Computational Physics [PH 881]

Mini Project - Proposal

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Topic: Creating Musical Variations with Chaotic Attractors

Abstract: In Physics, Chaotic dynamics refers to dynamics that have a sensitive dependence on initial conditions. That is, a small change in the Initial Conditions (ICs) results in a dramatic change in the resulting trajectory which can reach an attractor such as a Lorenz attractor. Now, suppose some sequential data is mapped onto the points on such a chaotic attractor. In our case, we map the pitch sequence of a musical piece. Say that the original sequence is mapped onto a certain trajectory called the reference trajectory with a specific IC. Then by changing the IC slightly from the reference trajectory's IC, one can observe a new sequence when the attractor is reached via trajectories different from the reference trajectory. But a flavour of the original sequence will still remain in the new sequence since the same entities (pitches, in our case,) are found in both the sequences. As a result, in our case, we produce a 'Musical Variation' of the original musical piece. Note that the variation can be moderated by tracking the reference trajectory by using different step sizes, initial conditions etc.. This project can be a very intuitive explanation of sensitive dependence of initial conditions and hence very useful in pedagogical situations. Further this procedure can be applied to any sequential data as alluded to before. For instance, one can map a nucleotide sequence of a gene and follow the same procedure. In this case, one will obtain Genetic Mutations (analogous to Musical Variations).

References:

Primary reference:

1. Dabby, Diana S. "Musical variations from a chaotic mapping." *Chaos: An Interdisciplinary Journal of Nonlinear Science* 6, no. 2 (1996): 95-107.

Other references:

2. Strogatz, Steven H. *Nonlinear dynamics and chaos.* Kolkata: Levant Books, 2007.
3. Tamari, Ben. "Attractors." Accessed 16th October, 2018. http://www.bentamari.com/attractors.html
4. Dannenberg, Roger.B. "An Introduction to Music Concepts." Tutorial material for *Computer Music Systems and Information Processing* course, Carnegie Melon University, https://www.cs.cmu.edu/~music/cmsip/readings/music-theory.htm

Some details on implementation:

I am going to be using Python for all the coding. The project involves understanding non-linear dynamics, musical theory, solving non-linear differential equations, representing sequential data with appropriate data structures (lists, dictionaries etc.) and a basic knowledge of how to deal with external files (mostly MIDI files in my case) in Python. I will first be replicating the paper mentioned as primary reference above. This requires:

1. Using 4th order Runge-Kutta solver for solving the Lorenz equations and obtaining the Lorenz attractor
2. Mapping a certain trajectory(for a certain initial condition) to the pitch sequence of a musical piece (available in the public domain)
3. Changing the initial conditions to obtain a new trajectory and finally mapping the pitches to this new trajectory based on a certain rule, to get a variant of the musical piece ie a new pitch sequence.

Then I am planning to change the rule for mapping the pitches to new trajectories, parameters, step size etc. and observe how all these varaibles affects the variants. If time permits, I will also try to use other types of strange attractors (mentioned in the 3rd reference) and see how that makes a difference. During my presentation, I will only try to wildly speculate on how all these ideas maybe applied to Nucleotide sequences since I can't find many sources that do so except for a passing mention in the primary reference above.