Abstract

Celestial bodies are claimed to be able to generate music, whereas the ratio among
the orbital period of the celestial bodies can be easily converted to the ratio of musical
interval. But seldom is the celestial movement examined from the perspective of rhythm.
The aim of this project is to show the orbital period of celestial bodies as the rhythm
of music.

1 Introduction

Ancient philosophers, Pythagoras in particular, came up with the idea of Music of the Spheres that the harmonic order of the universe is actually music-based, whereas musical intervals can be calculated by the simple ratios of simple integers and the operation of the universe is governed by these simple ratios too. Hundred years later, Kepler discovered the laws of planetary movement and refined the concept of celestial music, where the musical intervals and planetary movements are closely related. However this concept of celestial music focuses more on the musical intervals. A more direct relationship between orbital periods and musical rhythms is often ignored. The goal of this project is to experimentally compose music using this relationship.

[1]

2 The Exoplanet Suite

Many periodic characteristics can be observed on celestial objects, for instance, planets obit around the hosting star in fixed orbital periods, pulsars emit radiation in very regular rotational periods. And all these periods can be easily transformed into rhythm that can be perceived by human. Therefore, based on this principle, I compose a three-movement suite that examines three types of celestial objects - The solar system, a pulsar and exoplanetary systems.
2.1 First movement: Home - Solar system

The whole suite opens with the music of our sweet home - the solar system. Given the wide range of orbital periods that the planets have, it is handled in logarithm scale. The tempo of each planet is proportional to its orbital period. (Table 1) This movement basically has two section: the first movement (Figure 1) can be seen an introduction of the system. Starting from the the outermost Pluto, inner planets are successively added in. After all the planets are presented, the second section (Figure 2) cuts in, with all planets starting at the same time, giving the feeling of the new start of the solar system as a whole after we closely examined each planet one by one.

Table 1: Solar system planet orbital period

<table>
<thead>
<tr>
<th>Planet</th>
<th>Period of revolution, yrs.</th>
<th>Ratio</th>
<th>Natural log of the ratio×e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.241</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Venus</td>
<td>0.615</td>
<td>2.551867</td>
<td>1.936825</td>
</tr>
<tr>
<td>Earth</td>
<td>1</td>
<td>4.149378</td>
<td>2.422958</td>
</tr>
<tr>
<td>Mars</td>
<td>1.88</td>
<td>7.80083</td>
<td>3.05423</td>
</tr>
<tr>
<td>Jupiter</td>
<td>11.9</td>
<td>49.37759</td>
<td>4.899497</td>
</tr>
<tr>
<td>Saturn</td>
<td>29.5</td>
<td>122.4066</td>
<td>5.807349</td>
</tr>
<tr>
<td>Uranus</td>
<td>84</td>
<td>348.5477</td>
<td>6.853775</td>
</tr>
<tr>
<td>Neptune</td>
<td>165</td>
<td>684.6473</td>
<td>7.528904</td>
</tr>
<tr>
<td>Pluto</td>
<td>248</td>
<td>1029.046</td>
<td>7.936387</td>
</tr>
</tbody>
</table>

Figure 1: Section 1 of the first movement, each row represents a planet and the color bars are the beats, whose densities are related to the orbital revolving frequency
2.2 Second movement: The encounter of a pulsar

In second movement, I examined another celestial object that has temporal characteristic that can generate rhythms - pulsars. Basically it describes an imaginary observation of an approaching pulsar. It starts with lower pitches that pulse regularly, indicating the observing pulsar is far away, then the pulses gradually makes transition to higher pitches as it gets closer to the observer. More variation can be observed as pitches gets higher, implying a finer level of detail can be observed as it gets closer. Finally, as the pulsar gets away from the observer, the pitches become lower and fade away. You can also hear meteorites quickly move by with Doppler effect.

2.3 Third movement: The sound of the exoplanets

This movement explores the rhythm of four exoplanetary system, namely, HD 20794, HD 40307, Kepler 33 and HD 10180. These four particular system were chosen because all of them has at least three planets in them, therefore made it possible for me to form a rich-texture polyphonic rhythm based on the orbital periods of each planets in the system.

Each musical part in this movement is written programmatically using MATLAB software (the code used for the composition is shown in the Appendix section), with the hope to precisely reflect the planetary motions and then mixed using sound-mixing software. Besides retrieving the rhythm from each planets orbit period, I also took the tone into account, whereas a arbitrary frequency is given to the planet with shortest orbital period (therefore highest pitch) as the fundamental frequency, then the pitches of the other planets are calculated, so that the musical interval is proportional to the ratio among the orbital period. I believe, with these two factors combined, this movement can provide a basic overview of each chosen system, as well as showing the interaction among them, through sound.
2.3.1 HD 20794

As figure 3 shows, this movement starts with the slow groaning of the HD 20794, because HD 20794 has a relatively long orbital period compared to the orbital periods of other planets from the planetary system I chose.

