Synchronization and Music

A different paradigm & new perspective on leader-follower interactions

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Tapping synchronization → Music ensemble

- Recall: Kuramoto model

  - for tapping: Continuous → Discrete

  - for music:
    - Variable rhythms
    - Non-constant tempo
    - Real-time causality

A Different Synchronization Method

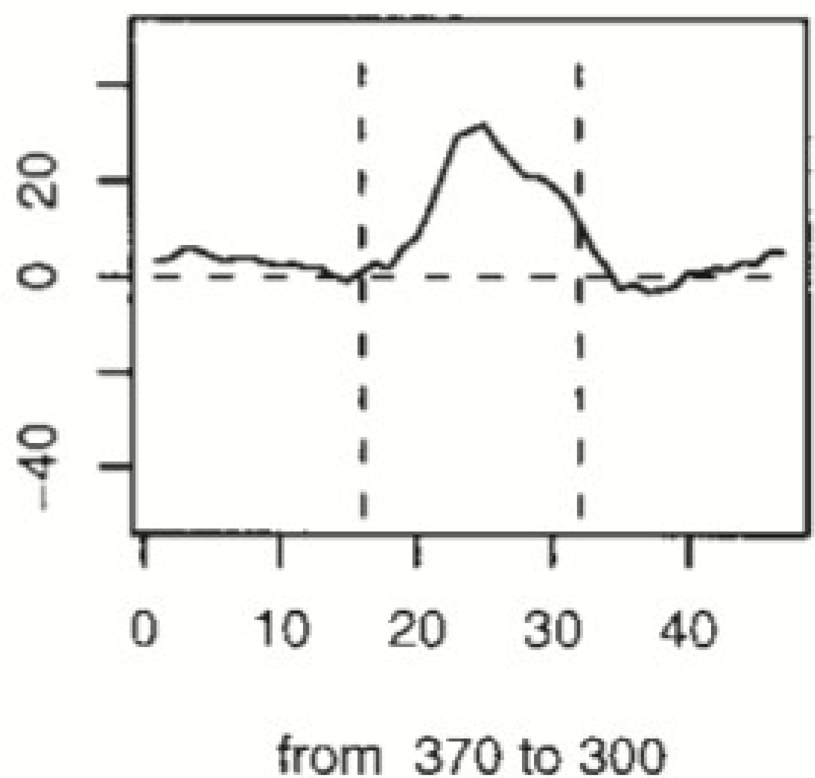
Schulze et al. (2005)

- Motivating scenario:
  tapping at non-constant tempo
  (accelerando & ritardando)

A Different Synchronization Method

Schulze et al. (2005)

- We measure <u>asynchrony</u> A_i at each step



A Different Synchronization Method

Schulze et al. (2005)

- Input:
  - "Metronome" C_i
- Primary elements of the model:
  - Timekeeper (random variable T_i)
  - Motor noise (random variable M_i)
  - Attention to asynchrony: error decays exponentially

A Different Synchronization Method

Schulze et al. (2005)

- We wish to model A_i
- $A_{i\text{-}1} + T_{i\text{-}1} - C_{i\text{-}1}$ is the "expected asynchrony"
- To this we add:
  - Motor noise M_i
  - Active correction factor $-\alpha A_{i\text{-}1}$

