3 Manual Microtonal Organ

http://www.bek.no/~ruben/Research/Downloads/software.html

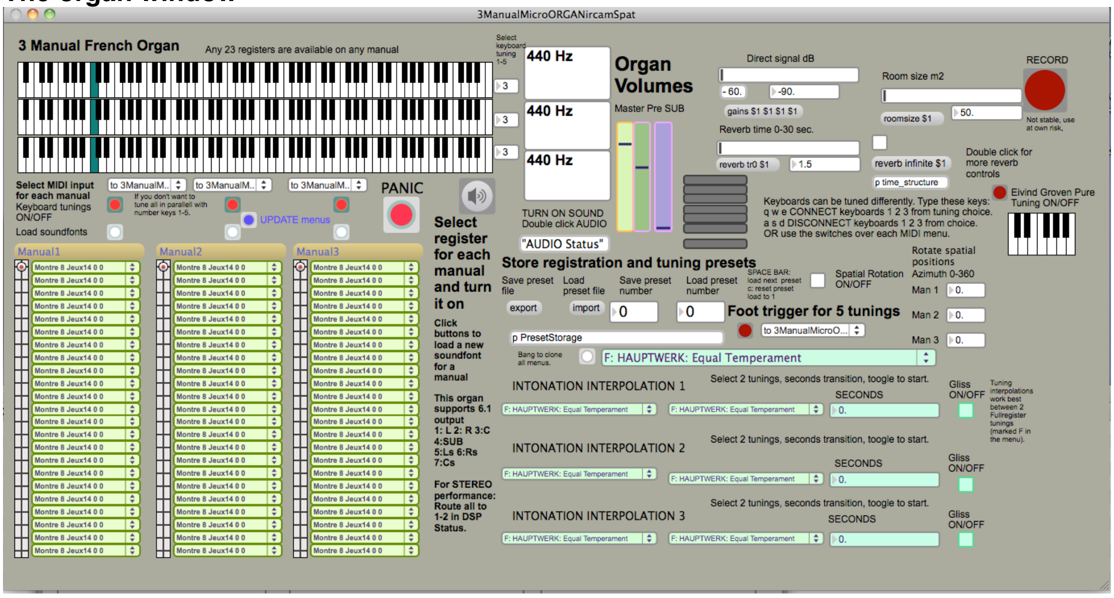
Ruben Sverre Gjertsen 2013

An interface to existing software

A motivation for creating this instrument has been an interest for gaining experience with a large range of intonation systems. This software instrument is built with Max 6[1], as an interface to the Fluidsynth object[2]. Fluidsynth offers possibilities for retuning soundfont banks (Sf2 format) to 12-tone or full-register tunings. Max 6 introduced the dictionary format, which has been useful for creating a tuning database in text format, as well as storing presets. This tuning database can naturally be expanded by users, if tunings are written in the syntax read by this instrument. The freely available Jeux organ soundfont[3] has been used as a default soundfont, while any instrument in the sf2 format can be loaded.

The organ interface

The organ window



3 MIDI Keyboards

This instrument contains 3 separate fluidsynth modules, named Manual 1-3. 3 keysliders can be played staccato by the mouse for testing, while the most musically sufficient option is performing from connected MIDI keyboards. Available inputs will be automatically recognized and can be selected from the menus. To keep some of the manuals silent, select the bottom alternative "to 2ManualMicroORGANircamSpat 1", which will not receive MIDI signal, unless another program (for instance Sibelius) is sending them.

A separate menu can be used to select a foot trigger. The red toggle must be pressed for this to be active. This has been tested with Behringer FCB1010 triggers. Other devices could possibly require adjustments to the patch.

Organ registrations

The organ stops below are working like on a large organ with up to 23 simultaneus sounds for each manual. Select sounds from the menu, and toogle them on with the matrix buttons.

---

[1] http://cycling74.com/

[2] http://imtr.ircam.fr/imtr/FluidSynth_for_Max/MSP

[3] http://www.realmac.info/jeux1.htm#ABOUT

All these choises are included in the preset system. In order not to overload the fluidsynth objects, organ registrations have individual trigger delays whenever a preset is loaded.

Keyboard tunings
In order to perform tunings with more than 12 tones per octave, the user can switch between 5 parallel tunings or bendings. This is done routing the input between 5 parallel MIDI channels for each of the 23 stops, adding up to 115 MIDI channels for each manual.
The meaning of this change is defined in the tuning database for each tuning. Often it's done by pitch bend. For this reason the input MIDI pitchbend wheels have been disabled, as they would reset individual bendings. The modulation wheel is still active, even though using it would take away some of the realism from the organ samples.

Switching between keyboard tunings
To select a keyboard tuning for all 3 manuals type numbers 1-5 with the organ patch in the foreground, or select a "Foot trigger for 5 tunings" from the MIDI menu to the right.
To select keyboard tunings for an individual manual, type directly into the number box at the right of each keyboard, or disconnect some of the keyboards by turning off the red toggles below the keysliders.[4] Foot triggers or number keys will now only affect only the enabled keyboards.
Information about the selected keyboard tunings will be displayed in the textbox by each keyslider. For the 'partials' tuning, this will include partial number currently performed at the keyboard.

Load soundfonts
To load other sounds than the default Jeux organ, push the bottons to load sf2 files for each of the 3 modules. Menus below will be automatically updated (from a dump of current state of the fluidsynth object). If not, push the blue "UPDATE menus" button. Sounds from different soundfonts can be combined as long as they don't share the same bank and program number (in this case they will replace each other in the menus). All of the Jeux stops are handled correctly, while not all sounds from the larger Stefans Cathedral soundfont can be loaded at the moment. This is a future challenge.

Selecting output
Double click Audio Status to select output device, routings or other audio options.

Organ Volumes
Volume can be adjusted for Master, Pre and Sub through the volume sliders.
It is not recommended to increase Pre Volume when combining several loud organ stops, as clipping may occur and not be visible on the master level meters below. Increasing this level can be useful when performing with only one sound.

Store registration and tuning presets
This storage system saves current settings in a text format. MIDI inputs or reverb settings cannot be saved and must be manually selected each time. Changes to reverb settings could cause clicks, this is the why they are kept out of the preset system.
To save settings: type a preset number in the box, press enter.
To load settings: type a preset number in the box, press enter. Or press the spacebar to start counting from 1. This count will be reset when a new preset file is loaded.
Because of necessary triggering delays with a large number of midi channels, completely loading settings may take up to 2 seconds.
To save a preset file: Press "export".
To open a preset file: Press "import".

Main tuning
The large green menu will by default load an equal tempered tuning with 1/8-tone pitchbends.

[4] The piano keyboards in the patch.

This menu will be automatically filled from the database stored in TemperamentsDICTIONARY.json . This file can be edited in any pure text editor, like Textwrangler or BBedit. Press "Bang to clone all menus" to syncronize the interpolation menus, as they can in some cases send competing messages when triggering a cue. The selected tuning will be triggered for all the midi channels, and keyboard bend information will be updated. The text box will be updated when you start playing at the keyboards.

Intonation interpolations

This instrument also offers the possibility to perform a glissando between 2 tunings, for each manual, selected from the small menus. You must actively select 2 tunings, seconds interpolation time, and check the "Gliss ON/OFF" toogle to make it start. Turning it off and on will start the interpolation again from the start. If you select the same initial and final tuning (in 1 second), you can use this to set a different tuning for each manual.

Interpolation will work best between 2 fullregister tunings. These are marked F in the menus, while 12-tone tunings are marked 12t. Interpolations between F and 12t will not work well, because these lists do not have the same length.

Eivind Groven

The Eivind Groven pure tuning organ has been added as an additional option. Toogling this on will override all the other tuning settings. The system will recognize thirds, fifths and major/minor chords, retune them to Eivind Grovens system. This will happen when repeating the same chord twice. The effect will be most clear performing tonal music staying within a key.