The HD 20794a star hosts three planets which were discovered recently in 2011, the three planets, HD 20794 b, c and d, have the orbital period of 18.315, 40.11 and 90.31 days respectively. The sound frequency chosen for HD 20794 b is 440Hz (A4), and the rest were calculated accordingly.

2.3.2 HD 40307

After about one minute, HD 40307 kicks in. The orbital periods of planets in HD 40307 are 4.3115, 9.62 and 20.46 days. With shorter orbital periods than HD 20794 planets, it goes on faster and at a higher tone and the fundamental frequency was set to 523.3 Hz (C5).

2.3.3 Kepler 33

Kepler 33 comes in at about 1m:30s. It contains five planets, with a broad range of orbital periods of 5.66, 13.17, 21.77, 31.78 and 105.576 days. 880Hz (A5) was set as the fundamental frequency.

2.3.4 HD 10180

Finally HD 10180 joins in at about 1m:45s. Having seven planets covering such a variety of orbital periods of 1.18, 5.76, 9.66, 16.354, 49.75, 67.55 and 122.88 days, the lower pitches are really heavy and slow, making it hard to hear, while the higher pitches make a incisive
Figure 4: Visualized facts about HD 20794 [2]

(a) Orbital diagram of HD 20794 planets
(b) Size diagram of HD 20794 planets, comparing to planets in solar system

Figure 5: Visualized facts about HD 40307 [2]

(a) Orbital diagram of HD 40307 planets
(b) Size diagram of HD 40307 planets, comparing to planets in solar system
sound, rapidly repeating. The fundamental frequency is made to be 7459Hz (B sharp 8). HD 10180 is a very recently found multi-planetary system in Jan. 2012.

2.3.5 Solar system

The music of solar system from first movement is used as background. The sound is weak and faint and the melody goes on fitfully, just like hearing from a very long distance away, because I am trying to remind the audience how powerless and low in existence of the universe.
References


3 Appendix

3.1 MATLAB code for composing the third movement.

```matlab
fs = 44100;
dt = 1/fs;

% HD 10180

pl1 = 1.18;
pl2 = 5.76;
pl3 = 9.66;
pl4 = 16.354;
pl5 = 49.75;
pl6 = 67.55;
pl7 = 122.88;

planet1 = pl1/1;
planet2 = pl2/1;
planet3 = pl3/1;
planet4 = pl4/1;
planet5 = pl5/1;
planet6 = pl6/1;
planet7 = pl7/1;

ratio21 = planet2/planet1;
ratio31 = planet3/planet1;
ratio32 = planet3/planet2;
ratio41 = planet4/planet1;
ratio51 = planet5/planet1;
ratio61 = planet6/planet1;
ratio71 = planet7/planet1;

speedFactor = 0.125;
planetNoteTime1 = planet1 * speedFactor;
planetNoteTime2 = planet2 * speedFactor;
planetNoteTime3 = planet3 * speedFactor;
planetNoteTime4 = planet4 * speedFactor;
```
planetNoteTime5 = planet5 * speedFactor;
planetNoteTime6 = planet6 * speedFactor;
planetNoteTime7 = planet7 * speedFactor;

barPlanet1 = [0:dt:planetNoteTime1];
k = size(barPlanet1, 2);

barPlanet2 = linspace(0,planetNoteTime2,ratio21*k);
barPlanet3 = linspace(0,planetNoteTime3,ratio31*k);
barPlanet4 = linspace(0,planetNoteTime3,ratio41*k);
barPlanet5 = linspace(0,planetNoteTime3,ratio51*k);
barPlanet6 = linspace(0,planetNoteTime3,ratio61*k);
barPlanet7 = linspace(0,planetNoteTime3,ratio71*k);

j = size(barPlanet2, 2);
i = size(barPlanet3, 2);
l = size(barPlanet4, 2);
m = size(barPlanet5, 2);
o = size(barPlanet6, 2);
p = size(barPlanet7, 2);

mod7 = sin(pi*barPlanet7/barPlanet7(end));
mod6 = sin(pi*barPlanet6/barPlanet6(end));
mod5 = sin(pi*barPlanet5/barPlanet5(end));
mod4 = sin(pi*barPlanet4/barPlanet4(end));
mod3 = sin(pi*barPlanet3/barPlanet3(end));
mod2 = sin(pi*barPlanet2/barPlanet2(end));
mod1 = sin(pi*barPlanet1/barPlanet1(end));

