the original volume with the preceding and following 45 seconds constituting a fade-in and -out. Fig.10 shows a map of the world with my airports of call, all within 30 degrees north of a great circle poled in the North-West Pacific and the South Atlantic.

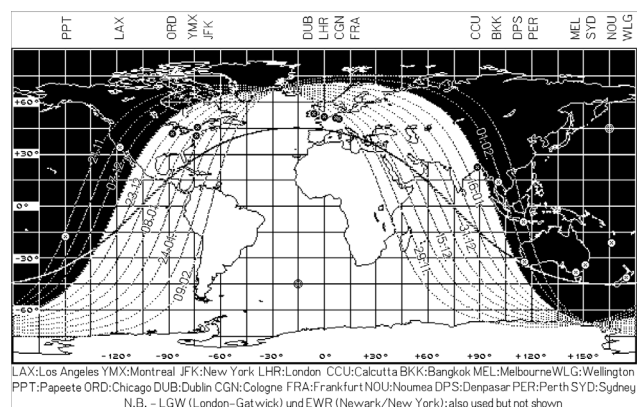


Figure 10: *Zero Crossing*: Equirectangular World Map with Airports of Call, neighbouring Great Circle

The system of the layering of the 83 editions is shown in Fig.11; each edition is faded in up to the core and faded out thereafter. Incomplete editions are numbered in square brackets.

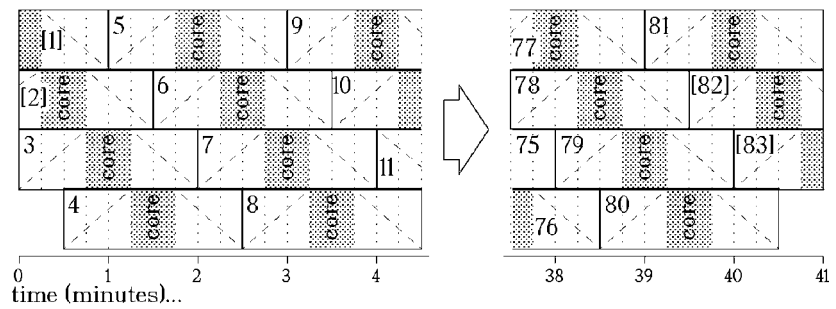


Figure 11: *Zero Crossing*: the System of Edition Layering.

See also references (Barlow, 1997, 2000, 2005b, 2012).

### 3. VISUAL SOURCES

#### 3.1. *TEXTMUSIC VERSION 8 (1971/1973)*

This version of Textmusic (see §1.1 above) is based on a poem in Cologne dialect (a Moselle-Franconian language akin to Dutch) praising that city's virtues. Fig.12 shows at left abstracted postcards of I. the Opera House, II. the Cathedral and nearby bridge, III. the mediaeval city West Gate, IV. Rhine panorama with Cathedral and the Church of St. Martin Major, and V. St. Gereon's Church, which were applied as parametric curves in a computer program. The unique result is inextricably linked to these curves; e.g. postcard II sets the key-colours initially at 90% mixed (chromatic) and 10% white (diatonic) and finally at 100% black (pentatonic), due here to the bridge's proximity at the picture's right end – see the two scored examples at right: the upper one shows the mostly chromatic beginning, the lower one the piece's pentatonic end. See also references (Barlow, 2009a, 2012a, 2018).

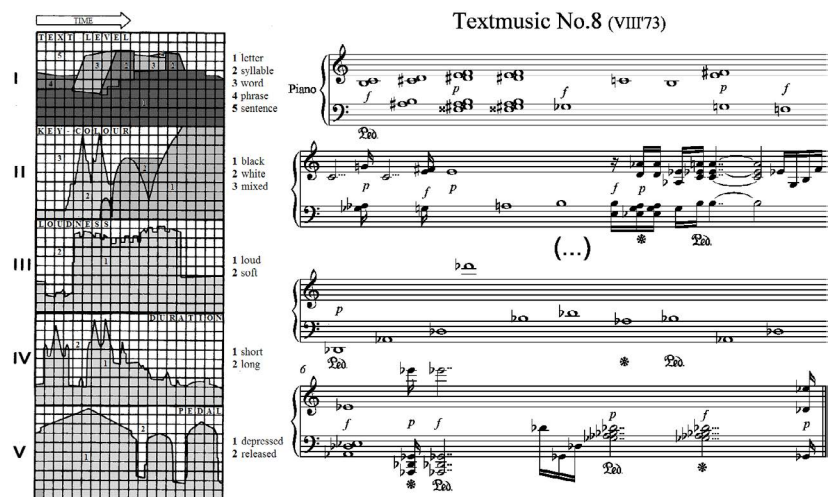


Fig.12: *Textmusic for piano* (1971) – parametric plan, beginning and end of *Version 8* (1973).

### 3.2. ESTUDIO SIETE (1995)

In 1995 I was commissioned by the “100 Years of Film” festival of the Art and Exhibition Hall of the Federal Republic of Germany (“Bundeskunsthalle”) for music to be synchronised to the 1930 film *Study No.6* by Oskar Fischinger (1900-1967). The original soundtrack by Jacinto Guerrero (1895-1951), to which Fischinger had synchronised his images, was to be replaced for the festival by a contemporary work. One of the composition’s layers is a metamorphosis of Fischinger’s dancing objects; here I effected a phonetic linkage between the width and height of the objects and the sound colour of a resulting tone-cloud: horizontally stretched shapes yielded (as does the human mouth) an [i] (‘ee’) sound, squat shapes an [u] (‘oo’), with sonic interpolations for in-between shapes. *Estudio Siete* (Spanish for “Study” or “Studio” No.7) was composed in Cuenca near Madrid and realised in the studio that I used to head in the Royal Conservatory The Hague (Studio 7). It is best film-synchronised on a player piano. Fig.13 shows schematically at left the first 12 frames of the Fischinger film with their spectastically (see §1.3.3 above) extracted notes, starting at frame 3. At centre right is a hypothetical frame with five objects, further right are the “X Y” coordinates of these objects’ lower left corners and their respective widths and heights (“W H”) followed at far right by phonetic formants as MIDI numbers and amplitude curves. Spectastically interpreted formant amplitudes are seen as overall probability curves and as their sum in the “Σ” box (top right corner).

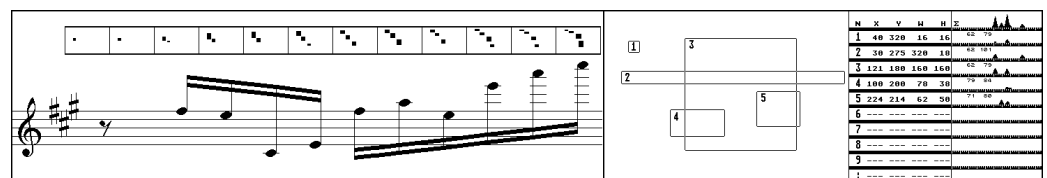


Fig.13: Schematical frames 1-12 of Fischinger’s Study No.6: *Estudio Siete* “spectastics”/“phonetics”.

See also references (Barlow, 1996, 2009a, 2010a, 2018).

