The Use of Interactive Web-Based Courseware in Intro Biology

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Corey is the laboratory and course coordinator for the large introductory biology course at the University of Toronto, BIO150Y: Organisms in their Environment. He is a past president of ABLE, hosted the 1993 ABLE conference in Toronto, and edited nine volumes of ABLE's conference proceedings. Presently he chairs ABLE's Web Site Committee and serves as ABLE's webmaster. Corey is a senior lecturer in biology and a recipient of the Faculty of Arts and Science's Outstanding Teaching Award.

Introduction

This hands-on workshop introduced participants to three interactive Web-based exercises that complement the laboratories and lectures in introductory biology at the University of Toronto.

- *The Evolution of Cooperation* introduces game theory and its application to animal behavior.
- *Saving the Whooping Crane* applies principles of population growth to management of an endangered species.
- In the *Optimal Foraging Game* students learn how animals feed efficiently in patchy habitats.

These exercises are freely available for anyone to use via the course's Web site. They have been developed for BIO150Y in collaboration with Michael Dennison and Alejandro Lynch of Hopscotch Interactive Inc. (www.hopscotch.ca); funding was provided from the University of Toronto's Information Technology Courseware Development Fund and the departments of Botany and Zoology.

BIO150Y, the introductory biology course at U of T, is noted for its large number of students (1,500), its teaching of evolution, ecology, and behavior (typically taught in upper-year specialist courses), and its suite of laboratory exercises which emphasize experimentation and hands-on skills and which are designed to complement lectures. Online self-study exercises have proved a useful addition to traditional in-class laboratories in BIO150Y. They allow simulated experiments on topics which cannot be adequately addressed by lectures alone, extend traditional in-class laboratory exercises by allowing theoretical study of topics, and add unique experiences and benefits, such as providing users with an instant snapshot of their results compared with class results.

The desire for laboratory exercises which stress experimentation has influenced the development of our online exercises. In developing these exercises our objectives were to: (1) provide experimental simulations of biological phenomena; (2) provide an individual, custom experience; (3) create a sophisticated and graphically-rich interface; (4) create Web-based exercises for wide, simple accessibility, (5) make the exercises fun and engaging; (6) ensure each exercise is a stand-alone experience, but clearly integrated with the course laboratories and lectures; and (7) ensure the exercises can be simply administered (e.g., easy to update content).

With these objectives in mind, our online exercises use a novel, game-based approach to teaching. Each exercise is designed to take about 1 hour to complete. Some of the key design and content innovations are: (1) Simulations: Specially-designed Java applets allow users to conduct experiments using game and graph interfaces; since Java applets can run on any client, they are most flexible (Java and Javascript must be enabled on the student's Web browser). (2) Dynamic reporting of individual results: An individual's results are tracked and passed to subsequent pages, so that each user gets a unique, custom experience. (3) Class results graph: The game outcome is added to a class database and a frequency distribution graph of game results is instantly displayed so each user can see how they fared relative to the rest of the class. (4) Quizzes: Java applet multiple-choice quizzes with instant marking and explanations. (5) Engaging interface and content: Exercise pages include engaging graphics and natural history illustrations. The core text is kept to a minimum (expanded text is provided in a reference section); layout has a "comic-strip" approach. (6) Authoritative reference material: An extensive reference section for further reading with links from appropriate places in the exercise for easy navigation. (7) Database: The exercise, quiz, and reference text content for each exercise are databased: Perl scripts create the HTML pages on-demand (databasing of the text simplifies the updating and administration of the Web pages).

Student Outlines

The Evolution of Cooperation

Can cooperative behavior emerge from groups of selfish individuals?
Here you can use a popular puzzle called the Prisoner's Dilemma Game
to examine how cooperation might arise and evolve
in animal groups. The results might surprise you!

Objectives

- Play single and iterated versions of the Prisoner's Dilemma game against the computer.
- Conduct computer experiments to see how strategies might be maintained and evolve in populations.
- Learn how animals, including humans, appear to use successful strategies in behavioral interactions.

Availability

• From the BIO150Y Web site: www.cquest.utoronto.ca/zoo/bio150y/pdgame

Introduction

The online exercise, which complements and extends the laboratory exercise[1] starts with a single-move Prisoner's Dilemma game in which you play against the computer. Your move, the computer's move, and your payoff are displayed and your payoff is added to class results and summarized in a frequency distribution graph so that you can see how you did relative to other players. The single-move game is analyzed and the results are explained. You then play an iterated Prisoner's Dilemma game against the computer where, again, your results are compared with the class results, and the results are explained. The concept of a game strategy is introduced.

The final part of the exercise is reminiscent of the famous computer tournaments organized by Robert Axelrod, where game theorists would play their preferred strategy against other strategies in many rounds of iterated Prisoner's Dilemma games. We have preset the strategies available to you in this online exercise, but you can still have fun exploring the long-term success of different strategies in mixed populations, and learn about the characteristics of the best strategies.

