Dynamic Transposition Notation

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This document describes how one can write music using numbers. To do that we will create a simple text file with a music score for Pachelbel's Canon in D.

Initial Parameters

```
; Pachelbel Canon in D
; Dynamic Transposition Markup
;
base_freq 36.7081 ;Hz: D1
sec_per_beat 2.4
beats_per_meas 4
ticks_per_beat 4
picks_per_tick 2
```

Figure 1: Initial Parameters

Here you see the beginning of the file where one can define some parameters and also provide comments after semi-columns. The first parameter is the base frequency, which in our case is the frequency of note D in the first octave.

Next you define seconds per beat. The composition is split into time intervals of different duration. The longest one is called *measure* which is sub-divided into *beats*. That's why the next parameters specifies beats-per-measure. Beats are further split into *ticks*, so the next parameter specifies the number of ticks in a beat, and finally, ticks are split into *picks*.

Instruments Section

Next we define our instruments or sounds. In this case we are using the standard sound font library where sounds are identified by numbers from the bank of sounds.

*Tectral/andrei.

```
; Pachelbel Canon in D
; Dynamic Transposition Markup
;
base_freq 36.7081 ;Hz: D1
sec_per_beat 2.4
beats_per_meas 4
ticks_per_beat 4
picks_per_tick 2
;
; INSTRUMENTS        Soundfont-2 bank
;
snd    40    vi1    ; violin
snd    40    vi2    ; violin
snd    41    vla    ; viola
snd    42    cel    ; cello
snd    52    cho    ; chorus

                        Names of your choice
```

Figure 2: Instruments Section

Each instrument is defined on one line starting with the ‘`snd`’ tag followed by the sound-font bank number for that instrument and the name of the instrument that you gave it. One can pick any name but here we are using a three-letter abbreviation for all instruments for brevity. This particular composition is plaid on two violins, viola, cello, and chorus.

Orchestra Section

Next we combine our instruments into orchestra using a table. Each row of the table relates to a specific parameter identified by the tag in the beginning of the row.

The first row starts with the tag ‘orc’ and lists all the instruments in the orchestra by the names you assigned earlier.

The next row with the tag ‘pan’ provides pan value for each instrument placed under respective name of that instrument.

The final parameter is the initial volume or ‘amplitude’ provided in a similar manner for each instrument.

Score Section

Now we can start writing the score. At the bottom we see the first beat of the first measure written as four lines - one line per tick.

```
base_freq 36.7081 ;Hz: D1
sec_per_beat 2.4
beats_per_meas 4
ticks_per_beat 4
picks_per_tick 2
;
; INSTRUMENTS
;
snd     40      vi1     ; violin
snd     40      vi2     ; violin
snd     41      vla     ; viola
snd     42      cel     ; cello
snd     52      cho     ; chorus
;
; ORCHESTRA
;
orc     cel     vi1     vi2     vla     cho     ; instrum
pan     0.4     -0.4    0.8     -0.8    0.0     ; panning
amp     100     120     100     100     120     ; amplitu
```

Figure 3: Orchestra Section

```
beats_per_meas 4
ticks_per_beat 4
picks_per_tick 2
max_amp 127
;
; INSTRUMENTS
;
snd     40      vi1     ; violin
snd     40      vi2     ; violin
snd     41      vla     ; viola
snd     42      cel     ; cello
snd     52      cho     ;chorus-aah
;
; ORCHESTRA
;
orc     cel     vi1     vi2     vla     cho     ; instruments
pan     0.4     -0.4    0.8     -0.8    0.0     ; panning
amp     100     120     100     100     120     ; amplitude (volume)
;
; measure 1 (one row per tick)
1:1     1:1:2   -       -       -       -       ; D
1:1     +       -       -       -       -       ;        beat
1:1     +       -       -       -       -       ;
1:1     +       -       -       -       -       ;
             base_freq*(1/1)*(1/1*2^2) = 146.83 Hz => D3
```

Figure 4: Score Section

The first pair of numbers on each line represents a fraction as `A:B = A/B`. This fraction is used to multiply the base frequency of the composition and apply it to the whole line. This will be the base frequency of that line. In this case this fraction it is simply one: `1:1=1/1=1`. So the base frequency, of that line will be equal to the base frequency of the composition which is D of the first octave.