### 3.3. KURI SUTI BEKAR (1998)

Written for the pianist Kristi Becker, whose name, pronounced in Japanese, inspired the title, *Kuri Suti Bekar* (1998) consists of a *Prelude* and a *Chaconne*. The short *Prelude* (see the left box in Fig.14) is taken from the pianist’s name in Japanese Katakana script (top) – the right hand plays [ku-ri-su-ti] and the left [bæk-ka-ro] simultaneously (MIDI pitch-time map below). For the *Chaconne* (see the lower half of the box at right), Ms Becker’s photograph, scanned into an 88x88-pixel matrix (box top centre left), was filtered and mapped ten times to form a ten-page score with eight bars per mapped page: in each map, 88 horizontal pixels mark 88 pulses in time (11 per bar), and 88 vertical pixels the 88 piano keys. The first two maps are shown enlarged at top left of this box. For each map, pixels were selected by constraints, the three most significant being 1) the transection of the pixellated portrait by two sets of 120 radial

lines three degrees apart, 20 of them unused – see comment below, 2) a harmonic matching of my piece ...*until...* #5 (1972/74) in 11/16 metre, frequently played by Ms Becker (each of the ten mappings scans eight bars or 88 pulses of this piece, reflected in the eight bars of each page of *Kuri Suti Bekar*), and 3) a phonetic spectral analysis, serving as a sonic filter, of three Bengali words also forming the title: “kuri” (twenty), “suti” (cotton threads) and “bekar” (jobless), referring to the 20 idle radial lines. Superimposed, the ten pitch maps yield the graph at top centre right, clearly resembling the pixellated photograph. Bar one of the score is at top right. See also references (Barlow, 2009a, 2010a, 2012, 2018).

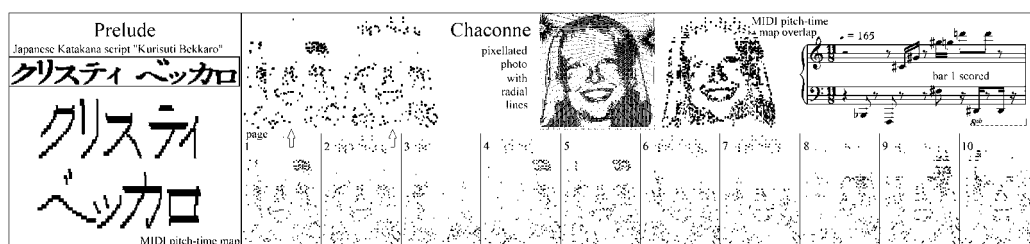


Figure 14: MIDI pitch-time maps of Kuri Suti Bekar: left box the *Prelude*, right box the ten pages of the *Chaconne* shown individually (below) and superimposed (top centre right).

### 3.4. LES CISEAUX DE TOM JOHNSON (1998)

The French title refers to the “O”s in composer Tom Johnson’s name, for whose 60<sup>th</sup> birthday this piece was written, and the six circles indicated below – “Six O” is pronounced [sizo] in French, as is “Ciseaux” or scissors, a pun. Composing Instructions:

- Write T, O, M, J, O, HN, S, O, N from left to right, the alphabetical order upwards.
- Draw six circles through the letter groups TOM, MJH, JOS, JNS, SON and OOO, the last group in a straight line, i.e. a circle with an infinitely distant centre.
- Allow the six letter groups to move anticlockwise along their respective circles by  $\frac{1}{90}$ <sup>th</sup> of the smallest circle’s circumference (SON): doing this 90 times causes all groups to traverse variously sized angular distances, SON going full circle.
- Scan each of the 91 obtained configurations by a vertical line moving smoothly from left to right: the height of all letters encountered by the line gives pitch (alphabetically chromatic), the moment of encounter gives time: the pitch-time interpretation yields a “mini-score”.
- Place the 91 mini-scores along a time axis, such that the time gap between any OOO group and the next equals the gap between the “O”s in themselves: all  $91 \times 3 = 273$  “O”s should be temporally equidistant. Insert a small pause at the end of the first mini-score.

Voilà, *Les Ciseaux de Tom Johnson* is complete! (see Fig.15 for the first seven bars)

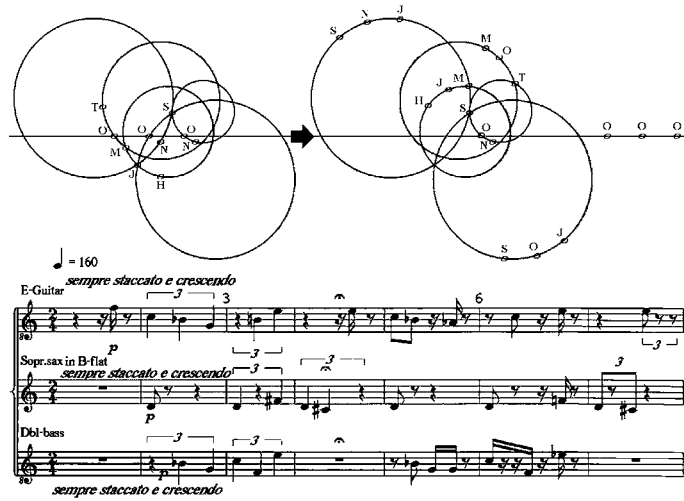


Figure 15: The geometric derivation plan of *Les Ciseaux de Tom Johnson* and the first seven bars.

See also references (Barlow, 2009a, 2010a, 2017, 2018).

### 3.5. LE LOUP EN PIERRE (“==”) FOR TWO ORGANS

This piece (=The Stone Wolf, “loup” = wolf, “pierre” = stone = Peter) was composed for the two organs in St. Peter’s Church in Leiden, the mean-tone Van Hagerbeer organ at A=419 Hz and the equal-tempered Thomas Hill organ at A=440 Hz. This mean-tone-tuning has a so-called “wolf fifth” between G# and Eb, noted in the title. The first section of the piece involves a sonification of a pixellated image of the church building, calibrated to the Bark scale of subjective pitch (see Fig.16): the pixels in the image are allocated to keys on either or both organs, the Bark or 12-tone tempered pitches of which are the closest.

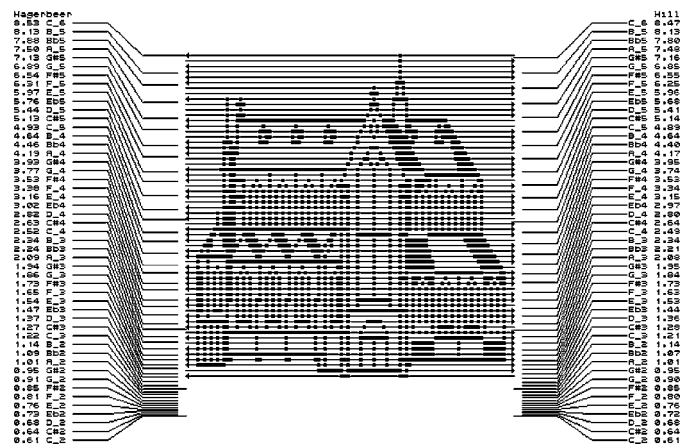


Figure 16: Pitch derivation from an image of St. Peter’s Church in Bark and 12-tone-tempered scales

The building, graphically rescaled to the MIDI-pitch-scale (see Fig.17), now provides the first 97 chords, initially filtered by a horn shaped centre on pitch No.68=Ab, the only note common in pitch to both organs. Starting with this pitch, the range gradually widens to large microtonal clusters engendered by the central Gothic window. After the first section, the piece continues with other considerations related to harmony (see §4.2. below) and synthrummentation (see §1.3.1 above).

