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Scale-free brain ensemble modulated by phase synchronization

Key words: Brainwave, Ensemble, Music, Scale-free, Synchronization

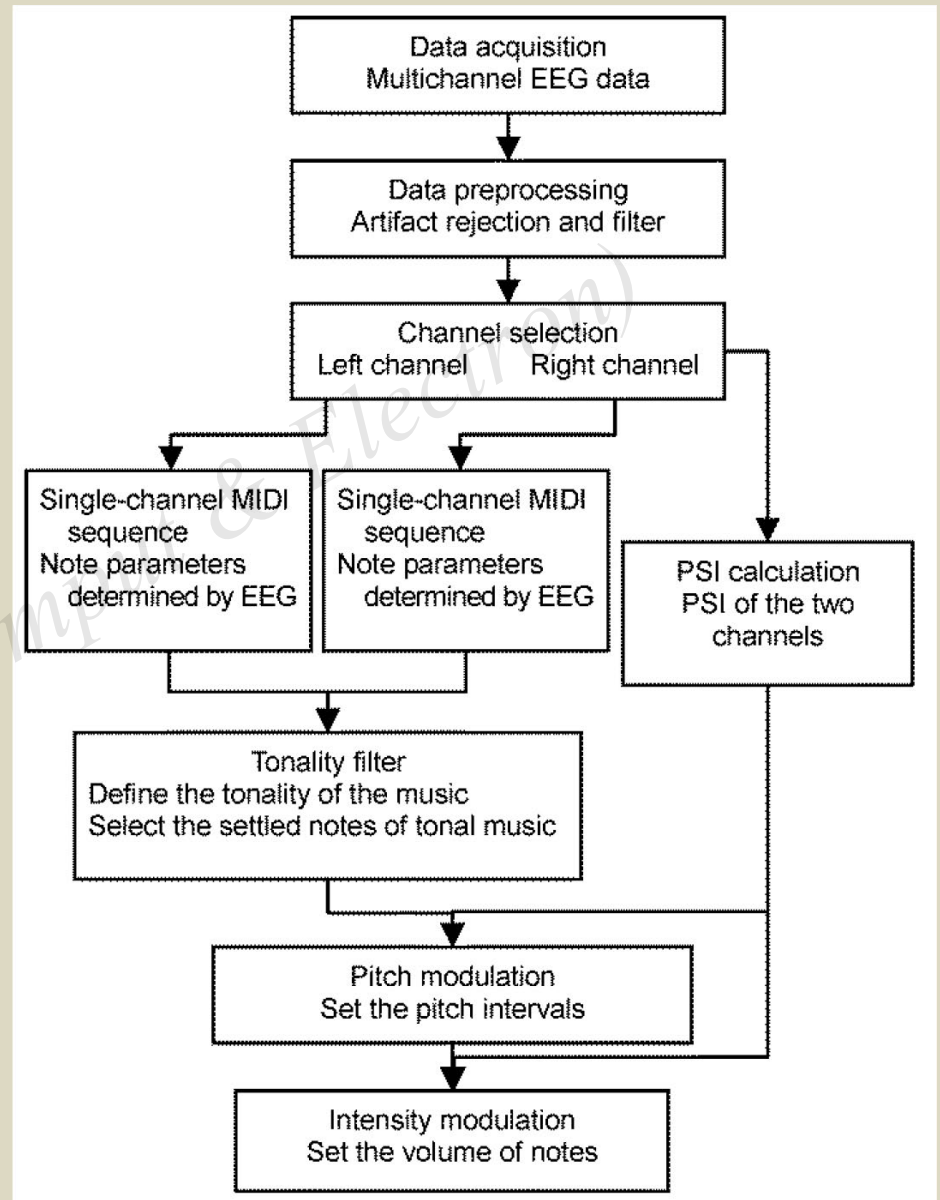
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Introduction

- EEG has been a useful tool for monitoring the neural electrical activities of the brain in a non-invasive way. We can directly ‘perceive’ what the brain ‘sings’ by brainwave music.
- There are three categories of brainwave music. The first is called “sonification”, the second is the musical application of brain-computer interface (BCI), and the third is scale-free brainwave music (SFBM).
- The power law, or scale-free, exists at almost all levels of neural physiology, including EEG. It appears applicable to music, audio signal and the number of note occurrences which show a power law distribution.