The textfile Groven36.json contains the corresponding cent values for every note name in the Groven system. All twelve notes have 3 alternative intonations, which will add up to 36 tones.

The textfile GrovenSetChords.json contains sets of notes to retune when recognizing certain chords. It would of course be possible to edit these textfiles and change the Groven system into something completely different.

With some work one could create a similar menu system with a database of intonation systems retuning themselves after performed pitches. I provide the basics for Groven here and will leave development of this to interested users.

Record

You can use the record button to record your performance in surround. This is not completely safe for use, due to some buffering problems in the *sfrecord~* object in Max. It will crash at some time, especially if recording for more than 30 minutes.

Spatial rotation

Each manual has a stereo output. When "Spatial rotation" is on, manuals will rotate individual through the speaker setup through random walks. Direction and speed will automatically vary. This is not available in the stereo version not using Ircam Spat.

Static manual positions can be set in degrees 0-360 in the nearby number boxes.

Reverb

Ircamverb is used for the surround version. Basic settings like "Direct signal", "Room size", "Reverb time" and "Infinite reverb" are available from the main window. The Ircamverb interface will be open behind the main window, and offers more detailed options.

The stereo version uses a simpler type of reverb. In this version, time (0-1) cannot be set higher than .99, as time 1 would not damp properly.

Sources of tunings

It will be fair to give sources for the tunings made available in this instrument. A footnote reference is provided for each of these paragraphs.
Tunings are notated either as cent deviations from each note, a scale 0-1200, or full-register tuning. The organ is programmed to handle these 3 notations.

12-tone tunings

Equal temperaments

12-tone equal temperament is the default MIDI tuning. Cents deviation for an octave is:
0 0 0 0 0 0 0 0 0 0 0 0 0
1/8-tones, 1/6-tones and 1/10 are just further subdivisions of this, done by detuning the 5 parallel keyboards.

Lasse Thoresen has preferred 1/6-tones (33 cents) to 1/8-tones for his Micropalette[5]. I have included this as an option named "Concrescence Thoresen 1/8-tones", where 1/4-tones and 1/6-tones are combined.

Huai Nan Tzu Temperament (+123 B.C.)[6]

Huai Nan Tzu 750 Temperament (+123 B.C.)
c g d a e h f# c# g# d# a# e#
0 702 204 906 408 1137 608 110 801 303 1018 520
In order: 0 110 204 303 408 520 608 702 801 906 1018 1137 0

Chu Tsai-Yü 749 Temperament
c g d a e h f# c# g# d# a# e#
0 702 204 906 408 1096 608 110 801 303 1018 520
In order: 0 110 204 303 408 520 608 702 801 906 1018 1096 0

Chin Shu Temperament (without e#)
0 113.82 201.84 293.83 418.69 418.69 611.71 699.71 791.93 906.23 995.82 1109.86

Irregular temperament of Ho Ch'êng-T'ien (after Sung Shu c. 500 A.D.)
c g d a e h f# c# g# d# a# e#
0 699 200 897 398 1092 596 101 791 297 985 493
In order: 0 101 200 297 398 493 596 699 791 897 985 1092 0

Old Lü (Pythagorean) temperament (after Sung Shu c. 500 A.D.)
c g d a e h f# c# g# d# a# e#
0 702 204 906 408 1110 612 114 816 318 1020 522
In order: 0 114 204 318 408 522 612 702 816 906 1020 1110 0

Temperaments and Tunings: A Guide for Lute Players[7]

Pythagorean tuning (starting from G)
Sharps: 0 114 204 318 408 498 612 702 816 906 1020 1110 1200
Flats: 0 90 204 214 408 498 588 702 792 906 996 1086 1200

1/4 Comma (starting from G)
Sharps: 0 75.5 193 268.5 386 503.5 579 696.5 772 889.5 965 1082.5 1200
Flats: 0 117.5 193 310.5 428 503.5 621 696.5 814 889.5 1007 1124.5 1200

1/5 Comma (starting from G)
Sharps: 0 83.2 195.2 278.4 390.4 502.4 585.6 697.6 780.8 892.8 976 1088 1200
Flats: 0 112 195.2 307.2 419.2 502.4 614.4 697.6 809.6 892.8 1004.8 1116.8 1200

1/6 Comma (starting from G)
Sharps: 0 88.3 196.6 285 393.3 501.6 590 698.3 786.6 895 983.3 1091.6 1200
Flats: 0 108.3 196.6 305 413.3 501.6 610 698.3 806.6 895 1003.3 1091.6 1200

1/8 Comma (starting from G)
Sharps: 0 94.75 198.5 293.25 397 500.75 604.5 699.25 794 897.75 992.5 1111.6 1200
Flats: 0 103.75 198.5 302.25 406 500.75 604.5 699.25 803 897.75 1001.5 1111.6 1200

"396" (starting from G)
Sharps: 0 93 198 291 396 501 594 699 792 897 990 1005 1095 1200
Flats: 0 105 198 303 408 501 606 699 804 897 1002 1107 1200

"Gerle" (starting from G)
Sharps: 0 88.8 196.8 285.6 393.6 501.6 590.4 698.4 787.2 895.2 984 1092 1200
Flats: 0 108 196.8 304.8 412.8 501.6 609.6 698.4 806.4 895.2 1003.2 1111.2 1200

Pure intervals (starting from G)
0 90 112 204 316 386 498 590 702 814 884 996 1088 1200

Nicola Vicentino [8]

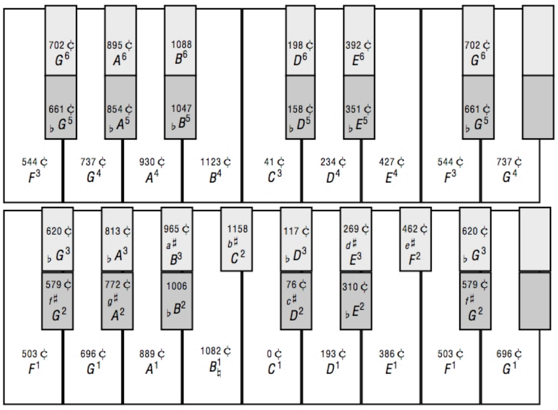
Nicola Vicentino (1515-1575/76) developed the Archicembalo, an instrument with 2 keyboards both containing two sets of upper keys. Notes are sorted to start at c.

---

[5] The Micropalette patches are freely available at the Concrescence website: http://www.lassethoresen.com/concrescence/micropalette.html
[6] Kuttner, 1975, Asian Music, 6, No. 1/2, 88-112.

[7] The following tunings are found at this website: http://www.theaterofmusic.com/temperaments.html
[8] This information and illustration is found at: http://en.wikipedia.org/wiki/Nicola_Vicentino

Upper keyboard , with upper keys:
41 198 234 392 427 544 702 737 895 930 1088 1123 41
Upper keyboard, with lower keys:
41 158 234 351 327 544 651 737 854 930 1047 1123 41
Lower keyboard, with upper keys:
1158 117 193 269 385 462 462 620 696 813 889 965 1082 1158
Lower keyboard, with lower keys:
0 76 193 310 385 503 579 696 772 889 1006 1082 0



For comparision, this tuning table is provided by Kaufmann[9] (starting from A):

A 0

*A 38.7

A# 77.5

Bb 116.1

*Bb 154.8

B 193.6

*B 232.3

B# 270.9

C 309.7

*C 348.4

C# 387.1

Db 425.8

*Db 464.6

D 503.2

*D 541.9

D# 580.6

Eb 619.3

*Eb 658.1

E 696.8

*E 735.5

E# 774.2

F 813

*F 851.5

F# 890.4

Gb 929

*Gb 967.7

G 1006.5

*G 1045.2

G# 1083.9

Ab 1122.6

*Ab 1161.3

A 1200

For further studies, read Vicentino[10]. Performing in this tuning would be more practical if this organ was expanded to 4 manuals, or through the use of an entirely different keyboard type. Applying the Harry Partch system to 12-tone keyboards brings up similar problems.