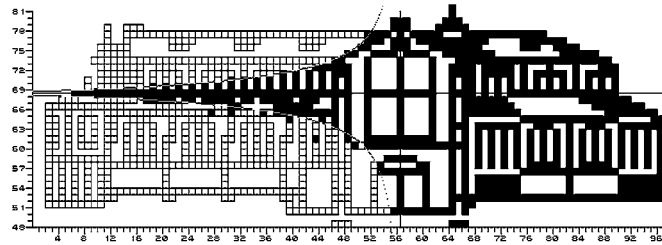


Figure 17: The MIDI pitch-time map of the score of the first part of *Le loup en pierre*.

See also references (Barlow, 2009a, 2010a, 2018).

#### 4. MATHEMATICAL SOURCES

Two sources are demonstrated here, one – ISIS – in the realm of Digital Sound Processing and the other – the quantification of harmony and metre – in the realms of pitch and pulse, melody and rhythm.

##### 4.1. ISIS – FOR “INTRA-SAMPLAR INTERPOLATION OF SINUSOIDS”

This technique resulted from my having doubted, already fifty years ago, that white noise is the sum of all frequencies. I argued that if this were the case, each frequency, one of an infinite number, would have to have zero amplitude, in order not to add up in loudness to infinity. The model I preferred for white noise was that of a single sine tone moving randomly to all possible frequencies at high speed. After some experiments with MIDI in the 1980s that seemed to bear out this supposition, I finally got down in 2001 to the mathematics of determining the variable sine-tone frequency of any sound wave in general. Presuming that it was sufficient to set the speed of frequency change at the sampling rate (currently commonly 44.1 or 48 KHz), I interpolated hypothetical sine-wave segments between the samples of a sound wave, such that each segment would pass through limiting values  $\pm 1$  once each and the final phase of one sine segment would equal the initial phase of the next.

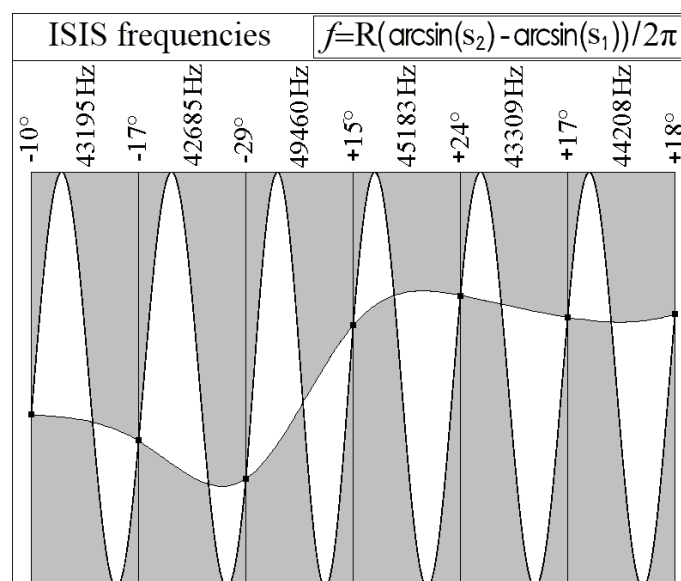


Figure 18: Formula for ISIS-analysis of a sound wave with a graphic example



Figure 18 shows a set of seven samples (dots) connected by a spline, but more significantly by six sine segments, the frequencies and inter-segment phase of which are given near the top. The formula yielding these frequencies is at top right, where “ $f$ ” is the frequency, “ $R$ ” the sampling rate and “ $s_1$ ” and “ $s_2$ ” the values (within  $\pm 1$ ) of two successive samples. It is easy to see why the frequencies centre around the sampling rate: if two successive samples are equal in value, the sine segment between them will form exactly one period of the sampling rate frequency.

This extraction of sine frequencies from a sound wave really turns the latter into a ‘melody’, albeit ultrafast and ultrasonic. But it is possible to transpose this melody down into the audible range and to decelerate it to a perceptible speed.

The reverse is equally possible, to transpose any melody in pitch and speed up to the sampling rate, thus converting it into a sound wave, as in Fig.19, which shows J. S. Bach’s *Jesu Joy of Man’s Desiring* applied to the reverse formula for ISIS-synthesis – and the resulting sound wave and DFT spectrum. The input is in the column at lower left: labelled “SIS” for “sustained interval sequence”, it expresses in cents the Bach melody centred on B4 with the numbers in the right column “ $x_n$ ” signifying the extent of holding or sustaining the notes to their left.

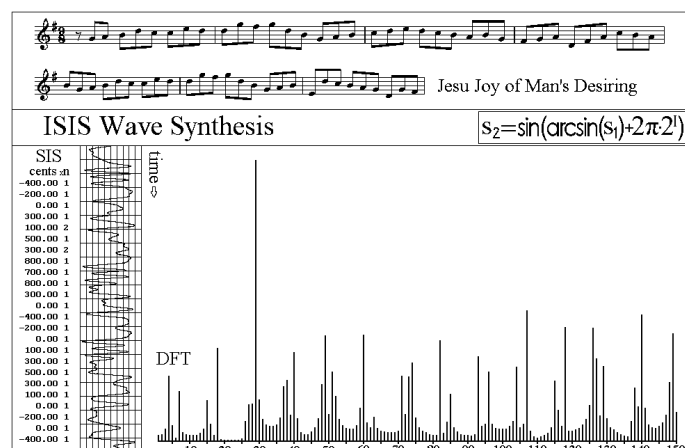


Figure 19: J.S.Bach’s *Jesu Joy of Man’s Desiring* converted to a sound wave with spectrum.

ISIS thus combines the domains of melody and rhythm with that of timbre to form a continuum. I have used this technique in my *Four ISIS Studies* (2003-2008) and in the second of my *Five Dodecaphonic Pieces* (2016-2017) and plan to continue its use. See also references (Barlow, 2005b, 2010b, 2012, 2017, 2017).

#### 4.2 THE QUANTIFICATION OF HARMONY AND METRE

In the late 1970s, in search of an effective way to numerically estimate how harmonic a pitch interval is (including so-called micro-intervals), I studied work by Pythagoras, Hindemith, Partch and other music experts as well as relevant work in the field by the mathematician Euler. None of the above helped me make an exact and usable measurement, leading me to research on my own. This resulted in a formula for “harmonicity”, based on one for a coefficient I called the “indigestibility” of natural

numbers based on both their size and divisibility. Both formulae and corresponding tables are shown in Fig.20. Take the numbers 7, 8 and 9: the indigestibility of the prime 7 (=10.3) is high in comparison to that of 8 (=3.0), a number divisible down to the smallest prime 2. The indigestibility of 9 (5.3), lies between the values for 7 and 8. I define the harmonicity formula as the reciprocal of the sum of the indigestibilities of the numerator and denominator of the ratio or fraction for the interval, with an added feature: if the numerator is less indigestible than the denominator (as in 4/3), the upper note becomes the the interval’s root and the harmonicity is made negative as determined by the plus-minus “sign” function “sgn(ξ(Q)–ξ(P))” where “P” is the denominator, “Q” the numerator and “ξ” indigestibility. The harmonicity e.g. of 4/3 or 3:4 is –0.214, as seen in the two right-most columns of Fig.20.