A Different Synchronization Method

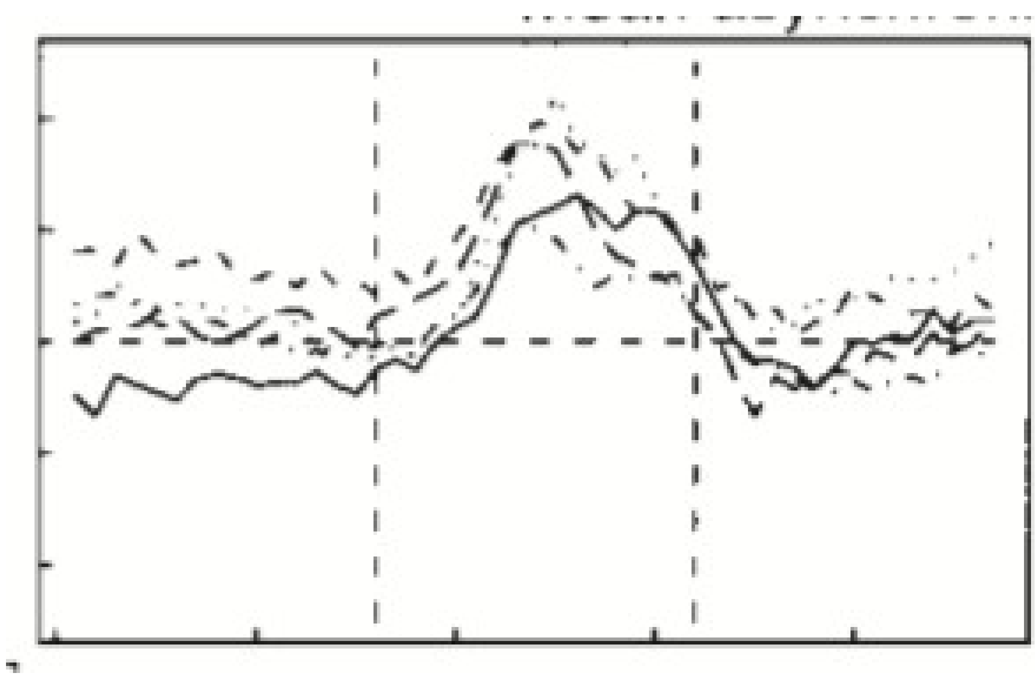
Schulze et al. (2005)

- We also update the timekeeper T at each step
- $t_i = t_{i-1} - \beta A_{i-1}$

A Different Synchronization Method

Schulze et al. (2005)

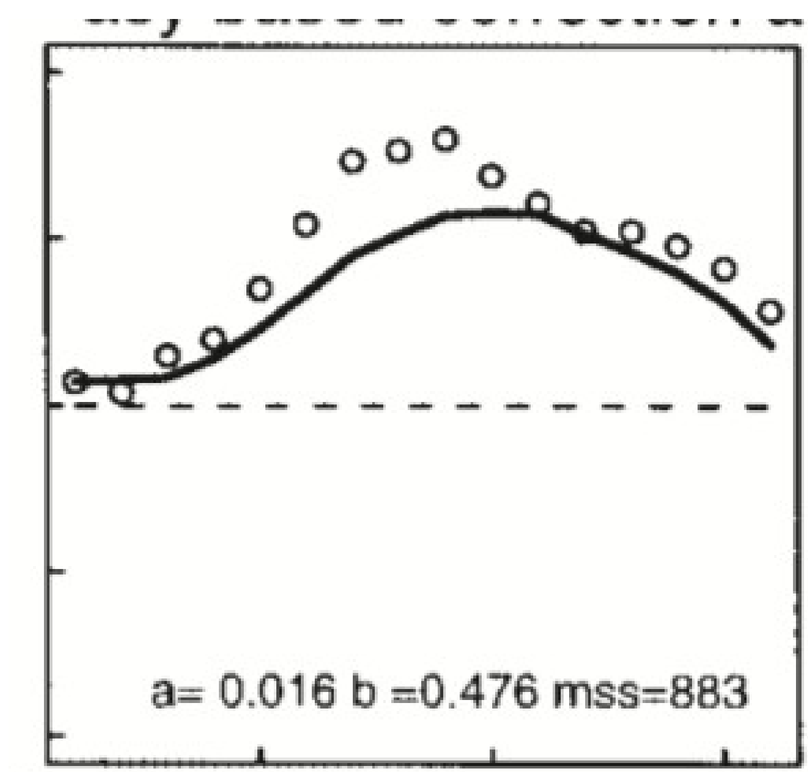
- Now estimate α & β to best fit the observed A_i



A Different Synchronization Method

Schulze et al. (2005)

- Result (by least-SSE criterion):



A Different Synchronization Method

Schulze et al. (2005)

- Properties/Advantages:
  - Naturally discrete
  - Deals with changing tempo
- NB this is a model for *post hoc* analysis.
  In real-time, $A<0$ cannot be implemented.