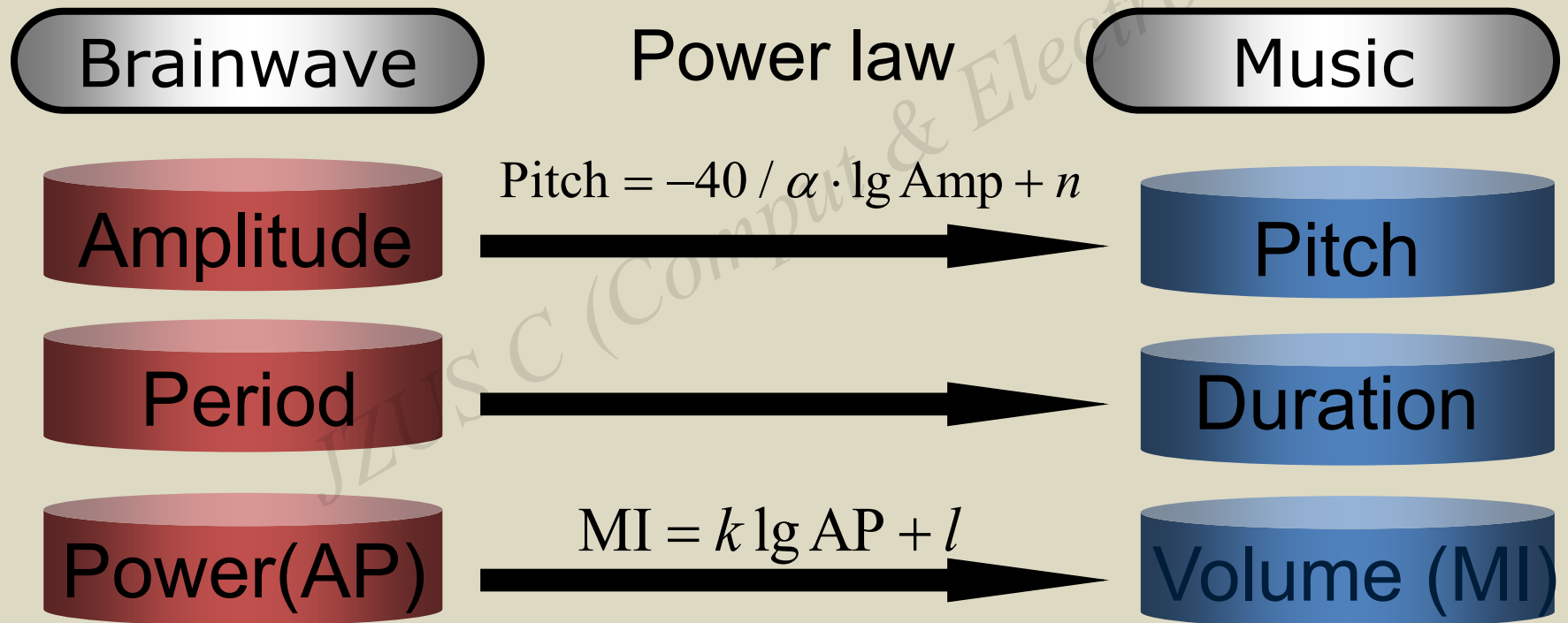
Method (I)

Fig. 1 Signal flow of the scale-free brainwave chorus music generation



Method (II)

1. Translation from EEG to music:



Method (III)

2. Phase synchronous index (PSI) calculate:

Step 1: compute the instantaneous phases $\phi_x(t)$ and $\phi_y(t)$

$$\phi_x(t) = \arctan \left\{ \left(\int_{-\infty}^{\infty} [x(\tau) / \pi(t - \tau)] d\tau \right) / x(t) \right\}$$

Step 2: define the phase difference

$$\Phi_{xy}(t) = \left| \phi_x(t) - \phi_y(t) \right|$$

Step 3: calculate PSI

$$\gamma \equiv \left| \left\langle e^{i\Phi_{xy}(t)} \right\rangle_t \right| = \sqrt{\left\langle \cos \Phi_{xy}(t) \right\rangle_t^2 + \left\langle \sin \Phi_{xy}(t) \right\rangle_t^2}$$