The Exercises

Single-move game: Play a one-off encounter against the computer. Based on your results: (1) What is the logical move in a single-move Prisoner's Dilemma game? (2) What is the dilemma in a single-move Prisoner's Dilemma?

Multiple-move game: Play an iterated game against the computer and see how well you do. (1) Did you use a strategy against the computer? Was it nice or nasty (for the definition of nice and nasty strategies in Prisoner's Dilemma games, refer to the online Frequently Asked Questions). (2) Was the computer using a nice or nasty strategy?

Evolution experiments: We have set up three different experiments. Data tables are provided online for you to record your results.

<u>Experiment #1</u>: Do cheats always do better than suckers?

Conduct simulations of a population initially composed of an equal mix of cheats (Always Defect) and suckers (Always Cooperate) to determine whether evolution occurs and if so which strategy predominates over the other. To look for patterns or generalizations in the results run several replicates. Complete the data tables provided for each of five time intervals for one of the strategies. Answer the following questions: (1) If the population was initially composed of 15 ALLC individuals and 15 ALLD individuals, what was the starting *frequency* of the sucker strategy in the population? (2) In your simulations of the population composed of ALLD and ALLC individuals what evidence, if any, was there for evolution? (3) In general, what is the expected long-term outcome for a

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[1]Lynch, A. 1994. The evolution of cooperative behavior. Pages 319–333, *in* Tested studies for laboratory teaching, Volume 15 (C. A. Goldman, Editor). Proceedings of the 15th Workshop/Conference of the Association for Biology Laboratory Education (ABLE).

population composed of cheats and suckers?

Experiment #2: Do nasty strategies always do better than nice strategies?

Conduct simulations of a population initially composed of an equal mix of cheats (ALLD), tit-for-tat (TFT), grudgers (GRU), and random (RND), to determine which strategies tend to be more successful in the long-term. Conduct replicate experiments. Record the final numbers of each strategy at the end of each replicate experiment in the data table provided online. Construct a score which summarizes the results of the five replicates for each strategy (e.g., sum of individuals). (1) In a mixed population where initially TFT, Grudger, ALLD, and Random are at equal frequency, which strategies tend to be most successful in the long-term? (2) In a mixed population of TFT, Grudger, ALLD, and Random, which strategies are nice and which are nasty? (3) What are the characteristics of a very successful strategy in Prisoner's Dilemma game?

Experiment #3: Can Tit-for-Tat invade a population of cheats?

Conduct simulations of a population which initially consists of a small number of TFT individuals ($N = 6$) and a large number of cheats ($N = 20$) to see if TFT can persist. Run replicates and complete the table provided online. Can a small number of TFT invade a population of cheats (ALLD)?

Additional Questions

Answers to these questions are available within the online exercise: (1) In the original Prisoner's Dilemma scenario, what does it mean to defect? (2) In the prison scenario, what was the payoff for mutual defection if the term for the minor crime is 3 years and the term for the major crime is 7 years? (3) Imagine a situation in which the costs of a cooperative behavior are equivalent to −4 points and the benefits are equivalent to +6 points. What would be your payoff in a Prisoner's Dilemma game for mutual cooperation? (4) What is the definition of a nasty strategy in a Prisoner's Dilemma game? (5) What is the definition of evolution in a Prisoner Dilemma game?

Further Reading

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Saving the Whooping Crane

This exercise complements course lectures on conservation biology and population ecology. Your goal is to design a management program for this endangered species which will ensure its survival.

Objectives

- Simulate the population growth of Whooping Cranes.
- Estimate the likelihood that the Whooping Crane would have eventually gone extinct if the population had not been actively managed since 1941.
- Experiment with managing the existing population of Whooping Cranes. Run simulations to see if your management strategy improves the chances of the population's long-term survival.

Availability

• From the BIO150Y Web site: www.cquest.utoronto.ca/zoo/bio150y/cranes

Introduction

In 1941 only 16 Whooping Cranes (*Grus americana*) existed in the wild after the population had crashed in North America because of hunting and because much of their wetland habitat in the prairies had been converted to farmland. In this exercise, you are on the management team that is responsible for their recovery. Can you design a management strategy which will save the species from extinction? In this online exercise, you will use a computer model to simulate Whooping Crane population growth under different management strategies.

The Exercise

This online self-study exercise is designed to take about one hour to complete and is composed of the following components:

Baseline simulations: Conduct simulations of population growth for the Whooping Crane population to estimate the probability that the population would have gone extinct if left unmanaged from 1941 onwards. Run several replicates of population growth – because each time the simulation is run the results differ. Complete the data tables provided online. Answer the following questions: (1) Based on the baseline simulations which you conducted, what is the estimated *pE*, probability of extinction, for the 1941 population? (2) In the baseline simulations when did most of the extinctions occur within the theoretical period of 100 years?

