Got Rhythm?

Network of Nonlinear Oscillators for Beat Tracking Revisited

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Neural Oscillator

Canonical model for a single neural oscillator introduced by Large, Almonte and Velasco in [5].

$$\dot{z} = z\left(a + b_1|z|^2 + \frac{b_2\varepsilon|z|^4}{1-\varepsilon|z|^2}\right) + \frac{x}{1-\sqrt{\varepsilon}x}\cdot\frac{1}{1-\sqrt{\varepsilon}\bar{z}} \quad (1)$$

where $a = \alpha + j\omega$, $b_1 = \beta_1 + j\delta_1$ and $b_2 = \beta_2 + j\delta_2$.

- $z \in \mathbb{C}$: oscillator state
- $x \in \mathbb{C}$: input
- $\varepsilon \in \mathbb{R}$: coupling strength
- ω: natural frequency of oscillation
- α, β_1 and β_2: determine behavior (linear, critical, limit cycle or double-limit cycle)
- δ_1 and δ_2: frequency detuning parameters.

Gradient Frequency Neural Network [5] (GrFNN)

Velasco et al. [7] proposed using these network for beat tracking.

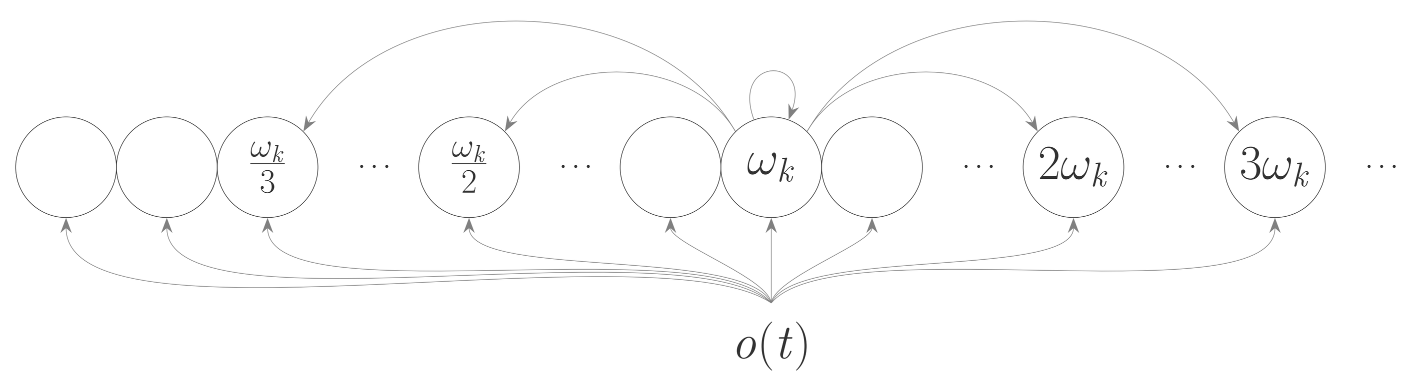

Figure 1 : Theoretical GrFNN configured for beat tracking: connections between oscillators with ω related by small integer ratios ($1:3, 1:2, 1:1, 2:1$ and $3:1$). Each circle represents an oscillator as described in equation 1.

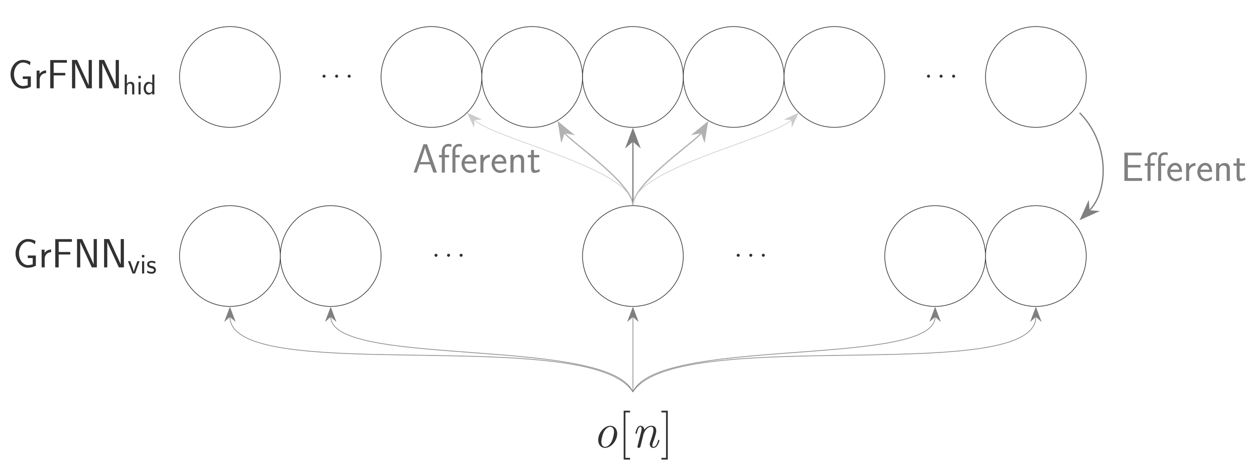

Figure 2 : Architecture used for the TF representation step. For clarity, efferent connections are shown as a single connection, but both GrFNNs are fully connected.