Irregular systems of temperament[11]

Pythagorean
0 114 204 294 408 498 612 702 816 906 996 1110 1200

Grammateus (Pythagorean Mean semitones)
0 102 204 306 408 498 600 702 804 906 1008 1110 1200

Just
0 70 182 316 386 498 568 702 772 884 996 1088 1200

Ganassi
0 88 182 281 386 498 597 702 790 884 983 1088 1200

Meantone (12 tones)
0 76 193 290 386 503 600 697 794 890 987 1083 1200

Werckmeister 1
0 90 192 294 390 498 588 696 792 888 996 1092 1200

Neidhardt's Circulating Temperament
0 94 198 296 390 498 592 700 794 894 998 1092 1200

Young's Second Temperament
0 90 196 294 392 498 588 698 792 894 996 1090 1200

[9] Henry W. Kaufmann, 1970, Journal of the American Musicological Society, 23, No. 1, 84-94.

[10] Vicentino, 1996, Ancient music adapted to modern practice.
[11] J. Murray Barbour, 1948, Journal of the American Musicological Society, 1, No. 3, 20-26.

Temperament by Regularly Varied Fifths
0 92 197 297 392 500 591 699 794 894 999 1091 1200

Historical temperaments[12]

Total Medieval (no c#, eb, g#)
0 0 192.3 192.3 387.1 499.9 587.3 698.2 698.2 890.1 1003.2 1086.6 1200

Total Early Ren
0 73.6 189.2 308.3 386.8 501.5 575.1 696.8 773.1 887.9 1003.5 1085.3 1200

Total Virg'ists
0 76.8 193.5 300.8 387.6 503.3 580.8 696.5 773.4 890.4 1005.9 1085.0 1200

Total Couperin
0 89.5 195.4 299.1 392.5 501.9 589.0 696.7 793.0 895.3 1000.5 1089.5 1200

Schlick Maria Zart (no Eb, G#, B nat.)
0 71.8 188.1 188.1 386.2 500.6 572.7 695.9 695.9 886.7 1002.8 1002.8 1200

Couperin Prelude
0 80.2 196.4 273.5 388.6 466.5 582.7 699.6 776.1 893.9 967.6 1085.7 1200

Bach Prelude
0 81.8 193.1 309.5 389.2 504.5 579.3 695.4 812.0 891.9 1007.8 1082.2 1200

Franck Chorale
0 100.4 203.7 303.1 404.0 493.4 600.1 701.7 801.8 907.0 998.1 1106.4 1200

1/4 Comma Meantone 12 tones (after Donald Hall)
0 76.1 193.2 310.3 386.3 503.4 579.5 696.6 772.6 889.7 1006.8 1082.9 1200

Hauptwerk tunings

The virtual pipe organs offered by Hauptwerk[13] include a few historical temperaments. I have included these in my tuning library. They are written in fullregister format. This will allow glissandi to any other fullregister tuning.

Other divisions of pitch space

Approaching tuning systems with other divisions of the octave than 12, or systems without octaves, will bring up problems of keyboard mapping. Many asian or african tunings use fewer intervals within an octave. A few different solutions have been tested here:

- Repeating notes to fill each octave.
- Filling the keys of the keyboard in order with stacked intervals. This may be less intuitive to perform, and sampled notes may appear in less than optimal transpositions. For tunings which are very different from standard 12-tone tunings (like partials of a deep fundamental), this can be hard to avoid when using the soundfont system and a pianotype keyboard. Slendro and pelog tunings may extend both over and under the audible register. In some cases audibility can be expanded by adding organ stops down to 32' or up to 1'. The keyboard needs to be explored in every case.

Javanese Pelog tunings[14]

Kunst Javanese Gamelan

	bem	gulu	dada	pélog	lima	nem	barang	(bem)
interv.	120	150	266.5	130.5	113	167.5	251	

Kunst Javanese Gamelan Simplified

bem	gulu	dada	pélog	lima	nem	barang	(bem)
125	150	250	125	125	175	250	

Javanese Gamelan Manfred Bukofzer

bem	gulu	dada	pélog	lima	nem	barang	(bem)
110	150	255	140	115	190	240	

Javanese Gamelan Wasisto Surjodiningrat

bem	gulu	dada	pélog	lima	nem	barang	(bem)
120	138	281	135	110	158	263	

Equal Tempered Gamelan [These are not implemented in the microtonal organ. Rather than seeking standardization one could embrace the irregularities.]:

Javanese Gamelan 1/23-tone tempered Jay Rahn

bem	gulu	dada	pélog	lima	nem	barang	(bem)
104	157	261	157	104	157	261	
2/23	3/23	5/23	3/23	2/23	3/23	5/23	

Javanese Gamelan 1/12-tone tempered Jay Rahn

bem	gulu	dada	pélog	lima	nem	barang	(bem)
100	200	200	200	100	200	200	
1/12	2/12	3/12	2/12	1/12	2/12	2/12	

Javanese Gamelan 1/9-tone tempered Jay Rahn

bem	gulu	dada	pélog	lima	nem	barang	(bem)
133	133	267	133	133	133	267	
1/9	1/9	2/9	1/9	1/9	1/9	2/9	

Slendro and Sadjagrama[15]

Slendro
0 218 473 721 954 1213 1458 1695

Sadjagrama

g	c	d	e	f	g	a	bb	c
+9	0	-36	-27	-9	+9	-27	-18	0

[12] Donald Hall, 1973, Journal of Music Theory, 17, No. 2, 274-290.
[13] http://www.hauptwerk.com/
[14] Jay Rahn, 1978, Javanese Pélog Tunings Reconsidered, 69-82.
[15] http://www.oddmusic.com/gallery/hang/hang_files/

Other tunings[16]

North Indian Ragas

Raga Dabari Kanada
0 203.9 266.9 315.6 498.1 702 764.9 813.7 996.1 1200

Raga Shuddha Kalyan
0 203.9 386.3 702 884.4 1200

Raga Hamsadhwani
0 203.9 386.3 702 1088.3 1200

Central Java Pelog & Slendro

Java Kanjutmesem Slendro
0 252 490 731 967 1220

Java Kanjutmesem Pelog
37 178 319 519 731 846 1018 1264

Java Si Darius Slendro
0 204 435 702 933 1200

Java Si Madeleine Pelog
137 276 404 740 839 933 1106 1337

Java Lipur Sih Slendro
0 273 509 733 991 1247

Java Lipur Sih Pelog
216 326 479 732 787 991 1170

Harry Partch's 43
This has been split this into 4 keyboards to fit with the MIDI keyboards. This is a limitation, another keyboard design could make these tunings more accessible. The diamond shaped percussion instrument designs by Partch could be an alternative. Tom Mudd has developed the *Just Intonation Toolkit*[17], where different ranges of the computer keyboard are used for each tuning, clearly shown through the interface. If this 3 Manual Microtonal Organ was not designed to make a large amount of tuning systems available in every octave for standard MIDI equipment, it would be tempting to have keyboard designs adapted for each individual tuning system.