The subsequent triple of numbers on each line determine notes plaid by respective instruments: the first two numbers define the fraction that the base frequency of this line will be multiplied by and the third one determines the octave. A `dash` sign means pause and a `plus` sign means continuation of the sound from the line above.

The octave number goes into the exponent of number 2. When we multiply any frequency by two raised to a number we shift the frequency to the octave equal to that number plus one. That's why our octave numbers are equal to those on a piano minus one.

For example, the frequency of the first note plaid by the first instrument in our example is calculated as

```
base-frequency * 1 * 1 * 2 * 2 = 36.708 * 4 = 146.8
```

This produces frequency of note D in the *third* octave in a traditional notation.

Figure 5: First Measure (01.mp3)

Next figure shows the first measure with all for beats. The base frequency of each row in that beat is five-fourths of the composition's base frequency which approximately corresponds to the interval between note D and F-sharp. Thus, the fourth beat is plaid in F#.

To calculate the frequency of the note plaid in the fourth beat, i.e. 6:5:1, we multiply the base frequency of the row by six-fifths and then by two raised to the power one. The result will be close to the frequency of note A in the second octave.

The first two measures of the composition are plaid by cello (01.mp3).

The second instrument, violin, joins cello in the third measure, and it's notes are written in column 3.

```
; measure 2
4:3     1:1:1   -       -       -       -       ; G
4:3     +       -       -       -       -       ;
4:3     +       -       -       -       -       ;
4:3     +       -       -       -       -       ;
1:1     1:1:1   -       -       -       -       ; D
1:1     +       -       -       -       -       ;
1:1     +       -       -       -       -       ;
1:1     +       -       -       -       -       ;
4:3     1:1:1   -       -       -       -       ; G
4:3     +       -       -       -       -       ;
4:3     +       -       -       -       -       ;
4:3     +       -       -       -       -       ;
3:2     1:1:1   -       -       -       -       ; A
3:2     +       -       -       -       -       ;
3:2     +       -       -       -       -       ;
3:2     +       -       -       -       -       ;
; measure 3
1:1     1:1:2   5:4:2   -       -       -       ; D
1:1     +       +       -       -       -       ;
1:1     +       +       -       -       -       ;
1:1     +       +       -       -       -       ;
3:2     1:1:1   5:4:2   -       -       -       ; A
3:2     +       +       -       -       -       ;
```

two instruments

Figure 6: Violin Joining Cello (02.mp3)

This duet plays for another two measures (02.mp3).
After that the third instrument joins and so on.

Writing with Letters

You might have noticed that there are only a few fractions used in the whole composition. This makes it possible to simplify the score by replacing all fractions with letters of your choice.

```
; measure 4
4:3     1:1:1   5:4:2   -       -       -       ; G
4:3     +       +       -       -       -       ;
4:3     +       +       -       -       -       ;
4:3     +       +       -       -       -       ;
1:1     1:1:1   3:2:2   -       -       -       ; D
1:1     +       +       -       -       -       ;
1:1     +       +       -       -       -       ;
1:1     +       +       -       -       -       ;
4:3     1:1:1   5:4:2   -       -       -       ; G
4:3     +       +       -       -       -       ;
4:3     +       +       -       -       -       ;
4:3     +       +       -       -       -       ;
3:2     1:1:1   5:4:2   -       -       -       ; A
3:2     +       +       -       -       -       ;
3:2     +       +       -       -       -       ;
3:2     +       +       -       -       -       ;
; measure 5
1:1     1:1:2   1:1:2   5:4:2   -       -       ;
1:1     +       +       +       -       -       ;
1:1     +       +       +       -       -       ;
1:1     +       +       +       -       -       ;
3:2     1:1:1   1:1:2   5:4:2   -       -       ;
3:2     +       +       +       -       -       ;
```

Figure 7: Third Instrument Joining

```
;
; Using letters for fractions:
;
def C 1:1 ; the main key
def D 9:8
def Eb 6:5 ; E-flat
def E 5:4
def F 4:3
def G 3:2
def A 5:3
def B 15:8
;
; ORCHESTRA
;
orc   cel   vi1   vi2   vla   cho   ; instruments
pan   0.4   -0.4  0.8   -0.8  0.0   ; panning
amp   100   120   100   100   120   ; amplitude (volume)
;
; SCORE
;
C     C2    -     -     -     -     ;
C     +     -     -     -     -     ;
C     +     -     -     -     -     ;
C     +     -     -     -     -     ;
```


Figure 8: Replacing Fractions with Letters

This can be easily done using definitions as shown in the next figure. Here we chose letters commonly used for notes in key C, just to follow the convention. With these definitions the score can be simplified and will look much cleaner. Next figure shows the example of the part plaid by five different instruments written in letter notation (03.mp3). We are still using octave numbers explicitly but all fractions are replaced with letters.