Experiment 1

- Beat tracking using hand-crafted connectivity
- Fully connected two-layer network
- Layers span 4 octaves, centered at 2 Hz
- 11 synthesized rhythms (4 conditions: 2 tempos and 2 accentuations)
- Evaluation used different metrics used in MIREX beat tracking competition [1].

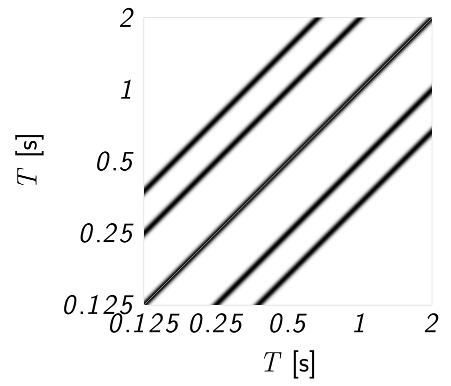

Figure 3 : Within layer connectivity

Evaluation

Performance was compared to other beat-trackers from the ISMIR community, with code made available by their authors [3], [2], [6].

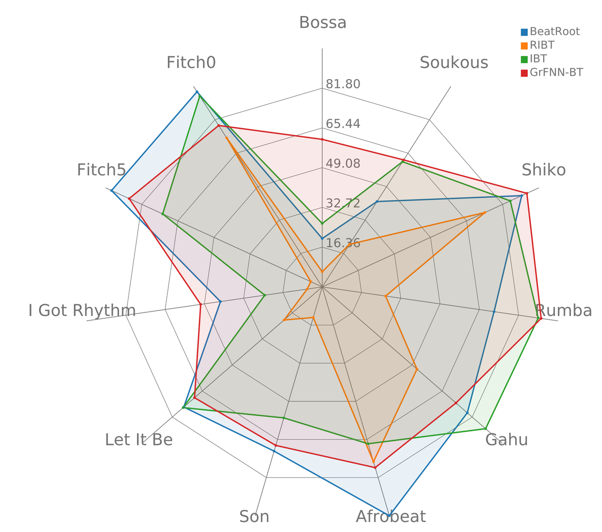

Figure 4 : Allowed Metrical Levels, continuity not required (AML$_t$) score

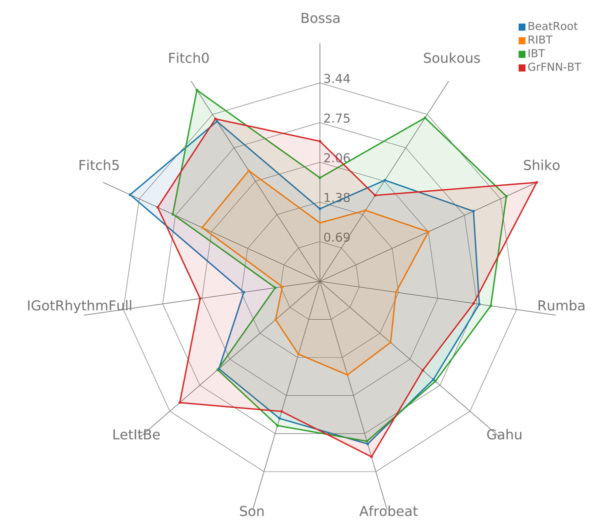

Figure 5 : Information Gain score

Experiment 2

Preliminary experiment to explore ability to learn connectivity, instead of using "hand-crafted" connections, according to formula derived by Large et al. [4]:

$$\dot{c}_{ij} = -\gamma_{ij}c_{ij} + k_{ij}\frac{z_i}{1-\sqrt{\varepsilon}z_i}\frac{\bar{z}_j}{1-\sqrt{\varepsilon}\bar{z}_j} \quad (2)$$

- Constant (un)learning rates γ_{ij} and k_{ij} were used
- Care must be taken to prevent "explosion"
- Connections learned are complex: need to explore the role of phase