<p>Formula for Indigestibility of a whole Number N of the natural numbers 1 to 16</p> $\xi(N) = 2 \sum_{r=1}^{\infty} \left\{ \frac{n_r (p_r - 1)^2}{p_r} \right\}$ <p>whereby:</p> <ol style="list-style-type: none"> <li><math>N = \prod_{r=1}^{\infty} p_r^{n_r}</math></li> <li><math>N, n_r, p \in</math> natural numbers</li> <li><math>p \in</math> prime numbers</li> </ol>		<p>Indigestibility ξ(N) of the natural numbers 1 to 16</p> <table border="1"> <tr><th>N</th><th>ξ(N)</th></tr> <tr><td>1</td><td>0.000000</td></tr> <tr><td>2</td><td>1.000000</td></tr> <tr><td>3</td><td>2.666667</td></tr> <tr><td>4</td><td>2.000000</td></tr> <tr><td>5</td><td>6.400000</td></tr> <tr><td>6</td><td>3.666667</td></tr> <tr><td>7</td><td>10.285714</td></tr> <tr><td>8</td><td>3.000000</td></tr> <tr><td>9</td><td>5.333333</td></tr> <tr><td>10</td><td>7.400000</td></tr> <tr><td>11</td><td>18.181818</td></tr> <tr><td>12</td><td>4.666667</td></tr> <tr><td>13</td><td>22.153846</td></tr> <tr><td>14</td><td>11.285714</td></tr> <tr><td>15</td><td>9.066667</td></tr> <tr><td>16</td><td>4.000000</td></tr> </table>		N	ξ(N)	1	0.000000	2	1.000000	3	2.666667	4	2.000000	5	6.400000	6	3.666667	7	10.285714	8	3.000000	9	5.333333	10	7.400000	11	18.181818	12	4.666667	13	22.153846	14	11.285714	15	9.066667	16	4.000000	<p>Complete Intraoctave Intervals for Harmonicity &gt; 0.05</p> <table border="1"> <thead> <tr> <th>Interval</th> <th>Prime Decomposition as Powers of</th> <th>Number</th> <th>Harmonicity</th> </tr> <tr> <th>size (Q)</th> <th>2</th> <th>3</th> <th>5</th> <th>7</th> <th>11</th> <th>13</th> <th>Number</th> <th>Harmonicity</th> </tr> </thead> <tbody> <tr><td>0:000</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1:1</td><td>∞</td></tr> <tr><td>70:472</td><td>-3</td><td>-1</td><td>+2</td><td>0</td><td>0</td><td>0</td><td>24:25</td><td>+0.054152</td></tr> <tr><td>111:731</td><td>+4</td><td>-1</td><td>-1</td><td>0</td><td>0</td><td>0</td><td>15:16</td><td>-0.036531</td></tr> <tr><td>182:404</td><td>+1</td><td>-2</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>9:10</td><td>+0.078534</td></tr> <tr><td>203:910</td><td>-3</td><td>+2</td><td>0</td><td>0</td><td>0</td><td>0</td><td>8:9</td><td>+0.120000</td></tr> <tr><td>231:174</td><td>+3</td><td>0</td><td>-1</td><td>0</td><td>0</td><td>0</td><td>7:8</td><td>-0.079269</td></tr> <tr><td>266:871</td><td>-1</td><td>-1</td><td>0</td><td>-1</td><td>0</td><td>0</td><td>6:7</td><td>-0.071472</td></tr> <tr><td>294:125</td><td>+5</td><td>-3</td><td>0</td><td>0</td><td>0</td><td>0</td><td>27:32</td><td>-0.074923</td></tr> <tr><td>315:441</td><td>+1</td><td>+1</td><td>-1</td><td>0</td><td>0</td><td>0</td><td>5:6</td><td>-0.099338</td></tr> <tr><td>386:314</td><td>-2</td><td>0</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>4:5</td><td>+0.119048</td></tr> <tr><td>407:800</td><td>+6</td><td>+4</td><td>0</td><td>0</td><td>0</td><td>0</td><td>44:81</td><td>+0.030000</td></tr> <tr><td>427:373</td><td>+5</td><td>0</td><td>-2</td><td>0</td><td>0</td><td>0</td><td>25:32</td><td>-0.056100</td></tr> <tr><td>435:084</td><td>0</td><td>+2</td><td>0</td><td>-1</td><td>0</td><td>0</td><td>7:9</td><td>-0.044024</td></tr> <tr><td>470:781</td><td>+4</td><td>+1</td><td>0</td><td>+1</td><td>0</td><td>0</td><td>16:21</td><td>+0.038989</td></tr> <tr><td>498:045</td><td>+2</td><td>-1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>3:4</td><td>-0.214286</td></tr> <tr><td>519:551</td><td>-2</td><td>+3</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>20:27</td><td>-0.069976</td></tr> <tr><td>546:717</td><td>+1</td><td>-2</td><td>+2</td><td>0</td><td>0</td><td>0</td><td>18:25</td><td>-0.052365</td></tr> <tr><td>582:512</td><td>0</td><td>0</td><td>-1</td><td>+1</td><td>0</td><td>0</td><td>5:7</td><td>-0.059932</td></tr> <tr><td>590:224</td><td>+5</td><td>+2</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>32:45</td><td>-0.059761</td></tr> <tr><td>609:276</td><td>+6</td><td>+2</td><td>0</td><td>0</td><td>0</td><td>0</td><td>45:64</td><td>-0.036091</td></tr> <tr><td>617:488</td><td>+1</td><td>0</td><td>+1</td><td>-1</td><td>0</td><td>0</td><td>7:10</td><td>-0.056543</td></tr> <tr><td>680:449</td><td>+3</td><td>-3</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>27:40</td><td>-0.057471</td></tr> <tr><td>701:955</td><td>-1</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>2:3</td><td>+0.272727</td></tr> <tr><td>728:219</td><td>+5</td><td>-1</td><td>0</td><td>-1</td><td>0</td><td>0</td><td>21:32</td><td>-0.055703</td></tr> <tr><td>748:916</td><td>+1</td><td>-2</td><td>0</td><td>+1</td><td>0</td><td>0</td><td>9:14</td><td>-0.030172</td></tr> <tr><td>772:627</td><td>-4</td><td>0</td><td>+2</td><td>0</td><td>0</td><td>0</td><td>16:25</td><td>-0.059524</td></tr> <tr><td>792:180</td><td>+7</td><td>-4</td><td>0</td><td>0</td><td>0</td><td>0</td><td>81:128</td><td>-0.056604</td></tr> <tr><td>815:086</td><td>+3</td><td>0</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>5:8</td><td>-0.106383</td></tr> <tr><td>884:359</td><td>0</td><td>-1</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>3:5</td><td>+0.110294</td></tr> <tr><td>905:865</td><td>+4</td><td>+3</td><td>0</td><td>0</td><td>0</td><td>0</td><td>16:27</td><td>-0.083333</td></tr> <tr><td>930:129</td><td>+2</td><td>+1</td><td>0</td><td>-1</td><td>0</td><td>0</td><td>7:12</td><td>-0.066079</td></tr> <tr><td>948:826</td><td>-2</td><td>0</td><td>0</td><td>+1</td><td>0</td><td>0</td><td>4:7</td><td>+0.081595</td></tr> <tr><td>996:090</td><td>+4</td><td>-2</td><td>0</td><td>0</td><td>0</td><td>0</td><td>9:16</td><td>-0.037145</td></tr> <tr><td>1017:596</td><td>0</td><td>+2</td><td>-1</td><td>0</td><td>0</td><td>0</td><td>5:9</td><td>-0.085227</td></tr> <tr><td>1088:269</td><td>-3</td><td>+1</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>8:15</td><td>+0.082873</td></tr> <tr><td>1120:328</td><td>+4</td><td>+1</td><td>-2</td><td>0</td><td>0</td><td>0</td><td>25:48</td><td>-0.051370</td></tr> <tr><td>1137:039</td><td>-1</td><td>+3</td><td>0</td><td>-1</td><td>0</td><td>0</td><td>14:27</td><td>-0.051852</td></tr> <tr><td>1200:000</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1:2</td><td>+1.000000</td></tr> </tbody> </table>						Interval	Prime Decomposition as Powers of	Number	Harmonicity	size (Q)	2	3	5	7	11	13	Number	Harmonicity	0:000	0	0	0	0	0	0	1:1	∞	70:472	-3	-1	+2	0	0	0	24:25	+0.054152	111:731	+4	-1	-1	0	0	0	15:16	-0.036531	182:404	+1	-2	+1	0	0	0	9:10	+0.078534	203:910	-3	+2	0	0	0	0	8:9	+0.120000	231:174	+3	0	-1	0	0	0	7:8	-0.079269	266:871	-1	-1	0	-1	0	0	6:7	-0.071472	294:125	+5	-3	0	0	0	0	27:32	-0.074923	315:441	+1	+1	-1	0	0	0	5:6	-0.099338	386:314	-2	0	+1	0	0	0	4:5	+0.119048	407:800	+6	+4	0	0	0	0	44:81	+0.030000	427:373	+5	0	-2	0	0	0	25:32	-0.056100	435:084	0	+2	0	-1	0	0	7:9	-0.044024	470:781	+4	+1	0	+1	0	0	16:21	+0.038989	498:045	+2	-1	0	0	0	0	3:4	-0.214286	519:551	-2	+3	+1	0	0	0	20:27	-0.069976	546:717	+1	-2	+2	0	0	0	18:25	-0.052365	582:512	0	0	-1	+1	0	0	5:7	-0.059932	590:224	+5	+2	+1	0	0	0	32:45	-0.059761	609:276	+6	+2	0	0	0	0	45:64	-0.036091	617:488	+1	0	+1	-1	0	0	7:10	-0.056543	680:449	+3	-3	+1	0	0	0	27:40	-0.057471	701:955	-1	+1	0	0	0	0	2:3	+0.272727	728:219	+5	-1	0	-1	0	0	21:32	-0.055703	748:916	+1	-2	0	+1	0	0	9:14	-0.030172	772:627	-4	0	+2	0	0	0	16:25	-0.059524	792:180	+7	-4	0	0	0	0	81:128	-0.056604	815:086	+3	0	+1	0	0	0	5:8	-0.106383	884:359	0	-1	+1	0	0	0	3:5	+0.110294	905:865	+4	+3	0	0	0	0	16:27	-0.083333	930:129	+2	+1	0	-1	0	0	7:12	-0.066079	948:826	-2	0	0	+1	0	0	4:7	+0.081595	996:090	+4	-2	0	0	0	0	9:16	-0.037145	1017:596	0	+2	-1	0	0	0	5:9	-0.085227	1088:269	-3	+1	+1	0	0	0	8:15	+0.082873	1120:328	+4	+1	-2	0	0	0	25:48	-0.051370	1137:039	-1	+3	0	-1	0	0	14:27	-0.051852	1200:000	+1	0	0	0	0	0	1:2	+1.000000
N	ξ(N)																																																																																																																																																																																																																																																																																																																																																																																																													
1	0.000000																																																																																																																																																																																																																																																																																																																																																																																																													
2	1.000000																																																																																																																																																																																																																																																																																																																																																																																																													
3	2.666667																																																																																																																																																																																																																																																																																																																																																																																																													
4	2.000000																																																																																																																																																																																																																																																																																																																																																																																																													
5	6.400000																																																																																																																																																																																																																																																																																																																																																																																																													
6	3.666667																																																																																																																																																																																																																																																																																																																																																																																																													
7	10.285714																																																																																																																																																																																																																																																																																																																																																																																																													
8	3.000000																																																																																																																																																																																																																																																																																																																																																																																																													
9	5.333333																																																																																																																																																																																																																																																																																																																																																																																																													
10	7.400000																																																																																																																																																																																																																																																																																																																																																																																																													
11	18.181818																																																																																																																																																																																																																																																																																																																																																																																																													
12	4.666667																																																																																																																																																																																																																																																																																																																																																																																																													
13	22.153846																																																																																																																																																																																																																																																																																																																																																																																																													
14	11.285714																																																																																																																																																																																																																																																																																																																																																																																																													
15	9.066667																																																																																																																																																																																																																																																																																																																																																																																																													
16	4.000000																																																																																																																																																																																																																																																																																																																																																																																																													
Interval	Prime Decomposition as Powers of	Number	Harmonicity																																																																																																																																																																																																																																																																																																																																																																																																											
size (Q)	2	3	5	7	11	13	Number	Harmonicity																																																																																																																																																																																																																																																																																																																																																																																																						
0:000	0	0	0	0	0	0	1:1	∞																																																																																																																																																																																																																																																																																																																																																																																																						
70:472	-3	-1	+2	0	0	0	24:25	+0.054152																																																																																																																																																																																																																																																																																																																																																																																																						