Keyboard 1
0 111.7 203.9 315.6 435.1 551.3 680.5 782.5 905.9 1017.6 1115.5 1200 1200

Keyboard 2
21.5 150.6 231.2 347.4 470.8 582.5 702 813.7 933.1 1035.0 1146.8 1200 1200

Keyboard 3
53.5 165 266.9 386.3 489 617.5 729.2 852.6 968.8 1049.4 1178.5 1200 1200

Keyboard 4
84.5 182.4 294.1 417.5 519.5 648.7 764.9 884.4 996.1 1088.3 1200 1200 1200

[16] http://eamusic.dartmouth.edu/~larry/published_articles/emi_tuning_chart.pdf
[17] http://tommudd.co.uk/justintonation/

Ben Jonhston's 22
Keyboard 1
0 63.0 182.4 266.9 386.3 470.8 590.2 702 764.9 884.4 968.8 1088.3 1200

Keyboard 2
0 111.7 231.2 315.6 435.1 519.6 639 702 813.7 933.1 1017.6 1137.0 1200

Slendro tuning[18]

Note number; Nearest equal tempered pitch; cents dev. from equal tempered tuning; intervallic size; interval

6 A# +2

1	C#	-30	268	6-1
2	D#	+5	235	1-2
3	F	+50	245	2-3
5	G#	-20	230	3-5
6	A#	+18	238	5-6
1	C#	-25	257	6-1
2	d#	+10	235	1-2
3	F	+47	237	2-3
5	G#	-20	233	3-5
6	A#	+12	232	5-6
1	C#	-38	250	6-1
2	D#	+12	240	1-2
3	D#	-42	254	2-3

Summed up :
Start A# +2 cent to C#-30 cent -> first interval:
268 235 245 230 238 257 235 237 233 232 250 240 254

Intervals:
0 268 503 748 978 1216 1473 1708 1945 2178 2410 2660 2900 3154

14 tones is too much for a 12 tone keyboard; this would require a fullregister tuning.

Table 1: The slendro tuning[19]

Pitch steps	Ratio between steps / Ratio relative to pitch 1	Cents between / Cents relative to pitch 1	Frequency
1	1/1	0.00	282.86
	8/7	231.17	
2	8/7	231.17	323.27
	7/6	266.87	
3	4/3	498.04	377.14
	7/6	266.87	
5	14/9	764.91	440.00
	8/7	231.17	

[18] http://eamusic.dartmouth.edu/~larry/misc_writings/jew_indonesia/LipurSihMeasurements.html
[19] http://www2.hmc.edu/~alves/pleng.html#table1

6 16/9 996.08
502.86
9/8 203.91
1' 2/1 1200.00
565.72

This tuning adds up to a perfect octave, and has not been implemented here.

Xylophones[20]

These scales start on 346 Hz.

Pelog tunings (intervals as cents)

Cambodia Pelog
1 2 3 4 5 6 7 8
178 178 152 155 185 176 186

Java Pelog
1 2 3 4 5 6 7 8
202 133 147 183 196 165 174

E. Africa Chopi Pelog
1 2 3 4 5 6 7 8
162 169 177 174 176 168 174

W. Africa Malinke 1 Pelog
1 2 3 4 5 6 7 8
200 156 200 142 211 136 160

W. Africa Malinke 2 Pelog
1 2 3 4 5 6 7 8
157 178 195 172 156 168 174

Congo Bakwese Pelog
1 2 3 4 5 6 7 8
173 203 180 193 200 176 153

Slendro tunings (intervals as cents)

Java Slendro
1 2 3 4 5
247 222 222 240

Congo Ngbandi Slendro
1 2 3 4 5
219 260 225 211

W. Africa Malinke 3 Slendro
1 2 3 4 5
259 234 228 255

Uganda Baganda Slendro
1 2 3 4 5
225 242 270 233

Balinese modes[21]

There is no fixed concert pitch.

Bali Lebeng
Starting C#+ (intervals as cents):
116 159 258 172 120 185 190 116 159 258 172 120 185

[20] A. M. Jones, 1959, The Journal of the Royal Anthropological Institute of Great Britain and Ireland, 89, No. 2, 155-168.
[21] Wayne Vitale, 2002, Perspective of New Music, 40, No. 1, 5-69.

Bali Gangsa Tunings[22]

(in Hz)
296.51 331.08 419.02 448.4 565.69 608.64
672.44 762.66 822.13 887.83 997.06 1137.3

Javanese scales[23]

Pelog scales
Cents from bem:
1-9:
0 120 258 539 675 785 943 1206 1326

Intervals cent:
120 138 281 136 110 158 263 120
29-36:
4824 4944 5082 5363 5499 5609 5767 6030

Intervals cent:
263 120 138 281 136 110 158 263

Slendro Scales
1-7:
0 231 471 711 951 1205 1436
Intervals cent:
231 240 240 240 254 231

27-31:
6256 6496 6796 6976 7230
231 240 240 240 254

These contain many 240 cent intervals, and are not implemented here.

[22] Andrew C. McGraw, 1999, Asian Music, 31, No. 1, 63-99.
[23] 1994, Leonardo Music Journal, 4, 59-68.

Building new scales from javanese intervals

Random slendro

Javanese gamelan ensembles all have their own tuning variations. If a 5-note slendro mode was built just by an interval of 240 cents, the octave would be divided into 5 equal parts. I find the shimmering quality of the detuned octaves especially interesting, and this has been a criteria for this selection. By including the irregular variations of the slendro interval, mentioned above, we will have this reservoir or intervals:
268 286[24] 235 245 230 238 257 235 237 233 232 250 240 254 273 236 224 258 256 218 255 248 233 259 245 237
The 50 random slendro tunings are built from random stackings of these intervals. This will create unique tunings, which can be explored one by one.
Intervals from the same reservoir are stacked to create 5 different keyboard tunings. This kind of transposition it not available within a single gamelan set. This transposition could be compared to bringing several different gamelan sets together.

Random pelog

The pelog scales have 7 notes, even though gamelan pieces may use only 5 of these. As this scale is build of smaller and larger intervals, not roughly equal steps like in slendro, I will make a distinction between the different steps of these scales. This reservoir of intervals can create new modes rich of detuned octaves.

Pelog step 1
120 110 120 141 139 110 202 120 120 132 128 126 158 136 138 132 130
Pelog step 2
150 150 138 141 128 153 133 138 146 154 166 136 162 142 140 126
Pelog step 3
266.5 255 281 200 336 253 147 281 284 272 254 266 270 294 292 268
Pelog step 4
130.5 140 135 212 99 55 183 136 126 130 180 140 116 118 120 112
Pelog step 5
113 115 110 115 94 205 196 110 108 110 102 110 102 106 108 96 108
Pelog step 6
167.5 190 158 172 173 179 158 206 198 176 198 214 204 208 224 206
Pelog step 7
251 240 263 246 231 174 263 220 242 220

The 50 included random pelog tunings, are in fact 250 variations, as each tuning includes 5 variations selected by triggers.

Melodyne tunings

The software Melodyne[25] offers the possibility to retune recordings to a pitch grid. A number of tunings are included as possible pitch grids. I have included these same tunings in my library and credit Melodyne as the source.
These include pelog and slendro scales, turkish commas and modes, Bohlen-Pierce scale, and the tunings of a number of asian and african instruments. Scales are stacked to fill the whole keyboard.

[24] The interval 286 cent is not present in the slendro sources, but has been kept to create more irregularities. The random tunings are made as creative reinterpretations of the preceding musicological information.
[25] http://www.celemony.com/cms/index.php?id=products_editor

Eivind Groven pure tuning organ

The Eivind Groven pure tuning organ will require a different programming, as intonation is adjusted after pitches being performed. A software version of this is freely available for download from Notam.[26] My own implementation of this has been made through study of information published by David Loberg Code,[27] and the functionality of the Notam patch. Adding the Groven system to this 3 Manual Microtonal organ adds the possibility to combine multiple organ stops. This table is found at the Code website:

