Dynamical Systems NPHY 115A Fall 2014

Meet Tues/Thurs 2-3:20pm. On those Thursday classes marked with * we will meet in the computer classroom to work on Matlab tutorials or a project.

For those of you new to Matlab, I urge you to download it onto your computer and begin the Matlab Tutorial as soon as you can, prior to the start of class (I will offer help one or two evenings in the first two weeks of class). Instructions on how to do this are in the “Matlab Tutorial” document on Latte.

Grades will be based on homeworks, which will include some computational questions.

Textbooks used
The course will mostly cover Chs 1-8 of “Nonlinear Dynamics and Chaos” by Stephen H. Strogatz with additional examples from “Dynamical Systems in Neuroscience” by Eugene M. Izhikevich.

Prerequisites
In order to take this course you should already be familiar with the following mathematics:

1) Solution of linear first order ordinary differential equations (ODEs) as exponentials.
   e. g. if \( \frac{dx}{dt} = a - bx \) then \( x(t) = \frac{a}{b} + \left(x(0) - \frac{a}{b}\right) \exp(-bt). \)

2) Solution of the simple harmonic oscillator (a single second-order linear ODE) e. g. if \( \frac{d^2x}{dt^2} = -k^2 x \) then \( x(t) = A \sin kt + B \cos kt \) where \( A \) and \( B \) can be obtained from initial conditions and should recognize that this is the same as the solution of the two coupled first-order ODEs
   \( \frac{dx}{dt} = ay \) and \( \frac{dy}{dt} = -bx \) if \( k^2 = \alpha \beta \).

3) Taylor expansion around fixed points:
   \[
   f(x - x_0) = f(x_0) + (x - x_0) \left( \frac{df}{dx} \right)_{x_0} + \frac{(x - x_0)^2}{2!} \left( \frac{d^2f}{dx^2} \right)_{x_0} + \cdots
   \]

4) How to calculate eigenvalues and eigenvectors of matrices.

5) Hyperbolic functions and their differentials ( \( \tanh(x), \sinh(x), \cosh(x) \) ).

If you have learned these but forgotten, please recap before class. If you have never seen these topics, you should not be in the class! If just one of these is new/puzzling to you, feel free to learn it over the summer and ask me for help as needed.

Grading
60% from homeworks, 10% from in-class quizzes and 30% from final exam.
Each homework will be graded out of 10, with 1 point lost for each day late. Make-ups will allow up to half of lost points to be regained. Homeworks due at midnight each Monday night.
**Provisional Course Schedule**

Wk 1: Aug 28  
Introduction: Graphical Methods (Strogatz Ch 2)

Wk 2: Sep 2,4*  
1D: Fixed points and their stability (Strogatz Ch 2)  
Saddle-node + Transcritical Bifurcations (Strogatz Ch 3)

Wk 3: Sep 9,11*  
1D continued: Pitchfork Bifurcations (Strogatz Ch 3)

Wk 4: Sep 16,18  
Flows on the circle. (Strogatz Ch 4)

Wk 5: Sep 23  
2D systems: eigenvalue analysis of fixed points. (Strogatz Ch 5)

Wk 6: Sep 30, Oct 2*  
Phase Planes and Nullclines (Strogatz Ch 6/Izhikevich Ch 4)

Wk 7: Oct 7  
Phase Planes and nonlinear systems continued (Strogatz Ch 6/Izhikevich Ch 4)

Wk 8: Oct 13, 14  
Limit Cycles, Van der Pol oscillator and Liénard Systems (Strogatz Ch 7)

Wk 9: Oct 21, 23*  
Relaxation oscillators : Fitzhugh-Nagumo Model (Izhikevich Ch 4)

Wk 10: Oct 28, 30  
Andronov-Hopf Bifurcations (Strogatz Ch 8, Izhikevich Ch 6)

Wk 11: Nov 4, 6*  
Bifurcations to oscillations continued (Strogatz Ch 8, Izhikevich Ch 6)

Wk 12: Nov 11, 13  
Applications: spiking neural models (Izhikevich Ch 5)

Wk 13: Nov 18, 20*  
Applications: Belousov-Zhabotinsky Reaction (Strogatz Ch 8)

Wk 14: Nov 25  
Applications: bursting neural models (Izhikevich Ch 9)

Wk 15: Dec 2, 4  
Coupled Oscillators (Strogatz Ch 8)