Acoustic Synchrony

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Introduction

• Do crickets synchronize their chirps with neighboring crickets?

• A field study by Thomas J. Walker in 1969 found that they do, but under certain conditions.

• Walker took recordings of actual crickets, and played them back to discover if a neighboring cricket would alter its chirp rhythm to synchronize.

• He found that neighboring crickets would synchronize their chirp, but not the number of pulses it chirps.

• We set out to reproduce these results with a simple microphone and speaking coupling.
Our Two Crickets
Experimental Setup

Supplies for each cricket:

1. USB soundcard
2. Microphone
3. Speaker
4. MATLAB window
Experimental Setup

• We wrote a MATLAB function that was able to communicate with the soundcard that had a speaker and microphone attached to it.
• Using a state variable, discussed previously, we would integrate the equation using a Runge-Kutta fourth order ODE solver (probably a bit much but I already had one).
• The microphone would record short instances in time and if it recorded anything louder than a certain threshold variable, which we set, it would add $\eta$ to the current state variable.
• Once the state variable reached one, it played a chirp. While playing a would could listen to it’s neighbor and we toggled the ability for listening to itself.
Experimental Setup

Integrate State with RK4

\[ x_i(t) + \eta \]

if \( x_i \geq 1 \)

Record Data
A Model for Pulse-Coupled Oscillators

Initially, we started with a model by Steven Strogatz. Given by,

\[ \frac{\partial x_i}{\partial t} = \omega_0 - \gamma x_i \]

where the state \( x_i \in [0,1] \), \( \omega_0 \) is the natural frequency, and \( \gamma \) is a dissipative term. The correction condition for phase shift is

\[ x_i = 1 \Rightarrow x_j(t^+) = x_j(t) + \eta \]

where \( \eta \) is the coupling strength of the cricket and its neighbor.
Strogatz Model

- $\gamma = 0.05$
- $\eta = 0.3$
- $\omega_{0L} = 12.01$
- $\omega_{0F} = 11.98$
Relative Phase Difference for $\eta=0.3$

Phase Difference (s) vs Iteration Number

0 10 20 30 40 50 60 70 80 90 100
Strogatz Model

- $\gamma = 0.05$
- $\eta = 0.7$
- $\omega_{0L} = 12.01$
- $\omega_{0F} = 11.98$
A Modified Model

To simplify the model we neglected the dissipative term.

\[ \frac{\partial x_i}{\partial t} = \omega_0 + \zeta(t) \]

where \( \zeta(t) \) is the external noise, which we took to be the mean of the recorded data.
Plots of Data

with parameter values:

\[ \omega_{0L} = 12.01 \]
\[ \omega_{0F} = 11.98 \]
\[ \gamma = 0 \]
Synchrony

Relative Phase Difference for $\eta=0.15$
Synchrony

Phase Drift for $\eta=0.15$

- Y-axis: Phase Drift (s)
- X-axis: Iteration Number

Graph showing data points for phase drift with iteration number.
Shifts by 180°
Shifts by 180°
Simulation

Initialization (including frequency, coupling etc)

One cricket sings at its own frequency + some noise disturbance

the other cricket hear chirps from others, it boosts its state. If not, goes with its own frequency

Records down each time it chirp.
Compare to experiment

in simulation:
  \( f(\text{leader}) \sim f(\text{follower}) \)
  boost strength \( \sim 0.3 \)
threshold

In Experiment:
  \( F(\text{leader}) \sim F(\text{follower}) \)
  The noise \( \sim 0.02 \)
  boost strength \( \sim 0.1 \)
  Threshold = 1
Stable disturbance

Phase plot for firing = 21

Phase plot for firing = 33

Boost = 27
Noise for one cricket?
Noise for two Cricket
Discussion

• This shows us that the leader-follower method leads to synchrony for most cases.
• This simple coupling is difficult to desync. It is very stable unless the disturbance is about a order to the “threshold” (large different natural frequency?)
Discussion: possible defects

1. extra unnecessary boosts in experiments
Chirps Time $\gg$ recording time
How to choose a suitable time scale.

2. for the present model, phase in and out oscillation is very likely. Maybe a “boost-changeable” model?