Pitch	Millioct.	Cents	Pitch	Millioct.	Cents
C_2	0,00	0.00	F#2	491,44	589.73
C_3	17,10	20.52	Gb3	508,55	610.26
$C\#_1$	59,13	70.95	G_1	567,65	681.18
$C\#_2$	76,20	91.44	G_2	584,76	701.71
Db_3	93,31	111.97	G_3	601,86	722.23
D_1	152,41	182.89	$G\#_1$	643,88	772.66
D_2	169,51	203.41	$G\#_2$	660,96	793.15
D_3	186,61	223.94	Ab_3	678,07	813.68
$D\#_1$	228,64	274.37	A_1	737,17	884.60
Eb_2	245,73	294.87	A_2	754,26	905.11
Eb_3	262,83	315.39	A_3	771,38	925.65
E_1	321,92	386.31	$A\#_1$	813,40	976.08
E_2	339,02	406.82	Bb_2	830,48	996.58
E_3	356,13	427.36	Bb_3	847,58	1017.1
$E\#_1$	398,16	477.79	B_1	889,58	1067.5
F_2	415,24	498.29	B_2	906,67	1088.0
F_3	432,34	518.81	B_3	923,75	1108.5
$F\#_1$	474,37	569.24	$B\#_1$	982,92	1179.5

[26] http://www.notam02.no/web/2005/11/portabel-renstemmingsautomat/

[27] http://www.wmich.edu/mus-theo/groven/

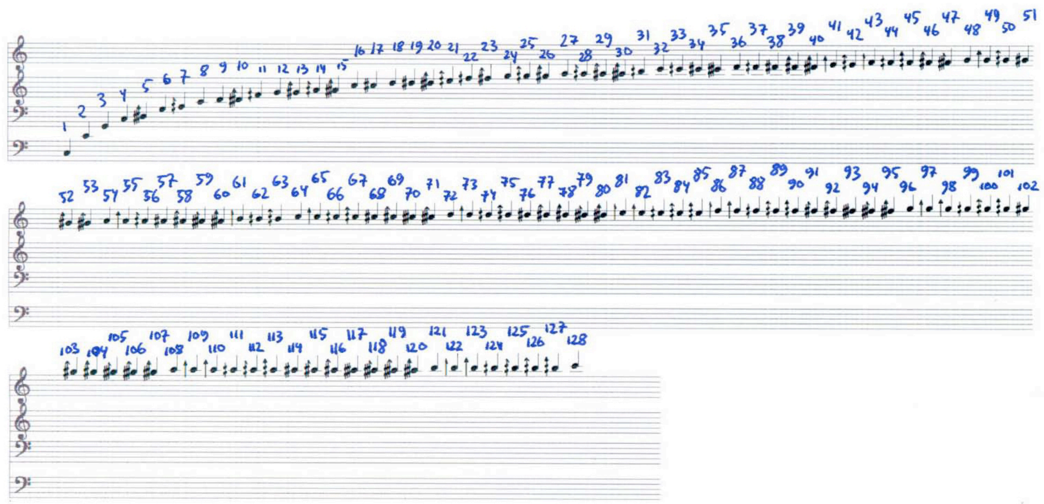
The Groven system consists of 36 tones, where notes are selected by what notes are being performed. Each of the 12 tones has 3 possible intonations (ex. B#1, C2, C3).
Studying the behavior of the Notam patch, I have notated rules into a dictionary file named GrovenSetChords.json:


```
{
	"C-dur" : [ "0 4 7", "C2 G2 E1" ],
	"Db-dur" : [ "1 5 8", "Db3 F2 Ab3" ],
	"D-dur" : [ "2 6 9", "D2 F#2 A2" ],
	"Ess-dur" : [ "3 7 10", "Eb3 G2 Bb3" ],
	"E-dur" : [ "4 8 11", "E2 G#2 H3" ],
	"F-dur" : [ "0 5 9", "F2 A1 C2" ],
	"F#-dur" : [ "1 6 10", "Gb3 Bb2 Db3" ],
	"G-dur" : [ "2 7 11", "G2 H2 D2" ],
	"Ab-dur" : [ "0 3 8", "Ab3 C2 Eb3" ],
	"A-dur" : [ "1 4 9", "A2 C#2 E2" ],
	"Bb-dur" : [ "2 5 10", "Bb2 D1 E#1" ],
	"H-dur" : [ "3 6 11", "H3 Eb2 Gb3" ],
	"C-ters" : [ "0 4", "C2 E1" ],
	"Db-ters" : [ "1 5", "Db3 F2" ],
	"D-ters" : [ "2 6", "D2 F#2" ],
	"Ess-ters" : [ "3 7", "Eb3 G2" ],
	"E-ters" : [ "4 8", "E2 G#2" ],
	"F-ters" : [ "5 9", "F2 A1" ],
	"F#-ters" : [ "6 10", "Gb3 Bb2" ],
	"G-ters" : [ "7 11", "G2 H2" ],
	"Ab-ters" : [ "0 8", "Ab3 C2" ],
	"A-ters" : [ "1 9", "A2 C#2" ],
	"Bb-ters" : [ "2 10", "Bb3 D2" ],
	"H-ters" : [ "3 11", "H3 Eb2" ],
	"C-kvint" : [ "0 7", "C2 G2" ],
	"Db-kvint" : [ "1 8", "Db3 Ab3" ],
	"D-kvint" : [ "2 9", "D2 A2" ],
	"Ess-kvint" : [ "3 10", "Eb3 Bb3" ],
	"E-kvint" : [ "4 11", "E2 H3" ],
	"F-kvint" : [ "0 5", "F2 C2" ],
	"F#-kvint" : [ "1 6", "Gb3 Db3" ],
	"G-kvint" : [ "2 7", "G2 D2" ],
	"Ab-kvint" : [ "3 8", "Ab3 Eb3" ],
	"A-kvint" : [ "4 9", "A2 E2" ],
	"Bb-kvint" : [ "5 10", "Bb2 F2" ],
	"H-kvint" : [ "6 11", "H3 Gb3" ],
	"C-liten-6" : [ "0 8", "C2 Ab3" ],
	"C#-liten-6" : [ "1 9", "C#2 A2" ],
	"D-liten-6" : [ "2 10", "D2 Bb3" ],
	"Ess-liten-6" : [ "3 11", "Eb2 H3" ],
	"c-moll" : [ "0 3 7", "C2 Eb3 G2" ],
	"c#-moll" : [ "1 4 8", "C#2 E2 G#2" ],
	"d-moll" : [ "2 5 9", "D1 F2 A1" ],
	"ess-moll" : [ "3 6 10", "Eb2 Gb3 Bb2" ],
	"e-moll" : [ "4 7 11", "E1 G2 H2" ],
	"f-moll" : [ "0 5 8", "F2 Ab3 C2" ],
	"f#-moll" : [ "1 6 9", "Gb3 A2 Db3" ],
	"g-moll" : [ "2 7 10", "G2 Bb3 D2" ],
	"g#-moll" : [ "3 8 11", "G#2 H3 Eb2" ],
	"a-moll" : [ "0 4 9", "A1 C2 E1" ],
	"bb-moll" : [ "1 5 10", "Bb2 Db3 F2" ],
	"h-moll" : [ "2 6 11", "H2 D2 F#2" ]
}
```


A problem with this is that, in the software version, a chord will only be pure the second time it is performed. This assumes the music has a stable tonality based on major and minor chords.

Harmonic series

The theoretical harmonic series can be calculated as
Fundamental Hz * n partial.
This forms the basis for pure tunings. An approximated notation of partials 1-128 of a deep C can be helpful for identifying just intonation intervals:



Spectrums of instruments or noises

A number of sounds have been analyzed through Open Music and Pm2[28]: Airplane cabin, thunder, thai gong, crushtones of viola and cello, goose, grasshoppers, breaking glass, cash machine, contrabass clarinet, tam-tams performed with various sticks and techniques.
Performing on these can show that the more noisy sounds have much less resonant spectrums. Playing clusters of these spectrums with soft organ registers can be a form of synthesis.

Rubens old just intonation scale

This is an attempt from around 1999 to find a just intonation scale for electroacoustic music, with a very pure C major and an out of tune A flat major.