111:731	+4	-1	-1	0	0	0	15:16	-0.036531																																																																																																																																																																																																																																																																																																																																																																																																						
182:404	+1	-2	+1	0	0	0	9:10	+0.078534																																																																																																																																																																																																																																																																																																																																																																																																						
203:910	-3	+2	0	0	0	0	8:9	+0.120000																																																																																																																																																																																																																																																																																																																																																																																																						
231:174	+3	0	-1	0	0	0	7:8	-0.079269																																																																																																																																																																																																																																																																																																																																																																																																						
266:871	-1	-1	0	-1	0	0	6:7	-0.071472																																																																																																																																																																																																																																																																																																																																																																																																						
294:125	+5	-3	0	0	0	0	27:32	-0.074923																																																																																																																																																																																																																																																																																																																																																																																																						
315:441	+1	+1	-1	0	0	0	5:6	-0.099338																																																																																																																																																																																																																																																																																																																																																																																																						
386:314	-2	0	+1	0	0	0	4:5	+0.119048																																																																																																																																																																																																																																																																																																																																																																																																						
407:800	+6	+4	0	0	0	0	44:81	+0.030000																																																																																																																																																																																																																																																																																																																																																																																																						
427:373	+5	0	-2	0	0	0	25:32	-0.056100																																																																																																																																																																																																																																																																																																																																																																																																						
435:084	0	+2	0	-1	0	0	7:9	-0.044024																																																																																																																																																																																																																																																																																																																																																																																																						
470:781	+4	+1	0	+1	0	0	16:21	+0.038989																																																																																																																																																																																																																																																																																																																																																																																																						
498:045	+2	-1	0	0	0	0	3:4	-0.214286																																																																																																																																																																																																																																																																																																																																																																																																						
519:551	-2	+3	+1	0	0	0	20:27	-0.069976																																																																																																																																																																																																																																																																																																																																																																																																						
546:717	+1	-2	+2	0	0	0	18:25	-0.052365																																																																																																																																																																																																																																																																																																																																																																																																						
582:512	0	0	-1	+1	0	0	5:7	-0.059932																																																																																																																																																																																																																																																																																																																																																																																																						
590:224	+5	+2	+1	0	0	0	32:45	-0.059761																																																																																																																																																																																																																																																																																																																																																																																																						
609:276	+6	+2	0	0	0	0	45:64	-0.036091																																																																																																																																																																																																																																																																																																																																																																																																						
617:488	+1	0	+1	-1	0	0	7:10	-0.056543																																																																																																																																																																																																																																																																																																																																																																																																						
680:449	+3	-3	+1	0	0	0	27:40	-0.057471																																																																																																																																																																																																																																																																																																																																																																																																						
701:955	-1	+1	0	0	0	0	2:3	+0.272727																																																																																																																																																																																																																																																																																																																																																																																																						
728:219	+5	-1	0	-1	0	0	21:32	-0.055703																																																																																																																																																																																																																																																																																																																																																																																																						
748:916	+1	-2	0	+1	0	0	9:14	-0.030172																																																																																																																																																																																																																																																																																																																																																																																																						
772:627	-4	0	+2	0	0	0	16:25	-0.059524																																																																																																																																																																																																																																																																																																																																																																																																						
792:180	+7	-4	0	0	0	0	81:128	-0.056604																																																																																																																																																																																																																																																																																																																																																																																																						
815:086	+3	0	+1	0	0	0	5:8	-0.106383																																																																																																																																																																																																																																																																																																																																																																																																						
884:359	0	-1	+1	0	0	0	3:5	+0.110294																																																																																																																																																																																																																																																																																																																																																																																																						
905:865	+4	+3	0	0	0	0	16:27	-0.083333																																																																																																																																																																																																																																																																																																																																																																																																						
930:129	+2	+1	0	-1	0	0	7:12	-0.066079																																																																																																																																																																																																																																																																																																																																																																																																						
948:826	-2	0	0	+1	0	0	4:7	+0.081595																																																																																																																																																																																																																																																																																																																																																																																																						
996:090	+4	-2	0	0	0	0	9:16	-0.037145																																																																																																																																																																																																																																																																																																																																																																																																						
1017:596	0	+2	-1	0	0	0	5:9	-0.085227																																																																																																																																																																																																																																																																																																																																																																																																						
1088:269	-3	+1	+1	0	0	0	8:15	+0.082873																																																																																																																																																																																																																																																																																																																																																																																																						
1120:328	+4	+1	-2	0	0	0	25:48	-0.051370																																																																																																																																																																																																																																																																																																																																																																																																						
1137:039	-1	+3	0	-1	0	0	14:27	-0.051852																																																																																																																																																																																																																																																																																																																																																																																																						
1200:000	+1	0	0	0	0	0	1:2	+1.000000																																																																																																																																																																																																																																																																																																																																																																																																						
<p>Formula for Harmonicity of an Interval P:Q (P&lt;Q)</p> $H(P,Q) = \frac{\text{sgn}(\xi(Q)-\xi(P))}{\xi(P)+\xi(Q)}$ <p>whereby <math>\text{sgn}(x)=-1</math> for <math>x&lt;0</math>, else <math>\text{sgn}(x)=+1</math></p>																																																																																																																																																																																																																																																																																																																																																																																																														

