Listening clocks
between empathy and confidence

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(Draft version)

1 ListeningClock: the algorithm

1.1 Introduction

ListeningClock[1] is the result of the attempt to implement the simplest possible model of how musical timing is negotiated between several musicians playing together. It is specially intended to allow experimenting with tempo adjustment without a single master clock, and with different listening and responding behaviours. In the current implementation, we simplify the situation by assuming that every musician knows every other musician's tempo and phase (the relative timing offset) directly at at all times. Every player may 'listen' to every other player and adjust their own playing according to: (1) a weighted average of the others' behaviours (2) a playing attitude, denoted by the two parameters empathy and confidence. The algorithm takes into account an unavoidable tension between ...

1.2 empathy and confidence

Every clock runs the following simple algorithm independently, at a given rate, per default 2 Hz (dt = 0.5s):

First, it calculates $\overline{\Delta\theta}$, the (weighted) average of the *phase* differences between its own phase θ_{ref} and the phases the clocks it is listening to. It also calculates the average *tempo* $\overline{\phi}$ of those other clocks.

$$\overline{\Delta\theta} = \frac{1}{n}\sum_{i=1}^{n}(\theta_i - \theta_{ref}) \cdot w_i \tag{1}$$

[1] It is part of the system *Virtual Gamelan Graz*, written by Rainer Schütz, Julian Rohrhuber and Alberto de Campo.

$$\overline{\phi} = \frac{1}{n} \sum_{i=1}^{n} \phi_i \cdot w_i \tag{2}$$

where:
θ_{ref} is the current phase of the currently adjusting clock
θ_i is the current phase of the ith clock
n is the number of clocks the adjusting clock is listening to
w_i is the ith weight in a normalized list. This way, one clock (e.g. the kendhang) may be given more attention than others.

In a next step, the clock derives its new tempo ϕ_{new} from these values. The clock's parameters *confidence* and *empathy* determine in what way the ensemble's average phase difference and tempo influence the clock's new tempo.

$$\phi_{new} = \overline{\phi} \cdot (1 - \text{confidence}) + \phi_{old} \cdot \text{confidence} + \overline{\Delta\theta} \cdot \text{empathy} \tag{3}$$

where:
$\overline{\phi}$ is the average tempo of the rest of the ensemble
$\overline{\Delta\theta}$ the average phase difference ϕ_{new}, ϕ_{old} is the previous and the new tempo of the currently adjusting clock

1.3 Explanation

The parameter confidence is intended to denote the confidence in the relevance of one's own tempo, so that high confidence entails a tendency to insist on one's own tempo. The parameter empathy models the willingness to adjust one's phase, "to be with the others". For instance, a fully confident player without empathy would simply remain unaffected by, and thus out of sync with the others.

It is easy to understand the influence of these parameters (which both range between 0.0 and 1.0), if we consider extreme cases. In each of the extreme cases, the formula (3) becomes even simpler.

Let's first consider the cases where empathy = 0.0, so that the second factor of the above formula can be left out (zero multiplied with anything remains zero). As a confident player without empathy, one may be thought to remain in one's own tempo despite changes in the ensemble (c = 1.0, e = 0.0):

$$\phi_{new} = \phi_{old} \cdot 1.0$$

Conversely, when both one's empathy and one's confidence are minimal, one would not remain with one's old tempo, but immediately jump to the average tempo of the rest of the ensemble (c = 0.0, e = 0.0):

$$\phi_{new} = \overline{\phi} \cdot (1 - 0.0)$$

As such a player, we will always follow tempo changes, but we will be indifferent to whether we play in sync with the others; there is no adjustment for phase differences, but only to tempo differences.

Now, the second parameter, *empathy*, is the degree to which a player reacts to the phase differences. In other words, while confidence is tempo-oriented, empathy is synchronicity-oriented, so that high empathy will cause us to follow other players very closely, low empathy will cause us to ignore phase differences, even if we follow their speed meticulously.

Imagine for instance being a player who is oriented mainly by an awareness for *where in the piece the others are now*, and less by *the own tempo*. In this case, the contiguity of one's own playing will be reduced, and adjustments to the ensemble quick. This situation is extreme when confidence is minimal (= 0.0) and empathy is maximal (= 1.0). In the above formula, the influence of one's own tempo can be left out, so that only the average ensemble tempo and the average phase difference have an effect (if the ensemble is faster, but behind – so that $\overline{\Delta\theta}$ is negative, the new tempo ϕ_{new} is not necessarily higher than the old one) (c = 0.0, e = 1.0):

$$\phi_{new} = \overline{\phi} + \overline{\Delta\theta} \cdot 1.0$$

If, however, we decide to play both maximally confidently and emphatically, our own tempo will not adjust very much because of the ensembles tempo changes, but because we try to play on the others' beats. This situation shows a maximum tension, and when the all the players of the ensemble listen to each other in this way, the ensemble may diverge, oscillate, or become chaotic. The simplified formula then looks like this (c = 1.0, e = 1.0):

$$\phi_{new} = \phi_{old} + \overline{\Delta\theta}$$

We can easily imagine that transitions can work plausibly, when the players have a well adjusted balance between confidence (considering each others' tempos, and their own), and empathy (neither jumping on the others' beats, nor ignoring their current phases). The way an ensemble slowly adjusts to tempo changes depends on the details of all these behaviours and to what degree each player listens to other players.

1.4 Overview

	confidence high	confidence low
empathy high	steady, but trying to catch up.	quickly following tempo, unsteady.
empathy low	steady and out of time.	fast following tempo, but remaining out of time.

2 Tempo Curves

A single player may not only change the tempo due to adjustment to the ensemble. As a player, we may take the initiative and change our tempo. In the current implementation, such tempo transitions are implemented by the function *fadeTempo*, which takes the following parameters:

- newTempo — the tempo at which the transition ends.
- dur — the time at which the transition has reached newTempo.
- warp — a shape for the transition (default is a cosine shape). The extendible list of shapes is: linear, exponential, cosine, sine.
- clock — a clock may be given relative to which this change happens. This clock may change tempo as well.

Other clocks that listen to a clock thus changing will adapt their tempo according to each of their inner dispositions determined by the algorithm given in the previous section.