f0 = 7459;

blank1 = zeros(1,k);
blank2 = zeros(1,i);
blank3 = zeros(1,j);
blank4 = zeros(1,l);
blank5 = zeros(1,m);
blank6 = zeros(1,o);
blank7 = zeros(1,p);

planetNote7 = mod7.*cos(2*pi*(1/ratio71)*f0*barPlanet7);
planetNote6 = mod6.*cos(2*pi*(1/ratio61)*f0*barPlanet6);
planetNote5 = mod5.*cos(2*pi*(1/ratio51)*f0*barPlanet5);
planetNote4 = mod4.*cos(2*pi*(1/ratio41)*f0*barPlanet4);
planetNote3 = mod3.*cos(2*pi*(1/ratio31)*f0*barPlanet3);
planetNote2 = mod2.*cos(2*pi*(1/ratio21)*f0*barPlanet2);
planetNote1 = mod1.*cos(2*pi*f0*barPlanet1);
planetMusic1 = [blank1 blank1 blank1 blank1 blank1 blank1 blank1 ... 
   blank1 blank1 blank1 blank1...
   blank1 blank1 blank1 blank1 planetNote1 planetNote1 planetNote1...
   planetNote1 planetNote1 planetNote1 planetNote1 planetNote1...
   planetNote1 planetNote1 planetNote1 planetNote1 planetNote1...
   planetNote1 planetNote1 planetNote1 planetNote1 planetNote1...
   planetNote1 planetNote1 planetNote1 planetNote1 planetNote1 ... 
   planetNote1...
   planetNote1 planetNote1 planetNote1 planetNote1 planetNote1 ... 
   planetNote1...
   planetNote1 planetNote1 planetNote1 planetNote1 planetNote1 ... 
   planetNote1...
   planetNote1 planetNote1 planetNote1 planetNote1 planetNote1 ... 
   planetNote1];

planetMusic2 = [blank3 blank3 blank3 blank3 planetNote2 planetNote2 ...
   planetNote2 planetNote2 ...
   planetNote2 planetNote2 planetNote2 planetNote2 planetNote2 ...
   planetNote2 planetNote2 planetNote2 planetNote2 planetNote2 ...
   planetNote2 planetNote2 planetNote2 planetNote2 planetNote2 ];

planetMusic3 = [blank3 planetNote3 planetNote3 planetNote3 planetNote3...
   planetNote3 planetNote3 planetNote3 planetNote3 planetNote3 ...
   planetNote3 ...
   planetNote3 planetNote3 planetNote3 ];

planetMusic4 = [blank4 planetNote4 planetNote4 planetNote4 planetNote4 ...
   planetNote4 planetNote4 ...
   planetNote4 planetNote4 planetNote4 planetNote4 planetNote4];

planetMusic5 = [blank5 planetNote5 planetNote5 planetNote5 planetNote5...
   planetNote5];

planetMusic6 = [blank6 planetNote6 planetNote6 planetNote6];

planetMusic7 = [planetNote7 planetNote7];

n1 = size(planetMusic1,2);

n2 = size(planetMusic2,2);
n3 = size(planetMusic3,2);
n4 = size(planetMusic4,2);
n5 = size(planetMusic5,2);
n6 = size(planetMusic6,2);
n7 = size(planetMusic7,2);

nMax = max([n1 n2 n3 n4 n5 n6 n7]);
p1 = nMax - n1;
p2 = nMax - n2;
p3 = nMax - n3;
p4 = nMax - n4;
p5 = nMax - n5;
p6 = nMax - n6;
p7 = nMax - n7;

PM1p = padarray(planetMusic1, [0 p1], 'replicate', 'post') ./ 7;
PM2p = padarray(planetMusic2, [0 p2], 'replicate', 'post') ./ 7;
PM3p = padarray(planetMusic3, [0 p3], 'replicate', 'post') ./ 7;
PM4p = padarray(planetMusic4, [0 p4], 'replicate', 'post') ./ 7;
PM5p = padarray(planetMusic5, [0 p5], 'replicate', 'post') ./ 7;
PM6p = padarray(planetMusic6, [0 p6], 'replicate', 'post') ./ 7;
PM7p = padarray(planetMusic7, [0 p7], 'replicate', 'post') ./ 7;

finalMusic = PM1p + PM2p + PM3p + PM4p + PM5p + PM6p + PM7p;
sound(finalMusic/max(finalMusic), fs);
wavwrite(finalMusic, fs, 'p3.wav');

%music = [planetNote1 planetNote2 planetNote3 planetNote3 planetNote2 ...
    planetNote1];
%sound(music, fs);