Modeling Nature: An Innovative Approach In Bioengineering

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Abstract – The newly formed bioengineering department at the State University of New York at Binghamton has taken an innovative step in integrating a technical elective in bioengineering with sufficient humanities content to qualify as a humanities course according to the university criteria.

Index Terms – Bioengineering, innovative approaches and curricula

INTRODUCTION

One of the expressed goals of the newly formed Department of Bioengineering at SUNY Binghamton is to foster interdisciplinary inquiry at all levels within the university community. Towards this end, an undergraduate level technical elective course has been developed and offered. In addition to the firm technical foundation of the course, a strong link is established with the humanities (philosophy). The course has also earned designation from the university’s general education requirements committee as an appropriate and acceptable humanities course, which students may use to satisfy state, mandated graduation requirements.

Nature is often considered the most complex word in the language. Williams suggests three possible areas of meaning: (1) the essential quality and character of something; (2) the inherent force which directs the world or human beings or both; and (3) the material world itself, taken as including or not including human beings.[1] For the purposes of this course, the third interpretation is adopted.

Modeling Nature seeks to develop in students the ability to formulate mathematical models for a wide spectrum of natural phenomena. The course builds upon the closed form deterministic solutions traditionally used in classical modeling techniques. Newer approaches based upon probability and cellular automata algorithms are then introduced and explored, providing students with a wide range of modeling tools. The course uses Mathematica extensively starting with an in-depth workshop focused upon developing the appropriate programming skills required.

After consideration of the various approaches (i.e. deterministic, probabilistic, and cellular automata), the philosophical implications of the different models upon our understanding of the natural world and subsequently our sense of responsibility towards nature are explored.

COURSE DESCRIPTION

The objectives of the course as laid out in the course syllabus are given in the following section. By the end of the course, each student will be able to:

- Model natural phenomena including population dynamics, spreading diseases, percolation, evolution, predator-prey ecosystems using deterministic, probabilistic, and cellular automata models
- Compare and contrast the strengths and weaknesses of the various models
- Consider and reflect upon the philosophical consequences of the various models
- Consider and reflect upon the implications of the various models, specifically focusing upon resultant responsibilities, if any.

The course is designed to meet the General Education prescription for a humanities course at the State University of New York at Binghamton (Binghamton University). Convinced that there are several areas of knowledge and experience that ought to be central to the academic experience of every undergraduate student, Binghamton University has adopted a comprehensive General Education curriculum. This curriculum has broad goals. It is intended to help students develop:

- An appreciation of and capacity for effective personal expression;
- Knowledge about various intellectual traditions;
- An understanding of and respect for different peoples and civilizations;
- Knowledge of and appreciation for the natural world, achieved through active engagement with the methods and philosophy of natural science;
- Logical thinking, balanced skepticism, and tolerance for ambiguity and uncertainty;
- A knowledge of and appreciation for the arts and creative expression.

TECHNICAL FOUNDATION

The technical foundation for the course lies on an adequate mastery of Mathematica. Towards that end the first segment of the course is devoted exclusively to developing the required skills. A series of highly interactive tutorials based on the
Rocky Mountain Mathematica workshops developed by Packel and Wagen. [2] A list of the subjects covered includes the following:

- Introduction to Mathematica
- Plotting
- Symbolic numbers
- Lists
- 2-D and 3-D graphics
- Ordinary differential equations
- Basics of Mathematica programming

Following the workshops, the course focuses on the various approaches that have been used and are presently being used to model natural phenomena.

Deterministic Models: Mathematica is used to solve the following deterministic approaches to population dynamics [3]:
- Malthusian model
- Verhulst model
- Lotka-Volterra model

Probabilistic Models: Mathematica is used to solve the following probabilistic systems type problem[3]:
- Random walk
- Self-avoiding walk
- Accretion
- Spreading phenomena (viral diseases)

Cellular Automata Models: Mathematica is used to solve the following cellular automata type problems [4]:
- Game of life
- Forest fires
- Predator-prey ecosystems

Students are first given a competency exam on their mastery of Mathematica. Subsequent to the exam, a project is assigned for each of the various modeling approaches. In addition, students work in teams of two or three on a term-length project. Some choice is allowed in the selection of the projects while the default assignment is modeling a predator-prey ecosystem with moving predator and moving prey species. This is an extension of the cellular automata project discussed in class which had only moving predator species while the prey species remained fixed.

**HUMANITIES FOUNDATION**

The university accomplishes compliance with the broad general education goals through a requirement for students to select courses in a series of categories. For the present course, an “H” designation has been identified. The description of this category is as follows:

Category 4: Aesthetics and Humanities (A or H)
By taking courses in this area, students gain an expanded sense and understanding of culture and a greater appreciation of human experience and its expressions.

*Aesthetics* (A) courses enhance students' understanding of the creative process and the role of imagination in it. Students study or practice artistic expression and production in such fields as art, art history, cinema, creative writing, dance, graphic design, music and theater.

*Humanities* (H) courses enhance students' understanding of human experience through the study of literature or philosophy.

In response to the Humanities or (H) guideline, highlights of the content of the course include:

- Readings on the various models of Nature [5]
  - “Organic Views of Nature” (from Lucretius, *De Rerum Natura*)
  - “Nature as Great Machine” (from Edward Alden Jewell)
  - “Nature as Computer” (from Buckminster Fuller)
  - “Nature as Biosphere” (from G.E. Hutchinson)
- Readings that focus specifically on ethical issues related to wildlife in America including [5]
  - Role of large predators in ecosystems
  - Implications of land and “game” management
  - Saving endangered species
- Readings that explore possible future descriptive models or understandings of the natural world including but not limited to the works of [6]
  - Barry Lopez
  - Bill McKibben
  - Gary Snyder
  - Wendell Berry
  - Anne LaBastille
- Students are exposed to the historical development of environmentalism in the United States and reflect upon its linkage with our understanding of the natural world
- Students are asked to write at length concerning various philosophical, ethical, environmental issues including but not limited to [6]-[8]:
  - Saving elephants in Tsavo Park in Africa
  - Why save endangered species?
  - Is Nature merely a collection of resources?
  - Predator/prey relationships
  - Nature as “discordant harmonies”

In the “Technical Foundation” section of the present work, a term project requirement was described. In addition to the modeling of the natural phenomena, students are asked...
individually to write a critical essay on the philosophical implications of their solution. For example, for the default project, the predator-prey ecosystem, students would be asked to consider the limitations of their proposed model. What assumptions are made concerning the predator species, the prey species and their interactions? What impact do those assumptions have on our understanding of the species' behavior? What impact do those assumptions have on our understanding of the natural world? Finally, how do such assumptions influence our sense of stewardship and/or responsibility?

**Final Thoughts**

As the course is presently in its first offering, a formal assessment of both the effectiveness of the course in meeting the course objectives and students reactions are not available at the time of the submission of the manuscript. However, such information will be included in the final version.

**References**