Figure 20: Formulae and Tables for Indigestibility (upper left) and Harmonicity (lower left).

In 1986 I installed these formulae in a computer program called “Autobusk” (completed in 2002), which I have used on numerous occasions to compose music in real time. Among the many pieces I have partly or wholly realised with Autobusk are *Variazioni e un pianoforte meccanico* (1986), *documissa '87* (1987), *Fruitti d'Amore* (1988), *Orchideæ Ordinariæ* (1988), *otodeblu* (1990), *flvXv\$* (1992), *Estudio Siete* (1995), *Amaludus* (1995), *Le loup en pierre* (2002), *Septima de facto* (2006), and with more recently developed Autobusk-derived software *Für Simon Jonassohn-Stein* (2012) and *ertur* (2015). Many of these pieces have been mentioned elsewhere in this paper in various contexts.

Parallel to these harmonicity formulae, I came up with another set of formulae for “metric indispensability”, the relative metric significance of a pulse within a metre. Shown with these formulae in Fig.21 at bottom right for the metres 3/4 and 6/8 on an eighth-note level, these indispensability values, unique to each pulse, are for the former 5 0 3 1 4 2, and for the latter 5 0 2 4 1 3, reflecting the respective metric significance of the six pulses therein. A process called “rhythmic dilution” is also shown at bottom right, removing attacks in order of increasing indispensability, further demonstrating this system, intrinsic to Autobusk.