We chose to use letters that correspond to the key of C for convenience since that key has minimum of flats and sharps. And we wrote the score for the whole composition in five different keys: D, A, Bm, Fm, and G, using only notes in key C.

Think about this - we can play music in any key using only notes from key C !

Off-Tick Notes

In the proposed musical notation each line corresponds to a time interval smaller than one beat. These intervals were introduced earlier as *ticks*. But what if we want to start a note between the ticks? For this purpose we introduced *picks* which are time intervals smaller than a tick.

One can start a note at certain picks by using a *dot* or *comma* notation. To start playing a note one pick before the current tick one should append `".1"` (dot-one) to the octave number of this note, and to start the note two picks ahead of the next tick one can append `",2"` (comma-two) to the octave number.

An example in the last figure shows the passage where the off-tick notes are used for the first violin. The corresponding music file is provided (04.mp3) along with a complete composition of Canon in D (canon.mp3) written in notation described here and rendered using the DTM Compiler.

Current implementation of the DTM Compiler converts the DTM score into either a MIDI file that can be plaid with FluidSynth using sound font library or can be converted to a CSound score file and plaid with CSound engine or converted to WAV or MP3 files.

Conclusions

Using this method one can simplify sequencing of music and produce more harmonious musical intervals. In particular:

- One can play music in any key using only handful of notes, for example, only those from key C.
- Music produced in this way is more harmonious because frequencies of notes are simple fractions of the base frequency, whereas in the standard

C	C2	C2	E2	C2	E2
C	+	+	+	+	+
C	+	E2	G2	+	+
C	+	+	+	+	+
G	C1	C2	E2	C2	E2
G	+	+	+	+	+
G	+	E2	C2	+	+
G	+	+	+	+	+
A	C1	C2	Eb2	C2	Eb2
A	+	+	+	+	+
A	+	Eb2	C2	+	+
A	+	+	+	+	+
E	C1	C3	Eb2	C3	Eb2
E	+	+	+	+	+
E	+	G2	C2	+	+
E	+	+	+	+	+
F	C1	G2	E2	G2	E2
F	+	+	+	+	+
F	+	E2	C2	+	+
F	+	+	+	+	+
C	C1	C2	E2	G2	E2
C	+	+	+	+	+
C	+	E2	G2	+	+
C	+	+	+	+	+

Figure 9: Score in letter notation for five instruments (03.mp3)

C	C2	C3	-	E2	C2
C	+	-	E2	+	+
C	+	G2.1	C3	G2	+
C	+	-	E2	+	+
G	C1	C2.1	E2	E2	C2
G	+	-	C1	+	+
G	+	E1.1	G1	C2	+
G	+	C2.1	E2	+	+
A	C1	G2.1	C2	Eb2	C2
A	+	-	Eb2	+	+
A	+	G2.1	C3	C2	+
A	+	-	G2	+	+
E	C1	Eb2.1	C2	Eb2	C2
E	+	C2	-	+	+
E	+	-	Eb2	C2	+
E	+	G2	-	+	+
F	C1	C2	-	E2	C2
F	+	+	C3	+	+
F	+	+	G2	C2	+
F	+	+	E2	+	+
C	C1	-	C2	E2	G2
C	+	E2	+	+	+
C	+	G2	+	G2	+
C	+	C3	+	+	+

Figure 10: Off-tick notes (04.mp3)

> Chromatic scale frequencies are defined by logarithmic transformation, producing intervals based on transcendental numbers.

Using rational numbers to set frequencies results in more harmonious musical intervals because this corresponds to harmonics of resonating strings. For more information please read the DTM Paper.

Sources

- Dynamic Transposition Method.
- Introduction to DT Sequencer.
- DT Sequencer on GitLab.
- Compositions
- Arrangements