Application to Music

Maezawa (2024)

- Piano duet
- Rhythm quantized (32^{nd} note)
- Linear interpolation when there is no onset

Application to Music

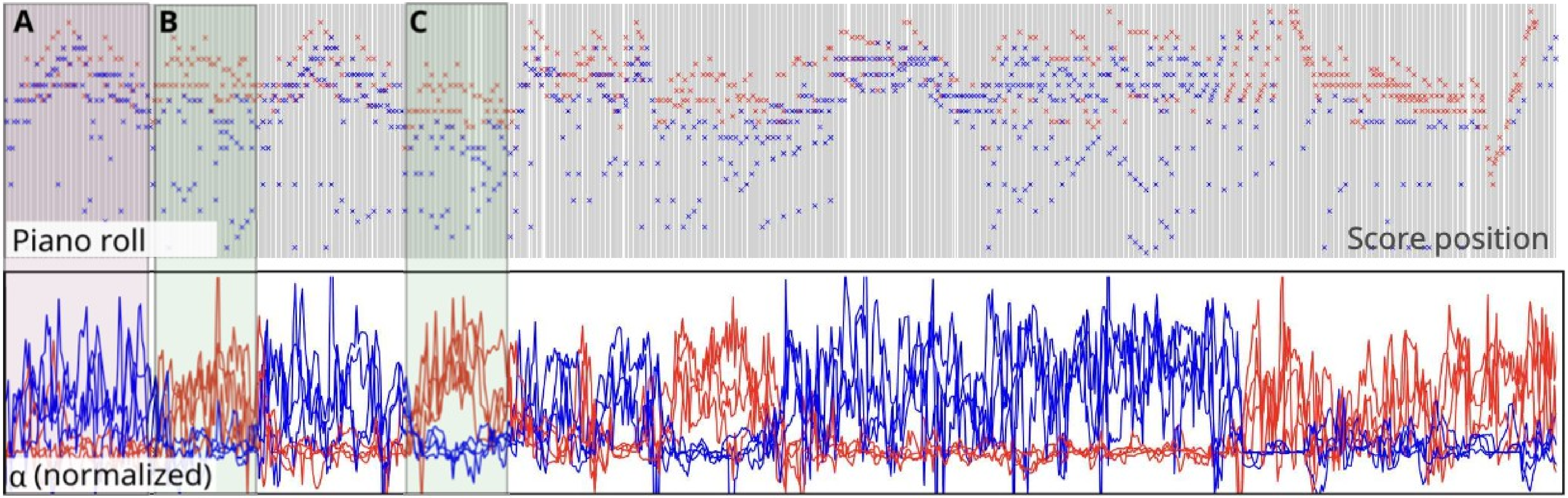
Maezawa (2024)

- If the pair of musicians act like this model, we can treat one as the “metronome” and compute the local α, β of the other one.

Application to Music

Maezawa (2024)

- If the pair of musicians act like this model, we can treat one as the “metronome” and compute the local α, β of the other one.
- The result is very interesting:



Application to Music

Maezawa (2024)

- α, β are not constants.
- Maezawa's hypothesis: they depend on the score.
- Let's also consider σ_M, σ_T to be functions of the score.

Application to Music

Maezawa (2024)

- Cut the score into frames (1 per 32^{nd} note)
- We look at "slices" composed of 32 frames, centered around each sequential frame.
- Create a model:

INPUT	$\rightarrow$	OUTPUT
Score slice		α, β, σ_M, σ_T

Application to Music

Maezawa (2024)

- Note: the model does not learn the parameters; it outputs the parameters.
  It learns “hidden variables” which determine how to extract them from a score.