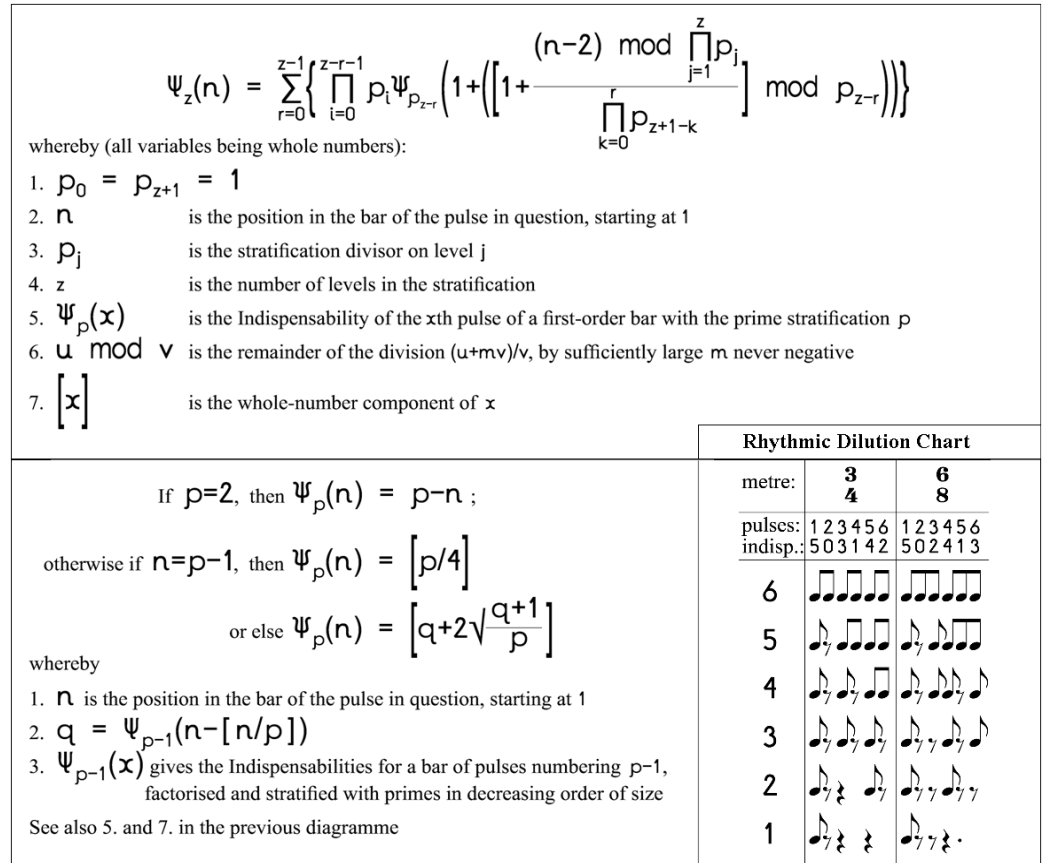


Figure 21: Formulae for Metric Indispensability, and an example of Rhythmic Dilution at lower right.

See also references (Barlow, 1998b, 2001a, 2001b, 2010b, 2012).

## 5 MUSICAL SOURCES

Here I will refer to three of my pieces drawing on pre-existing music works: *1981* (1981), *Würfengang* (1995) and *ertur* (2015).

### 5.1. 1981 (1981)

In my piano trio *1981*, piano trios by the three composers Muzio Clementi (*La Chasse* in C, 1788), Robert Schumann (*Trio No.2* in F, 1847) and Maurice Ravel (*Trio* in A minor, 1914), one movement each, formed the starting point. In Fig.22, each instrument, violin, cello and piano, describes an individual spiral starting at the centre of a triangle with the composers Clementi, Schumann and Ravel at apices C, S and R. The numbers beside the images of the three instruments are score markers of multiples of 18 bars. The distance of the instruments' position from an apex at any given time is mathematically related to the amount of the music of the composer at the apex in the general mix. Thus, at the start of the piece, at the triangle centre, 33% of the notes in the score come from each composer. But at bar 410, just to the left of marker 23, all three instruments are together at the Clementi apex: the score contains 100% of his music at this point, together with a small percentage of the music of the other two composers, above zero since they are not infinitely distant.

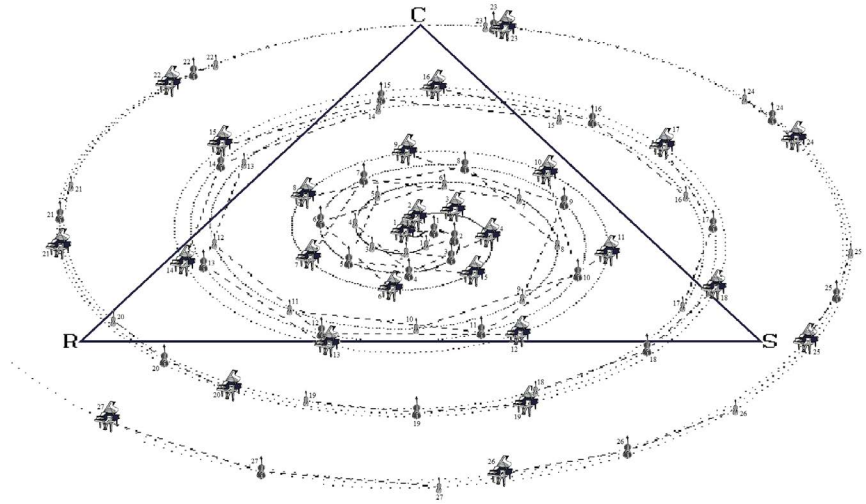


Figure 22: Triangle and Spiral used for the composition of 1981.

See also reference (Barlow, 2012).

### 5.2. WÜRFELGANG (1995)

As modular notes and instructions written by Wolfgang Amadeus Mozart, his *Musical Dice Game* published in 1793 made it possible through combinatorics to ‘compose’ a large number of new waltzes. For each of the 16 bars to be made he provided 11 alternatives, one of which is randomly picked by dice. This creates about  $46 \times 10^{15}$  different pieces. So far, many computer programmers have made real-time realizations of this piece. New in this project was that a statistical Markov-analysis, named after its inventor Andrey Markov (1856-1922), was applied to Mozart’s material causing as expected different degrees of ‘note-fidelity’ – at Markov level 4 it is not easy to tell the result from the original, at level 2 the music sounds interestingly distinct from the original, but remains stylistically relatively faithful. Level 0 is only able to produce clumsy but comical imitations of Mozart’s music. I realised this Markov-treated Mozart work as the computer program *Würfengang* (“Würfel” = “dice”, “Gang” = “course”), a pun on “Wolfgang”, which sends MIDI notes to a computer-driven player piano or synthesizer – see Fig.23.

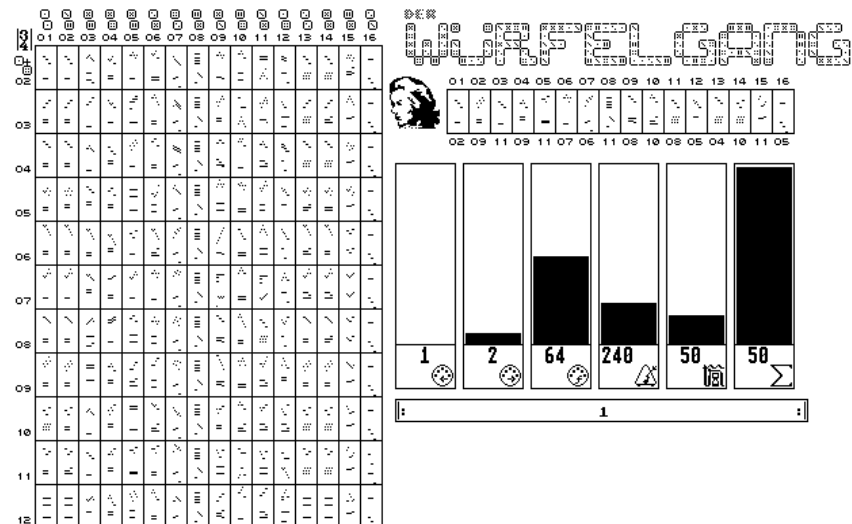


Figure 23: A screenshot of *Würfengang* – Mozart’s material at left, parameters and a dice choice at right

## 5.2. )ERTUR( (2015)

When requested by my Los Angeles-based art-collector friend Raj Dhawan to write music for an exhibition of his collection of Alphonse Mucha (1860-1939) paintings, I at once thought of basing the music on that of a Mucha contemporary and compatriot. My choice fell on the composer Leoš Janáček (1854-1928), born, like Mucha, in Moravia (then in the Austrian Empire, today in Czechia). 37 selected Mucha paintings are matched by 37 Janáček pieces, many of them movements of larger works. The bigger the paintings, the longer the music selections are: the square root of the areas in inches of the Mucha works equals the durations of the Janáček selection in seconds. Each of the 37 music selections is accompanied by a video showing the corresponding Mucha painting, expanding in accuracy from its centre as described below. A sharp crack preceding each section stems from a clapperboard as used in movie recordings.