The scale as multiplication
1 1.0625 1.125 1.1666666667 1.25 1.333333333 1.4 1.5 1.6 1.684210526 1.777777778 1.894736842

The scale as deviations from equal tempered tuning (from c to c)
0 4.955406 3.91 -33.128632 -13.686279 -1.955414 -17.487854 1.955017 13.68634 2.487488 -3.909729 6.397095 0

The scale in a 0-1200 cents notation
0 104.955406 203.91 266.871368 386.313721 498.044586 582.512146 701.955017 813.68634 902.487488 996.090271 1106.397095 0

This scale is transposed to 5 parallel concert pitches starting upwards from 450 Hz. Thereby comes my choice to create an instrument with 5 parallel tunings. The difference between lower and upper concert pitch is about a minor third. This is thus not a fine tuning, but a transposing intonation system.

These are the functions for deep fundamentals for each concert pitch:

igr1=(440*90)/5632
igr2=(440*9)/512
igr3=(440*297)/16384
igr4=(440*135)/7168
igr5=(440*117)/6144

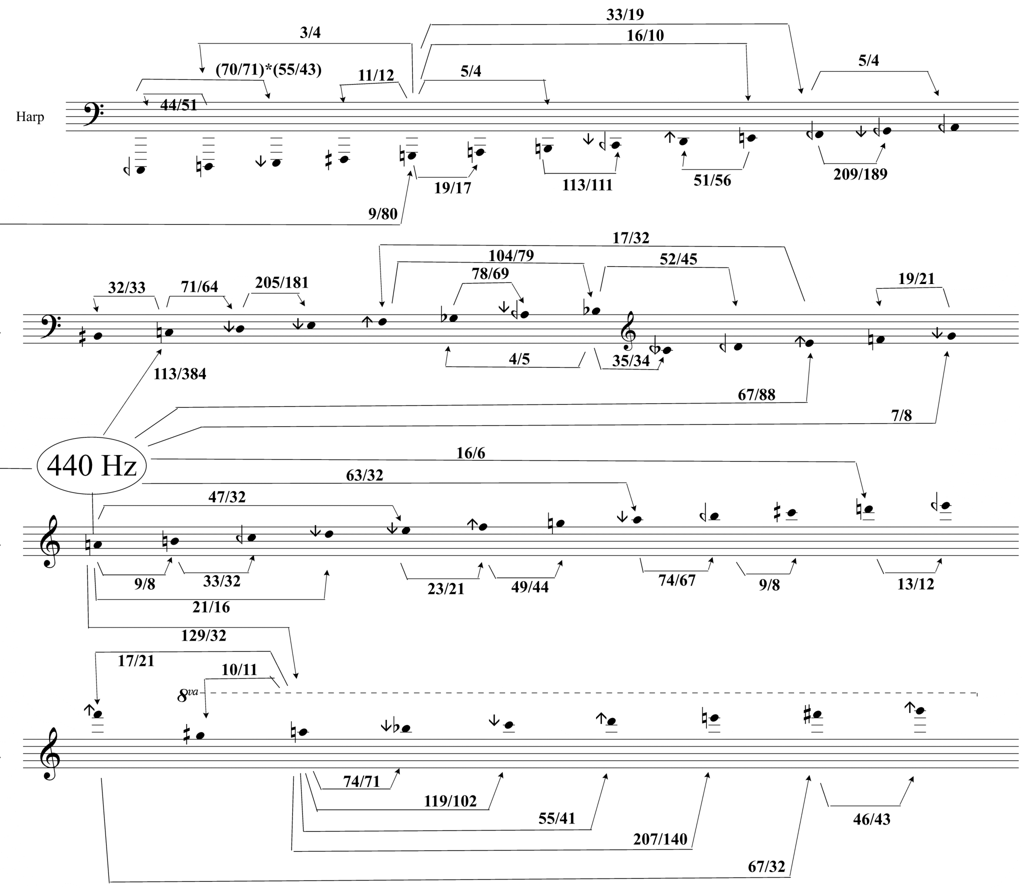
The 5 concert pitches approximated and transposed to the middle octave:
1: 450 Hz
2: 495 Hz
3: 510.46875 Hz
4: 530.357117 Hz
5: 536.25 Hz

[28] Both available from Ircam.
http://repmus.ircam.fr/openmusic/home
http://forumnet.ircam.fr/product/openmusic-libraries/

First version of the harp part in Grains

The work on *Grains* for harp, percussion and viola started in 2002. The first version required a complete retuning of the harp by overtone ratios. A tuning with no octaves and all unique pitches could make us reconsider the harp as a diatonic instrument. This idea was given up for practical reasons. This microtonal organ offers a possibility to test how this tuning would have worked.

This is the first tuning suggestion for the harp (tuned with pedals in middle positions):



Pitches as Hz

Line 1:
32.029411 37.125 40.390842 45.375 49.5
55.323528 61.875 62.989864 72.128571
79.199997 85.973686 95.071426 107.46711

Line 2:
125.555557 129.479172 143.640961 162.687271
177.96875 187.430389 211.877838 234.287979
241.178802 270.732758 335 348.333344 385

Line 3:
440 495 510.46875 577.5 646.25 707.797607
788.229126 866.25 956.753723 1076.3479
1173.333374 1271.111206

Line 4:
1435.892822 1612.5 1773.75 1848.697144
2069.375 2379.420654 2622.615967 3006.400635
3216.149414

Pitches as midicent

To fill the keyboard, note repetitions are added.

Line 1:
2363.958740
2363.958740
2619.551277
2619.551277
2765.515900

2966.959190
2966.959190
3117.596245
3117.596245
3310.153961
3310.153961
3503.910065

3534.825516
3534.825516
3769.367218
3769.367218
3931.282425

4073.356247
4073.356247
4247.496414
4247.496414
4459.669876
4459.669876

Line 2:
4728.986740

4782.259750
4782.259750
4961.956406
4961.956406
5177.517319

5332.944489
5332.944489
5422.621536
5422.621536
5634.875107
5634.875107
5808.935165

5859.119415
5859.119415
6059.239197
6059.239197
6427.989197

6495.558167
6495.558167
6668.825531
6668.825531

Line 3:
6900
6900
7103.910065

7157.183075
7157.183075
7370.780945
7370.780945
7565.506744

7723.000336
7723.000336
7909.333801
7909.333801
8072.735596
8072.735596
8244.773102

8448.683167
8448.683167
8598.045349
8598.045349
8736.618042

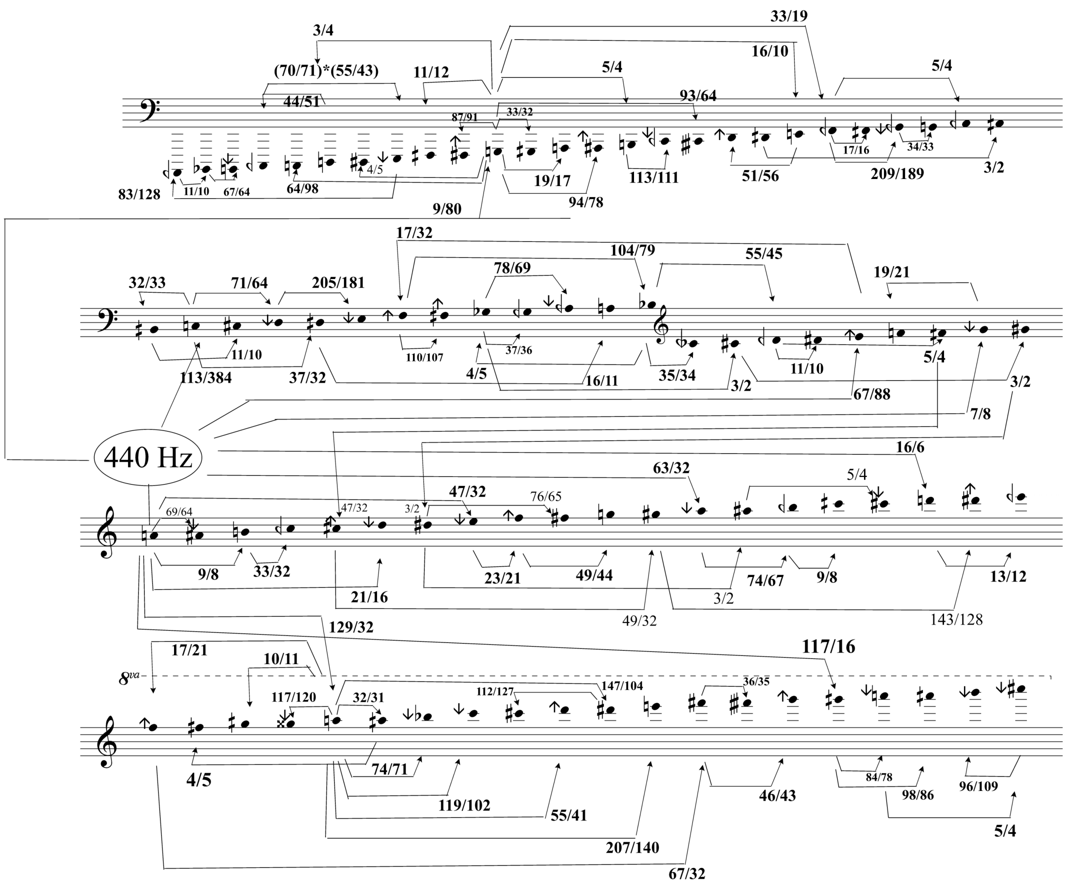
Line 4:
8947.647095
8947.647095
9148.468781
9148.468781
9313.472748
9313.472748
9385.120392

