昆山杜克大学
DUKE KUNSHAN UNIVERSITY

COMPSCI 107K; ISS 170K

Complex Systems: Artificial Life, Culture & Evolution

Fall 2015

Dates / contact hours:	Two three-hour sessions each week (300 minutes)
Academic Credit:	1 course
Areas of Knowledge:	QS
Modes of Inquiry:	STS (Hands-on engagement with computer representations of complex social phenomena)
Course format:	Integrated lecture, lab, seminar, and discussion.

Instructor's Information

Nicholas Gessler
Cell: (919) 308-6539
nick.gessler@duke.edu
2219 Running Pine Ct, Hillsborough, NC, 27278

Prerequisite(s), if applicable

No prerequisites.

Course Description

Listings at Duke: (Information Science & Info Studies - 170, Computer Science - 107, Visual & Media Studies - 172) Complex systems offer new ways to see and think about our world, new ways to describe, understand and explain it in computer models and simulations. These applications (apps) provide new avenues of inquiry into the sciences, engineering, humanities and arts. Uniting theory with practice in this hands-on course, developed over the last decade, we write simple rules for local agent interactions in order to observe the surprisingly complex global patterns of behavior that they generate. We critically explore the creative power of bottom-up emergence in multi-agent, multi-causal and evolutionary simulations. We construct "what-if" experiments of our own design to explain the past and "predict" the future. We examine the counterintuitive "chaos game" and investigate rich universe of "cellular automata." These methods are at the cutting edge of theory in physics, biology, the social sciences, astronomy and the visual arts. We progress from simple to more complex (and accurate) representations of time, space and agency, building and studying models of evolution, segregation, assimilation, growth, flocking, crowd behavior and asteroid orbital resonances. We learn how many small individual parts join together to produce something greater than themselves. These generative processes, which range "from quark to quasar," are key to explaining the origin and evolution of the solar system, life, culture, complexity, intelligence and creativity. We invoke the "blind" process of evolution to solve problems that challenge our own intelligence. We learn how agent-based simulation models may better describe the past, explain the present and enable us to evaluate policies for the future. We work with Embarcadero C++ XE6 for Windows. No previous programming experience is necessary.

Course Goals / Objectives

To provide participants with a critical understanding based upon hands-on practice of the new modes of scientific description, understanding and explanation enabled by computation, i.e. complex systems, multiple causation, and evolutionary computation. To provide participants with the intellectual tools needed to apply these modes of explanation to their own fields of study in creating, supervising, evaluating proposed "theories" leading to social policies and to assessing "what if?" arguments made for explaining the past and predicting the future.

Required Text(s)/Resources

The course should meet as two, three-hour sessions each week, Tuesdays and Thursdays, preferably from 10:00 a.m. until 1:00 p.m. with a break included. It requires a DKU provided computer classroom (25 PCs, Embarcadero XE6, PhotoShop, SynEdit, IconEdit, etc.)
"Reference for C++, Embarcadero & Windows API" (notes provided by the instructor)
Over 300 sample applications with source code: https://web.duke.edu/isis/gessler/borland/

Readings on SAKAI selected from:

Bentley, Peter. EVOLUTIONARY DESIGN BY COMPUTERS, Chapter 1, Morgan Kaufmann (2001x).
Egan, Greg. PERMUTATION CITY, Chapter 1, Eos (1995).
Fogel, David. "What is Evolutionary Computation?" in IEEE SPECTRUM, February 2000, pp. 26-32.
Fredkin, Ed. "A New Cosmogony." http://www.digitalphilosophy.org/
Gessler, Nick. "Fostering Creative Emergence in Artificial Cultures," in ARTIFICIAL LIFE XII, MIT Press (2010), pp. 669-676.
Gessler, Nick. "The Computerman, the Cryptographer and the Physicist," in ALAN TURNING: HIS WORK AND IMPACT, Springer (In Press).
Glass, Robert. "The Cognitive View: A different Look at Software Design," in SOFTWARE CONFLICT 2.0: THE ART AND SCIENCE OF SOFTWARE ENGINEERING, Developer (2006).
Lem, Stanislaw. "Non Serviam," in A PERFECT VACUUM, Northwestern Univrsity (1999).
Minsky, Marvin. "Public Lecture: Artificial Life V." Transcription by Nick Gessler (1996).
Schmidhuber, Jurgen. "A Computer Scientist's View of Life, the Universe and Everything," in LECTURE NOTES IN COMPUTER SCIENCE, Springer (1997), pp. 201-208.

Zuse, Konrad. "Calculating Space," MIT TECHNICAL TRANSLATION AXT-70-164-GEMIT.

Screenings outside of formal class time selected from:
Apted, Michael (director). ENIGMA (2001).
Rusnak, Josef (director). THE THIRTEENTH FLOOR, Columbia Pictures (1999).
Sims, Karl: Compilation including "Evolved Virtual Creatures," "Panspermia,"
Morten, Tyldum (director). THE IMITATION GAME (2014).
VPRO Amsterdam, ARTIFICIAL LIFE (1995).