At first the music is constrained to the range of a minor 7<sup>th</sup>, all notes outside this range being discarded. The notes are also redistributed among five spatially separated instruments – flute, clarinet, violin, cello and piano – and the pitch range gradually increases to just over four octaves, each instrument being allotted exactly ten different notes by then. Also every instrument except the piano plays microtonally – see Fig.24 for an example of a couple of bars of Janáček’s original *Barn Owl* compared with its treatment in )ertur( in section 5 – the grey-shaded notes in the Janáček example are filtered out in )ertur(.

The image displays a musical score for the piece 'Barn Owl'. On the left, the original piano score is shown with some notes shaded in grey. On the right, the reworked score for the piece 'ertur(' is shown, featuring five staves for Flute, Clarinet in Bb, Violin, Violoncello, and Piano. The tempo is marked as quarter note = 55. The reworked score includes microtonal adjustments indicated by numbers like -29c, -14c, +29c, and +14c. The original score has a 'rit.' marking, and the reworked score also has a 'rit.' marking.

Figure 24: Janáček’s *Barn Owl* treated for )ertur(

Analogue to this, each Mucha painting is first shown only with its most widespread colour, the rest being in grey. During the run of each Janáček piece, the colours of the Mucha works are gradually restored in range, starting at the middle of the image, to finally include all original colours in the entire picture. Fig.25 gives an example of this in section 5 of the piece, albeit grey shaded here. This audiovisual composition bears the title )ertur(, which – resembling the widening ranges of pitch, area and colour – could be expanded to include words like *aperture* (English, French), *apertura* (Czech, Italian, Polish), *abertura/cobertura* (Spanish, Portuguese) or *copertura* (Italian), all implying opening or covering. The reverse parentheses in the title are also relevant, the left one representing a fragment of a preceding “p” or “b”, the right one that of a following “e” or “a”. Irrelevant: “ertur” happens to mean “peas” in Icelandic.



Figure 25: Four stages in the unfolding of area and colour in a Mucha painting in section 5 of *Pierrot*

## 6. CONCLUSION

This is a comprehensive account of my use of a range of pre-existing sources to compose music by generative means other than the detailed imagination of sound. The processes outlined above were shaped by my taste, that subjective and descriptively elusive phenomenon, towards results aesthetically welcome to me and potentially to others. The processes were convergent on the conceptual and/or executional level: on reviewing each developmental stage in making the pieces described above, my artistic judgement would usually lead me to make a change in the generation process, typically algorithmic, often followed by further alterations, until I achieved a gratifying result I could declare final. This is analogous to preparing a meal, gradually improving its taste and texture until the result satisfies its cook, who thereby ‘overwrites’ each stage of the meal’s development, keeping the final result for consumption.

## REFERENCES

- Barlow, C. (1996). On the spectral analysis of speech for subsequent resynthesis by acoustic instruments. *Academy Bourges* Vol. II (pp. 82-88, 276-283). Mnemosyne Bourges. ↑ §1.3., 3.2. above.
- Barlow, C. (1997). Composed diffusion: the (in)soluble and the (ir)relevant in my work. *Academy Bourges* Vol. III (pp.12-19, 196-203). Mnemosyne Bourges. ↑ §2.
- Barlow, C. (1998a). Songs Within Words. In M. Bryden (Ed.), *Samuel Beckett and Music* (pp. 233–240). Oxford University Press. §1.1
- Barlow, C. (1998b). „...eine arithmetische Übung der Seele...“. In U.H. Engel (Ed.), *Report 34*, IAK-Sonderband (pp. 11-32), Musikinformatik & Medientechnik, Musikwissenschaftliches Institut, Gutenberg University. ↑ §4.2.

- Barlow, C. (2000). Auf der Suche nach dem reell Globalen – Zur physischen Ertastung der Erde in Raum und Zeit. Lab. In T. Hensel et al (Eds.), *Jahrbuch 2000 für Künste und Apparate, Academy of Media Arts Cologne* (pp.183-188). Walther König Verlag. ↑ §2.
- Barlow, C. (2001a). Autobusk. *Report 44, Autobusk*, 1-54. Musikinformatik & Medientechnik, Musikwissenschaftliches Institut, Gutenberg University. ↑ §4.2.
- Barlow, C. (2001b). On the Quantification of Harmony and Metre. In C. Barlow (Ed.), *Feedback Papers 43, THE RATIO BOOK*, (pp. 2-23). Feedback Studio Verlag. ↑ §4.2.
- Barlow, C. (2005a). Zero Crossing. In T. Möller et al. (Eds.), *SoundVisions* (pp. 34-35). Pfau-Verlag. ↑ §2.
- Barlow, C. (2005b). ISIS, an Alternative Approach to Sound Waves. *Proceedings International Computer Music Conference* (pp. 660–663). ↑ §4.1.
- Barlow, C. (2008). On the Derivation of Music from Language. In A. K. Dutta et al. (Eds.), *Proceedings International Symposium Frontiers of Research on Speech and Music* (pp. 91–95). ↑ §1.
- Barlow, C. (2009a). Visualising Sound – Sonifying the Visual. *Proceedings Hawaii International Conference on Arts & Humanities* (pp. 2727-2734). ↑ §3.
- Barlow, C. (2009b). On Music Derived from Language. In G. E. Lasker et al. (Eds.), *IIAS-Transactions on Systems Research and Cybernetics Volume IX, No.1* (pp. 29-33). The International Institute for Advanced Studies in Systems Research and Cybernetics. ↑ §1.
- Barlow, C. (2010a). Visualizando el Sonido – Sonificando lo Visual. Itamar – *Revista de investigación musical* 3, 279-291. ↑ §3.
- Barlow, C. (2010b). Mathematics as the Source of Music Composition. In G. E. Lasker et al. (Ed.), *Proceedings, 1<sup>st</sup> International Symposium on Music/Sonic Art* (pp. 1-5). The International Institute for Advanced Studies in Systems Research and Cybernetics. ↑ §4.
- Barlow, C. (2012). Music Derived from Other Sources. *The International Journal of the Humanities* 7(9), 135-146. ↑ §1.1., 1.4., 2., 3.3., 4., 5.1.
- Barlow, C. (2014a). On Ramifications of Intonation. In M. Sabat (Ed.) *KunstMusik* 16 (pp. 40-48). Maria de Alvear World Edition ↑ §1.3., 4.1.
- Barlow, C. (2017). On the Structural and the Abstract in My Compositional Work. In G. Pareyon et al. (Eds.), *The Musical-Mathematical Mind. Computational Music Science* (pp. 41-52). Springer International Publishing. ↑ §3.4., 4.1.

Barlow, C. (2018). Synästhesien? Klangvisualisierung – Bildsonifikation (2004). In G. Gronemeyer & al. (Eds.), *MusikTexte* 158 (pp. 35-39). ↑ §3.

Article received on 12/01/2021 and accepted on 23/03/2021.

[Creative Commons Attribution License](#) | This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.