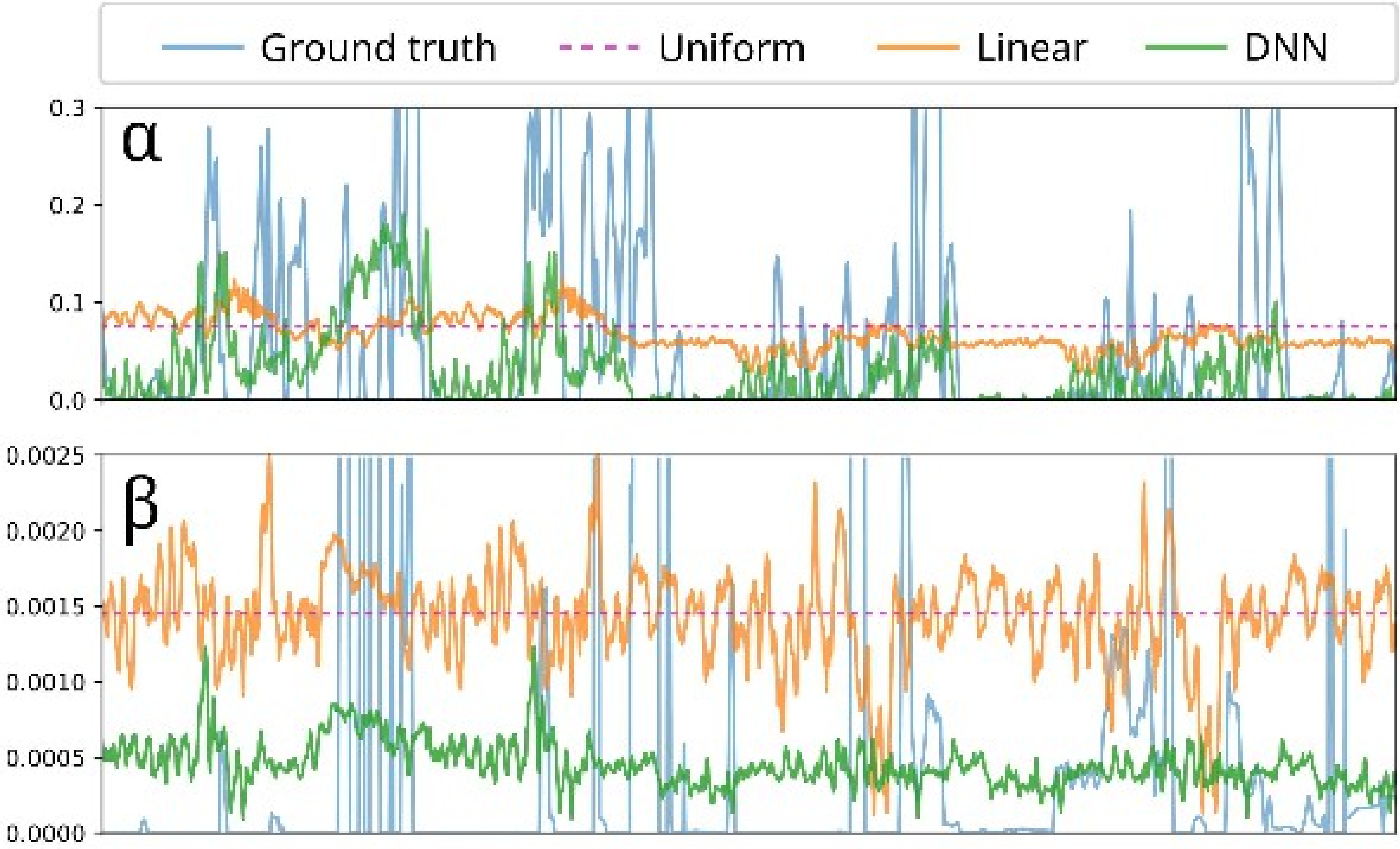
Application to Music

Maezawa (2024)

- Note: the model does not learn the parameters; it outputs the parameters. It learns "hidden variables" which determine how to extract them from a score.
- Evaluation: compare model-computed α, β, σ_M, σ_T to observation.

Application to Music

Maezawa (2024)



Application to Music

Maezawa (2024)

- Mean absolute error: (recall that $0<\alpha<1$)

Condition	α	β	σ_T	σ_M
Uniform-train	7.43E-2	2.85E-3	2.05E-2	2.76E-2
Uniform-valid	7.43E-2	2.84E-3	1.71E-2	2.74E-2
Linear	6.56E-2	**1.77E-3**	1.39E-2	2.42E-2
DNN	**5.65E-2**	1.80E-3	**1.19E-2**	**1.82E-2**

Discussion

- A way to approach the leader-follower problem
- General idea: the AI, having looked at the score, generates a "map" of the parameter values to be applied at each point of the score. It has learnt how to do this by analyzing how humans have performed other scores.
- We should be able to apply this concept to add another layer to our real-time ensemble player.
- However, its specificity w.r.t. certain salient musical features is probably low.