Recommended Text(s)/Resources

Batty, Michael and Paul Longley. FRACTAL CITIES: GEOMETRY OF FORM AND FUNCTION, Academic (1994).
Epstein, Josh and Rob Axtell. GROWING ARTIFICIAL SOCIETIES: SOCIAL SCIENCE FROM THE BOTTOM UP, MIT Press (1996).
Flake, Gary. THE COMPUTATIONAL BEAUTY OF NATURE, MIT Press (1999).
Fogel, David. EVOLUTIONARY COMPUTATION: TOWARD A NEW PHILOSOPHY OF MACHINE INTELLIGENCE, Wiley (2005).
Hillis, Dany. THE PATTERN ON THE STONE: THE SIMPLE IDEAS THAT MAKE COMPUTERS WORK, MIT Press (1999).
Kaandorp, Japp and Janet Kubler. THE ALGORITHMIC BEAUTY OF SEAWEEDS, SPONGES AND CORALS, Springer (2001).
Mandelbrot, Benoit. THE FRACTAL GEOMETRY OF NATURE, Freeman (1983).
Meinhardt, Hans. THE ALGORITHMIC BEAUTY OF SEA SHELLS, Springer (2003).
Prusinkiewica, Przemyslaw and Aristid Lindenmayer. THE ALGORITHMIC BEAUTY OF PLANTS, Springer (1990).

Additional Materials (required)

1 EACH: USB memory stick.
12 each: writable CD/DVD, paper CD/DVD sleeves, 8 ½ x 11 sheet protectors.

Course Requirements / Key Evidences

Participants are expected to envision, describe, understand and explain complex physical, biological and cultural phenomena from the bottom-up by experimenting with complex systems (CS) of interaction among populations of agents and analyzing the behaviors that emerge. Participants will learn to represent such descriptions in computer code (C++) and execute a suite of "what if?" experiments to analyze the entailments that ensue under different assumptions and conditions. In short, participants will be literally learning to "thinking with technology."

Technology Considerations, if applicable

This course requires a 25-student fully-equipped computer classroom with:
Standard Internet access, VHS, DVD playback and digital projection and 25 each high-end graphics PCs equipped with the latest versions Embarcadero C++ Builder XE7, Adobe Web Premium, Microsoft Office, SynEdit and IconEdit 32 software licensed and installed.
A Teaching Assistant would greatly improve the effectiveness of this course.

Assessment Information / Grading Procedures

Approximately four (4) "Programming Challenges"
Approximately four (4) "Discursive Challenges"
One (1) "Course Programming Challenge"
Challenges stress "four 'E'"s: Explore, Experiment, Enhance and Enjoy.
Grading will based on demonstrated engagement with course challenges. Both inexperienced and experienced participants will have equal prospects for success.

Diversity and Intercultural Learning (see Principles of DKU Liberal Arts Education)

Expressing one's theories, hypotheses and ideas in computational terms is an internationally recognized means of objectifying diverse subjective impressions and perceptions. It does so by forcing students to resolve the ambiguity of natural languages and the intersections of diverse natural languages into a coherent and objective model of reality. From a diversity of languages and cultural understandings, by building computational models and simulations, we can create a universal language of description and analysis.

Course Policies and Guidelines

- Academic integrity: Collaborative work is invited as long as there is "value added" (a multiplier effect) and each member's contributions are clearly indicated.
- Attendance: The initial sessions are critical as they lay the foundation for subsequent challenges. Absentees should consult other participants and/or the instructor to keep up to date.
- Attention to assignment deadlines: Late work is accepted if it is a substantial improvement upon the level of engagement expected for work submitted on time.
- Make-up work: Late work is accepted if it is a substantial improvement upon the level of engagement expected for work submitted on time.
- Appropriate or inappropriate use of cell phone, laptop, or other technology during class: Students are responsible for not disrupting the class environment. Use of laptops and PCs encouraged. Use of cell phones only in emergencies.

Tentative Course Outline or Schedule

Introduction: counterintuitive nature of complex systems (CS); emergence from local rules to global patterns of behavior, CS imply a deterministic but non-predictable world in which there are no shortcuts (no math, no calculus, no ways) to understand the future state of a system other than by running it to completion. The course includes four required challenges, each followed by one meeting devoted to students' presentations of explorations, experiments and enhancements. The class culminates with a fifth course challenge of the student's own choice and presentation.

Challenge 0: The Chaos Game: narrative of indecisive traveling half-way to a distant city, pattern from randomness, variations on the theme, visualizations and sonifications of data.

Challenge 1: Cellular Automata: Conway's "Game of Life" (GOL) and variations, including visualizing and sonifying the evolution of the process, enhanced rules, creating computers using GOL physics and running GOL within a GOL world (e.g. "MetaCel").

Challenge 2: Evolutionary Concert Tour: The Traveling Salesman Problem brought up to date, solving intractable problems, adding a third dimension (the Traveling Ferenghi Problem), adding constraints such as geographic boundaries and sequencing penalties, visualizing the detailed processes of evolution.

Challenge 3: Flocking: We experiment with coding crowd behavior, flocking in birds, schooling in fish, and the movement of people in their daily activities or in dire emergencies is often the result of individual perceptions, thoughts and actions in a mediated environment.

Challenge 4: A course project based upon an enhancement of one of the challenges on our simulations pages or an application programmed from scratch. Instructor approval is required.

Screenings may be made available after normal classroom hours as well as the following challenges:

Challenge X1: Segregation and Assimilation: Using a cellular representation of space, we examine the dynamics of segregation based upon Thomas Schelling's seminal work and the dynamics of assimilation, both separately and in combination. Based upon local rules, we synthesize the resultant pattern. In social science we often observe only the resultant patterns from which we must deduce the generative rules.

Challenge X2: Sensors and Actuators: We connect the previous challenges to the external world with infrared rangefinders, stepper motors, joysticks, to bring computation into our larger and more immersive human environments. (This would require the importation of additional equipment.)

Bibliography (optional)

See required and recommended texts and resources above.

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