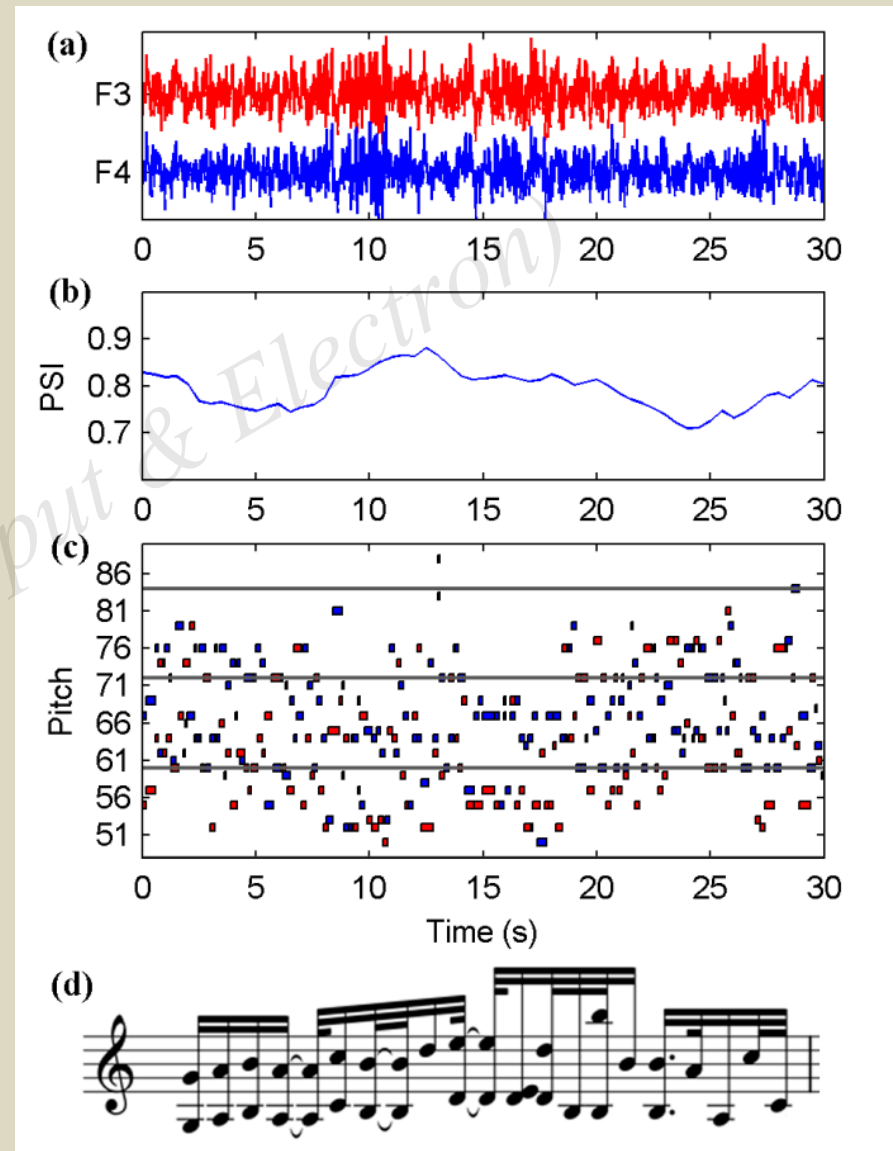
Method (IV)

3. Tonality filter and pitch modulation:

- (1) Verify the importance order of the two notes from the two MIDI sequences. The smaller one is settled.
- (2) If the two notes have the same importance order, the one with a greater duration is chosen.
- (3) If the importance order of the two notes are both 8, and $PSI > 0.2$, the note of the left hemisphere is set to the nearest tone notes.

Major results (I)

EEG and musical notes obtained from F3-F4 electrodes **with eyes closed**: (a) The EEG data from electrodes F3 (left hemisphere) and F4 (right hemisphere); (b) the PSI of the two channels; (c) the notes of the brain music (red from F3 and blue from F4); (d) example of the music scores



Major results (II)

EEG and musical notes obtained from F3-F4 electrodes **with eyes open**: (a) the EEG data from electrodes F3 (left hemisphere) and F4 (right hemisphere); (b) the PSI of the two channels, (c) the notes of the brain music (red from F3 and blue from F4); (d) example of the music scores