9580.343628
9580.343628
9822.042084
9822.042084
9990.517426

10226.95388
10226.95388
10343.711090
10343.711090

Chromatic expansion of the Grains tuning (2011)

Having tried out the first harp tuning for Grains I have found it best suited for folk music improvisations, as it is diatonic, have the characteristic stretced octaves and variable overtone intonations. With a microtonal organ, this can be expanded to a chromatic version. In this case we have the whole keyboard covered.



Pitches as Hz

Line 1:
26.190937 28.810032 30.160501 32.029411
32.32653 37.125 39.599998 40.390842 45.375
47.324177 49.5 51.046875 55.323528 59.653847
61.875 62.989864 71.929688 72.128571
76.570312 79.199997 85.973686 91.347038
95.071426 97.952377 107.46711 115.855469

Line 2:

125.555557 129.479172 138.111115 143.640961
149.710297 162.687271 177.96875 182.968527
187.430389 192.63678 211.877838 217.760437
234.287979 241.178802 281.145569 286.35199
314.987183 335 348.333344 357.940002 385
421.718353

Line 3:
440 474.375 495 510.46875 548.095642 577.5
632.577515 646.25 707.797607 739.629089
788.229126 839.271423 866.25 948.866272
956.753723 1076.3479 1082.8125 1173.333374
1265.463989 1271.111206

Line 4:
1435.892822 1464.77417 1612.5 1729.40625
1773.75 1830.967773 1848.697144 2069.375
2211.01001 2379.420654 2507.127441
2622.615967 3006.400635 3092.297852
3216.149414 3217.5 3465 3666.453369
3814.678955 4331.25

Pitches as midicent

2015.563232 2015.563232
2015.563232 2015.563232
2015.563232 2015.563232
2015.563232 2015.563232
2015.563232 2015.563232
2015.563232 2015.563232

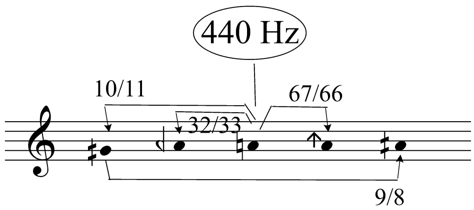
2015.563232 2015.563232
2015.563232 2015.563232
2015.563232 2015.563232
2015.563232 2015.563232
2015.563232 2015.563232
2180.565674 2259.874512

2363.95874 2379.94458
2619.55127 2731.282471
2765.515869

2966.959229 3039.774902
3117.596191 3170.869141
3310.154053 3440.620361
3503.910156
3534.825439 3764.586914
3769.367188 3872.824219
3931.282471
4073.356201 4178.311523
4247.496582 4299.178711
4459.67 4589.787109
4728.986816
4782.259766 4893.991211
4961.956543 5033.604004
5177.51709
5332.944336 5380.910156
5422.621582 5470.055664
5634.875 5682.286133
5808.935059
5859.119629 6124.57666
6156.343262 6321.347656
6427.989258
6495.558105 6542.657227
6668.825684 6826.531738
6900 7030.229492
7103.910156
7157.183105 7280.309082
7370.780762 7528.486328
7565.506836
7723. 7799.158203
7909.333984 8017.960938
8072.73584 8230.441406
8244.773438
8448.683594 8459.05
8598.044922 8728.90918
8736.618164
8947.647461 8982.123047
9148.46875 9269.641602
9313.472656   9368.4375
9385.120117
9580.34375 9694.956055
9822.041992 9912.551758
9990.517578
10226.954102 10275.724609
10343.710938 10344.4375
10472.736328 10570.571289
10639.183594 10859.05

Keyboard bendings

The whole tuning system can be transposed to concert pitches around from 440 Hz, related by overtone ratios:



Adding new tunings

New tunings can be added to the organ by adding lines to the text document "TemperamentsDICTIONARY.json" localed in the same folder. This information will be loaded by the organ the next time it is opened. This must be done with a pure text editor (for instance Textwrangler).

Structure of a dictionary file

The basic format of a dictionary file is:

```
{
"Example1" : [ 1, "text" ],
"Example2" : [ 2, "text" ],
"Example3" : [ 3,"text" ]
}
```

First element of each line must be a name in quotes with a colon, there must be a comma after each bracket, but NOT after the last line. Each number or string within the bracket must be separated by a comma. Lists of numbers are written as strings (""). This will allow them to be of any length. As long as this structure is kept, the patch will not complain.

Tuning syntax

Now to the specific syntax used in the microtonal organ. We will use the equal tempered tuning as an example:

```
"aTuning0" : [ 0, "12t: Equal tempered scale 1/8-tones", "tuning-octave", "centdeviations", "0 0 0 0 0 0 0 0 0 0 0 0", "UseCentlist1", "UseCentlist1", "UseCentlist1", "UseCentlist1", 1, "1/4 tone sharp", 0.5, "1/8 tone sharp", 0.25, "440 Hz", 0, "1/8 tone flat", -0.25, "1/4 tone flat", -0.5 ],
```

In order to read information correctly into the patch, all lines must have the same amount of elements, as numbers or strings (""). The function of these parameters are (this is an explanation, not a syntax):

- "**aTuningX**" (number of this tuning) :
- [Tuningnumber (Must correspond to tuning number, and not be already in use by another tuning. Keeping numbers in order will help avoiding mixing up menu items. The patch is using these numbers to trigger and order menu elements.),
- Tuning name for the menu,
- **"tuning-octave"** (12 tones) or "**tuning-keys"** (one pitch for each key on the keyboard),
- tuning format (**"centdeviations"** (cents difference from equal tempered tuning), or **"0t1200scale"** (0 100 200 300 400 500 600 700 800 900 1000 1100 1200 will be an equal tempered scale), or **"0t1200FOURTHdown"**(same as previous with a transposition to handle tunings starting at g), or **"fullregister"** (one note for each key, as a midicent value (middle c is 6000)),
- Centlist1 (cents for keyboard tuning 1, in the format selected at previous parameter),
- Centlist2 (cents for keyboard tuning 2, if this is the same, just write "UseCentlist1"),
- Centlist3 (cents for keyboard tuning 3, if this is the same, just write "UseCentlist1"),
- Centlist4 (cents for keyboard tuning 4, if this is the same, just write "UseCentlist1"),
- Centlist5 (cents for keyboard tuning 5, if this is the same, just write "UseCentlist1"),
- Halftones pitchbend range (1 is a range of an equal tempered halftone),
- Information text for keyboard tuning 1, to be displayed on the screen (example: "1/4 tone sharp"). If this text contains "$1", performed pitch will display on the screen (This is used for the partials tunings, where the lowest C will count as 1, and equal partial number 1) ,
- Pitchbend value 1 (Multiplier of the pitch bend range as entered already. If pitchbend range is 1, .5 will be a quartertone sharp. If this system uses separate centlists instead of overall pitchbends, you can set this value to 0.),
- Information text for keyboard tuning 2 (example: "1/8 tone sharp"),
- Pitchbend value 2,
- Information text for keyboard tuning 3 (example: "440 Hz"),
- Pitchbend value 3,
- Information text for keyboard tuning 4 (example: "1/8 tone flat"),
- Pitchbend value 4,
- Information text for keyboard tuning 5 (example: "1/4 tone flat"),
- Pitchbend value 5],

