CS401 – Introduction to Nonlinear Dynamics

Course format
- 3 hours of lecture per week.

Prerequisites
Introductory Calculus: vectors, linear differential equations, difference equations etc. Basic familiarity of concepts of high school mechanics such as Newton's equations of motion, conservation of momentum and energy, flux etc. Some experience with a programming language like Matlab, Python, or C++ is also needed although not at an advanced level.

Course Content
This course is an introduction to the interdisciplinary area of nonlinear dynamics. We encounter nonlinear effects in everyday life and in nature all the time. The examples range from water waves and hydrodynamic phenomena such as mixing and turbulence, cloud formation to collective phenomena such as flocking, neural network structures and group dynamics. While many of them are found in nature, they also have considerable industrial importance. This course in itself is therefore a language or a collection of techniques which provides the necessary background to model and understand non linear systems appearing in a variety of disciplines such as physics, biology, chemistry, computer science, engineering and meteorology. The main topics that will be covered include: one and higher dimensional non linear systems, concept of flows and phase plane analysis, bifurcation theory, chaos and attractors.

Foundation for
Mathematical modeling of natural and physical phenomenon. Any higher level course which deals with non linear dynamical systems.

Text Book

Reference books

Assessment method/Grading

Written exam: Two mid-semester examinations and a final exam: 80% (25+25+30)
Assignment and Quiz: There will be take home assignment which would require scientific programmin and in-class surprise quiz. (Weightage: 20%). Any instance of copying or plagiarism will result in 0 for the assignments.
Grading: Grading will be relative. Any student scoring less than 35% will receive a F grade.
Attendance: 80% attendance will be mandatory. Students not meeting this criteria will be not allowed to sit in the final examination.

Course Outcome
On successful completion of this course the students will:

1. learn the concepts related to a geometric and global way of thinking about nonlinear evolution equations through phase space analysis, linear stability theory, bifurcation theory, maps and surface of sections.

2. They would also be able to learn the algorithms for simulating, analyzing nonlinear systems. Since this course is completely interdisciplinary the techniques learnt would be applicable to problems from a variety of disciplines.
**Course Content/Lecture schedule**

<table>
<thead>
<tr>
<th>Topic Name</th>
<th>Content</th>
<th>No. of lectures (tentative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-dimensional systems, linear and non linear</td>
<td>Basic concepts such as phase portraits and fixed points and the philosophy behind solving the non linear equation without solving it. 1 dimensional non linear models of population growth, stability of LC circuits etc.</td>
<td>7</td>
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<tr>
<td>Bifurcations</td>
<td>Parameter space, Different kinds of bifurcations in 1-dimensional systems, phase transition and applications.</td>
<td>7</td>
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<tr>
<td>Two dimensional linear systems</td>
<td>Eigenvalues and Eigenvectors and their phase plane representation</td>
<td>5</td>
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<tr>
<td>Two or higher dimensional non linear systems</td>
<td>Linearization around the fixed point, phase space properties of simple conservative and reversible systems, Limit cycles, Bifurcation in two dimensional systems with physical examples such as hysteresis in driven pendulum and Josephson Junction, Predatory Prey Systems etc.</td>
<td>10</td>
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<tr>
<td>1 Dimensional maps</td>
<td>Logistic map, systems with discrete time steps, return maps</td>
<td>6</td>
</tr>
<tr>
<td>Lorenz equation</td>
<td>Introduction to chaos and strange attractors.</td>
<td>7</td>
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* The number of topics covered will depend on the overall enthusiasm and commitment of the class.