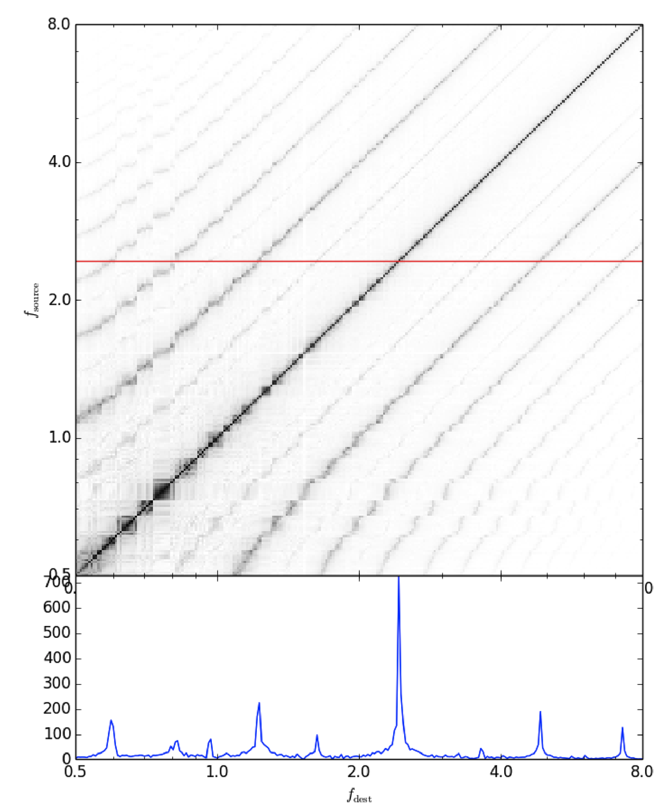

Figure 6 : Learned connections (magnitude)

Network Output Example

Figure 7 : Gershwins' *I Got Rhythm* melody (the original, in the key of F has been transposed to the key of C)

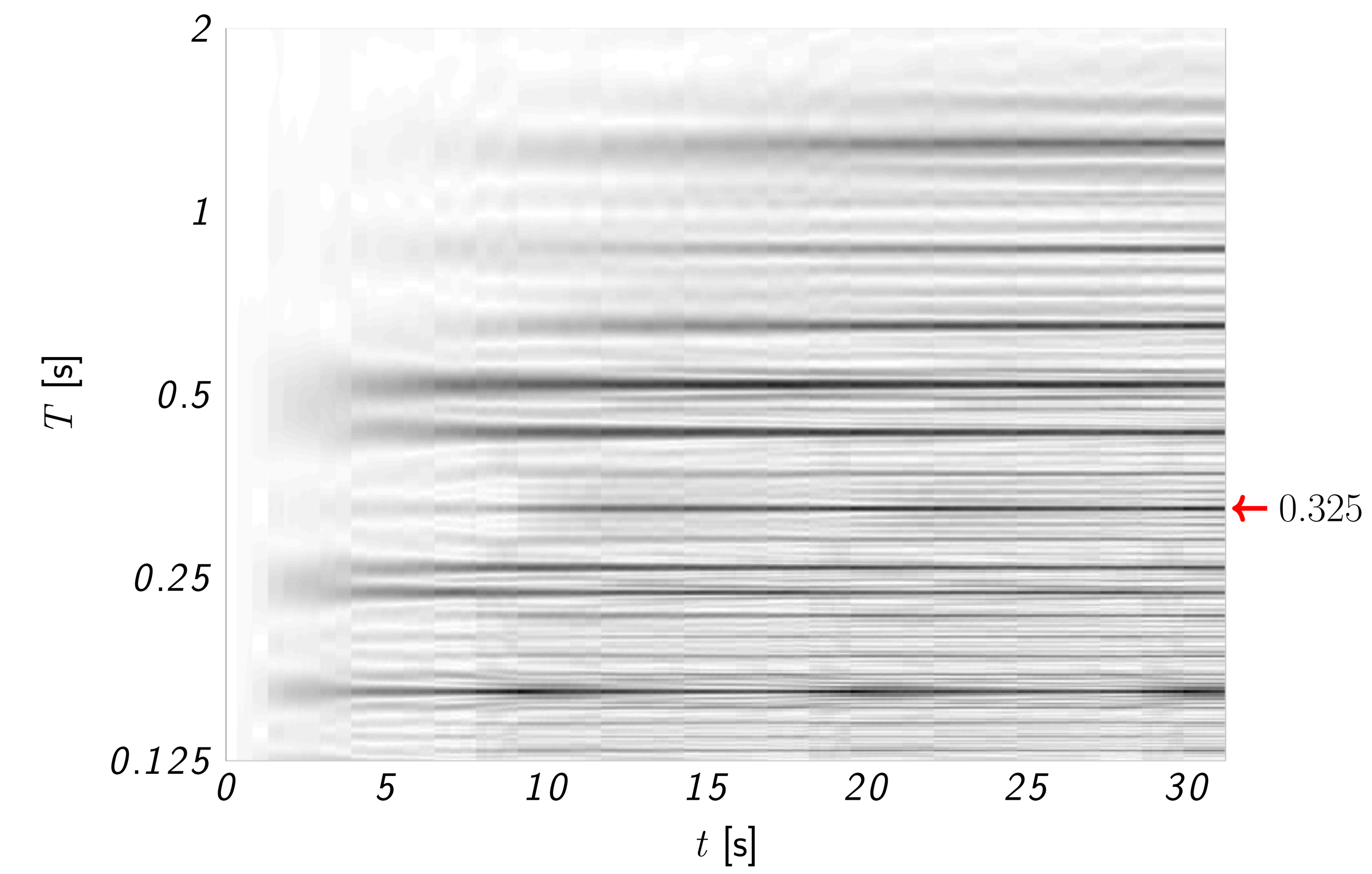

Figure 8 : Magnitude of the time-frequency representation of *I Got Rhtyhm*. The melody was rendered with a beat period $T = 0.325$ s (184.6 BPM approx) and repeated 3 times.

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