Management simulations: Experiment with different combinations of management options to boost population growth and reduce the long-term extinction risk for Whooping Cranes. The best strategy will give the largest reduction in *pE* compared to the baseline, at the lowest cost. Use the table provided online to record your results when applying the different management strategies. Transfer the average *pE* you obtained from your baseline simulations to the first row. (1) Based on your results, what type of management option is most cost-effective for the 1941 Whooping Crane population? (2) In the year 2000, the actual population size of Whooping Cranes was 185 after nearly 40 years of intense management. Was your theoretical management as successful as the actual management?

Additional Questions

Answers to these questions are available within the online exercise: (1) Which factor was most important in the decline in Whooping Cranes in the 1800s? (2) What is the essential difference between exponential and logistic growth models? (3) Between 1800 and 1900 the population of a hypothetical country grows from 200,000 to 300,000 individuals. What is r? (4) The present carrying capacity of Whooping Cranes is estimated to be $K = 250$ birds. What does this mean? (5) Computer simulations of population growth result in a population going extinct five times out of 20 simulations. What is the probability of extinction, pE? (6) Assuming a growth rate $r = 0.0167$ per individual year and an initial population size, $N = 16$, what was the predicted population size of the 1941 Whooping Crane population if it was unmanaged for 100 years? (7) A population consisting of 25 breeding pairs of birds produces 100 chicks in 1999. What is the birth rate, b?

Further Reading

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Novakowski, N. S. 1966. Whooping crane population dynamics on the nesting grounds, Wood Buffalo National Park, Northwest Territories, Canada. Canadian Wildlife Service Report Series, 1:1–20.

Web Sites

Visit Environment Canada's "Whooping Cranes" home page, which also has links to other Whooping Crane sites: www.mb.ec.gc.ca/nature/endspecies/whooping/index.en.html

Optimal Foraging Game

Animals must make decisions every day about where and when to feed. Their choices have important implications: how well they reproduce and how long they survive. It is not surprising then that scientists have been interested in how foraging behavior has evolved in different species.

Objectives

- Use a game simulation of a hummingbird feeding on flowers to learn about optimal foraging and, in particular, the marginal value theorem.
- What is the best way to feed in a patchy environment? Play the patch game to discover how the optimal foraging strategy changes with patch density.
- Learn how the marginal value theorem can be applied to animal behavior in nature.

Availability

• From the BIO150Y Web site: www.cquest.utoronto.ca/zoo/bio150y/foraging.

Introduction

In this exercise you will play the patch game where a hummingbird is faced with a typical challenge for most organisms: how to get as much energy as possible for survival and reproduction in a limited amount of time. Hummingbirds live in a habitat where its food, nectar, is distributed in flower clumps. Clumps are dispersed randomly within the habitat. As the hummingbird feeds in a patch it depletes the food and it takes longer and longer to obtain rewards.

The challenge for the hummingbird is what patches to visit and how long to stay in each patch so that it maximizes its energy rate gain. As with any behavior, this means balancing the costs and benefits: the costs of visiting and feeding in patches versus the benefits that flowers give as nectar.

In a patchy habitat what is the best, or optimal, strategy for feeding? By feeding as a hummingbird in patchy habitats, you will learn about optimal foraging theory and its more general application to many types of behavior in nature, including human behavior.

The Exercise

Play the patch game and experiment to find the optimal time to stay in each patch for two habitats which differ in patch density. In the good-quality habitat, flower patches are relatively close together. In the poor-quality habitat, flower patches are relatively far apart. Use the table provided online to record your attempts to find the optimal solution in each habitat. (1) In this exercise, what is the difference between the good-quality and poor-quality habitats in terms of costs? (2) What are your estimates of the optimal patch stay time in each habitat? Are your results consistent with predictions of the marginal value theorem?

Additional Questions

Answers to these questions are available within the online exercise: (1) What is the “currency” that is used in the hummingbird optimality model? (2) What does “optimal behavior” mean in the context of the game? (3) A predator spends 10 seconds traveling to a patch. In the patch it takes 15 seconds to search five flowers. It accumulates 50 calories of energy. What is its net rate of energy gain for this patch? (4) Explain the marginal value theorem. (5) What does the marginal value theorem predict for the difference in foraging strategy for two habitats in which patch density differs?

Further Reading

Cook, R. M, and B. J. Cockerell. 1978. Predator ingestion rate and its bearing on feeding time and the theory of optimal diets. Journal of Animal Ecology,47:529–547.

Parker, G. A. 1978. Searching for mates. Pages 214–244, *in* Behavioral Ecology: An Evolutionary Approach, First Edition (J. R. Krebs and N. B. Davies, editors). Blackwell Scientific Publications, Oxford.

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Tome, M. W. 1988. Optimal foraging food patch depletion by ruddy ducks. Oecologia, 76:27–36.