The above mentioned Expansion of Grains Tuning is stored this way:

"aTuning123" : [123, "F: Rubens Expansion of Grains Tuning", "tuning-keys", "fullregister", "2015.563232 2180.565674 2259.874512 2363.95874 2379.94458 2619.55127 2731.282471 2765.515869 2966.959229 3039.774902 3117.596191 3170.869141 3310.154053 3440.620361 3503.910156 3534.825439 3764.586914 3769.367188 3872.824219 3931.282471 4073.356201 4178.311523 4247.496582 4299.178711 4459.67 4589.787109 4728.986816 4782.259766 4893.991211 4961.956543 5033.604004 5177.51709 5332.944336 5380.910156 5422.621582 5470.055664 5634.875 5682.286133 5808.935059 5859.119629 6124.57666 6156.343262 6321.347656 6427.989258 6495.558105 6542.657227 6668.825684 6826.531738 6900 7030.229492 7103.910156 7157.183105 7280.309082 7370.780762 7528.486328 7565.506836 7723. 7799.158203 7909.333984 8017.960938 8072.73584 8230.441406 8244.773438 8448.683594 8459.05 8598.044922 8728.90918 8736.618164 8947.647461 8982.123047 9148.46875 9269.641602 9313.472656 9368.4375 9385.120117 9580.34375 9694.956055 9822.041992 9912.551758 9990.517578 10226.954102 10275.724609 10343.710938 10344.4375 10472.736328 10570.571289 10639.183594 10859.05", "UseCentlist1", "UseCentlist1", "UseCentlist1", "UseCentlist1", 2, "440*(10/11)*(9/8)", 0.194529, "440*67/66", 0.13017, "440Hz", 0, "440*32/33", -0.266365, "440*10/11", -0.825021],

This uses the fullregister format. The fullregister tunings will start 2 octaves below the lowest c on the piano keyboard. For this reason we can add repeated notes at the beginning of the list until the keyboard mapping is correct. A maximum pitch bend of 2 semitones is set to reach the bendings of this tuning system. Just intonation pitch bending can be calculated elsewhere, for instance in Ircams Open Music.

This is the partials tuning. The $1 input is used to show the user which partial number is currently being played:

"aTuning45" : [45, "F: Partials from fundamentals C-D", "tuning-keys", "fullregister", "1162.368042 2362.36792 3064.322998 3562.36792 3948.681885 4264.323242 4531.193848 4762.368164 4966.277832 5148.682129 5313.686035 5464.323242 5602.895996 5731.193848 5850.637207 5962.368164 6067.324219 6166.277832 6259.880859 6348.682129 6433.148926 6513.687012 6590.643066 6664.323242 6734.996094 6802.895996 6868.23291 6931.193848 6991.944824 7050.637207 7107.403809 7162.368164 7215.641113 7267.324219 7317.507812 7366.277832 7413.711914 7459.880859 7504.851074 7548.682129 7591.431152 7633.148926 7673.88623 7713.687012 7752.591797 7790.643066 7827.875 7864.323242 7900.02 7934.996094 7969.278809 8002.895996 8035.873047 8068.23291 8100. 8131.193848 8161.835938 8191.945801 8221.54 8250.636719 8279.25293 8307.404297 8335.103516 8362.368164 8389.21 8415.641602 8441.674805 8467.323242 8492.597656 8517.507812 8542.06543 8566.27832 8590.157227 8613.711914 8636.951172 8659.880859 8682.512695 8704.851562 8726.905273 8748.681641 8770.188477 8791.430664 8812.416016 8833.149414 8853.637695 8873.885742 8893.9 8913.686523 8933.248047 8952.591797 8971.72168 8990.642578 9009.359375 9027.875 9046.195312 9064.323242 9082.263672 9100.021484 9117.59668 9134.996094 9152.22168 9169.27832 9186.168945 9202.896484 9219.462891 9235.873047 9252.128906 9268.233398 9284.189453 9300. 9315.666992 9331.194336 9346.583008 9361.835938 9376.957031 9391.945312 9406.806641 9421.54 9436.149414 9450.636719 9465.003906 9479.25293 9493.385742 9507.404297 9521.30957 9535.103516 9548.79 9562.368164 9575.84082 9589.21 9602.476562 9615.641602 9628.707031 9641.674805 9654.546875 9667.323242 9680.006836 9692.597656 9705.097656 9717.507812 9729.83 9742.06543 9754.213867 9766.27832 9778.259766 9790.157227 9801.975586 9813.711914 9825.370117 9836.951172 9848.454102 9859.880859 9871.233398 9882.512695 9893.717773 9904.851562 9915.913086 9926.905273 9937.828125 9948.681641 9959.46875 9970.188477 9980.841797 9991.430664 10001.955078 10012.416016 10022.813477 10033.149414 10043.423828 10053.637695 10063.791016 10073.885742 10083.921875 10093.9 10103.821289 10113.686523 10123.495117 10133.248047 10142.947266 10152.591797 10162.183594", "UseCentlist1", "UseCentlist1", "UseCentlist1", "UseCentlist1", 2, "Partial $1 of D", 1, "Partial $1 of D 1/4 flat", 0.75, "Partial $1 of C#", 0.5, "Partial $1 C 1/4 sharp", 0.25, "Partial $1 of C", 0],

For further examples, open and read the file "TemperamentsDICTIONARY.json".

Literature

Jones, A. M. "Indonesia and Africa: The Xylophone as a Culture-Indicator." The Journal of the Royal Anthropological Institute of Great Britain and Ireland. 89, No. 2 (1959): 155-68.
McGraw, Andrew C. "The Development of the "Gamelan Semara Dana" and the Expansion of the Modal System in Bali, Indonesia." Asian Music. 31, No. 1 (1999): 63-99.
Hall, Donald. "The Objective Measurement of Goodness-of-Fit for Tunings and Temperaments." Journal of Music Theory. 17, No. 2 (1973): 274-90.
"Edward C. Carterette and Roger a. Kendall: On the Tuning and Stretched Octave of Javanese Gamelans." Leonardo Music Journal. 4 (1994): 59-68.
Kaufmann, Henry W. "More on the Tuning of the "Archicembalo"." Journal of the American Musicological Society. 23, No. 1 (1970): 84-94.
Barbour, J. Murray. "Irregular Systems of Temperament." Journal of the American Musicological Society. 1, No. 3 (1948): 20-26.
Rahn, Jay. "Javanese Pélog Tunings Reconsidered." (1978): 69-82.
Kuttner, Fritz A. "The 749-Temperament of Huai Nan Tzu (+ 123 B. C.)." Asian Music. 6, No. 1/2 (1975): 88-112.
Vicentino, Nicola. Ancient Music Adapted to Modern Practice, USA: Yale University, 1996.
Vitale, Wayne. "Balinese Kebyar Breaks the Five-Tone Barrier: New Composition for Seven-Tone Gamelan." Perspective of New Music. 40, No. 1 (2002): 5-69.