Running the Gauntlet: Modeling Mitigation of Wildlife-Vehicle Collisions

Project Module Associated with
2nd Edition, Introduction to Computational Science:
***Modeling and Simulation* by**
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Prerequisite: *Module 11.2, "Agents of Interaction: Steering a Dangerous Course"*

Introduction

Cars and trucks traveling on roads through more natural areas are a hazard to people, vehicles, and wildlife and can limit connectivity of animal populations. To reduce wildlife-vehicle collisions, parts of some roads have fencing and wildlife passages. However, such multiple construction is expensive. Projects in this module will study the impact on animal population size of employing fencing and/or wildlife passages.

Projects

For the models in this module, employ the simplifying assumption of only considering population abundance and not genetic differentiation. Develop agent-based simulations using the following information (Ascensãoa et al. 2013):

- The world is a 20-by-24 grid with boundaries that do not wrap.
- Inputs should include the following: duration in years, or the number of full years the simulation runs; year of establishment of a road, where the road is considered open on the first day of that year; the chance, *road-mortality*, that an animal on the road will die; the number of fences; and the number of passages. So that the system can stabilize for five years without a road, have the year of establishment of the road be at least 6. Allow the user to designate the number of fences and passages from 0 to 24 in step sizes of 6.
- Outputs should include the following: a plot of the number of juveniles, sub-adults, and adults versus time; the year; the month of the year; the day of the year; the number of animals; the number of road kills; the number of times passages are used; and the number of road crossings.
- A road, if it exists, could be represented as a line from top to bottom between the left and right halves of the grid. Also, pairs of patches, one on each side of the road and perhaps marked with coloring and/or properties, can indicate fencing and/or passages. Fences and passages only occur when a road exists. If the number of fences equals the number of passages, then once a road appears, that number of pairs of random patches indicate fencing and passages. If there are to

be more passages than fences, every pair of randomly placed patches indicating a fence also has a passage; while the remaining passages have no fence. If there are more fences than passages, then every pair of patches representing a passage also has a fence; while the remaining fences have no passage.

- Initially, the grid has one adult animal per patch with approximately 50% females and 50% males. An animal's patch is its territory. Time starts the first day of March in year 1.
- As part of the initialization and before time advances, each male searches for females with which to mate for 100 steps.
- While a male is searching for mates, assume that when a male and female are in the same patch, they mate and every mating results in the female becoming pregnant. However, males do not stray very far from home. Therefore, for each step, if a male is close to its territory (less than 1.5 patches from home), he faces a cell in a 60° arc. Otherwise, he faces one of the neighbors of his territory as long as it is not too close to the edge of the grid. Then, the male advances one step. Finally, we must consider ramifications if the male has crossed the road, if such a road exists. After a designated number of steps (100 initially, 10 for each day of mating season), the male returns home.
- If after facing a neighbor an animal is within 0.5 units of a border, the animal turns to face the center of the world.
- After crossing the road, we must check if the creature crossed through a passage or a vehicle killed the animal. We assume travel through a passage if the animal is within 2.01 patches of a passage.
- Mating season is from June through August. For each day in that season, males attempt to mate with females for 10 steps, in a similar fashion to their search for females upon initialization.
- On March 2, pregnant females give birth to two or three offspring, depending on animal density: For each side of the road, if there are available territories during mating, then the litter size is set to three, otherwise, two.
- An animal matures in one year and has a maximum life span of about 4 years. The *yearly* survival rate before the age of 4 is 0.74, while the *daily* survival rate starting at age 4 is 0.5.
- A juvenile remains with its mother and does not move. However, if the mother dies, so does the child. A juvenile becomes sub-adult after 2 months.
- A male or female sub-adult explores one cell per day, looking for its own territory, which is an unoccupied patch. The sub-adult stops exploration if it finds an unoccupied territory. If the animal does not find a territory in 180 days, it will die. During exploration, an animal typically faces in a 60° arc. Similar to movement of a male seeking a female, if the sub-adult is within 0.5 units of a border, he or she faces the center of the world. Then, the sub-adult advances one step. As with all movement situations, with each step, we must consider if the sub-adult crossed the road.

1. **a.** Develop an agent-based simulation incorporating the bulleted information above.

- **b.** Run the simulation several times for 35 years with no fencing and no passages and *road-mortality* = 0.5, and compute the average of number of animals at the end of the simulation.
- **c.** Repeat Part b for 6 (25%), 12 (50%), 18 (75%), and 24 (100%) passages and no fences.
- **d.** Plot mean final population size versus percent passages.
- **e.** Repeat Part b for 6 (25%), 12 (50%), 18 (75%), and 24 (100%) fences and no passages.
- **f.** Plot mean final population size versus percent fences.
- **g.** Repeat Part b for 6 (25%), 12 (50%), 18 (75%), and 24 (100%) fences and passages.
- **h.** Plot mean final population size versus percent fences.
- **i.** Discuss your findings and make recommendations for wildlife-vehicle collision remediation.
- **j.** Repeat Parts c-i for *road-mortality* = 0.1.
- **k.** Repeat Parts c-i for *road-mortality* = 0.9.

2. **a.** Instead of manually running the simulation several times, automate the process so that your program will run the simulation of Project 1a a designated number of times and compute the average number of animals at the ends of the simulations.

b-k. Using your program of Part a with 10 designated simulation executions, repeat each corresponding part from Project 1, Parts b-k.

3. Ascensãoa et al. (2013) employed a more realistic animal movement than using step sizes of length one unit. Instead, considering a patch, or territory, to represent an area of 2200 m by 2200 m (529 ha), the modelers employed a step size of one-tenth of the length of a territory (0.1 units or 220 m) with twenty steps (total of 4400 m) per day. Revise Project 1 to reflect this movement pattern.

4. Revise Project 2 to reflect the movement pattern of (Ascensãoa et al. 2013) discussed in Project 3.

References

Ascensãoa, Fernando, Anthony Clevengerb, Margarida Santos-Reisa, Paulo Urbanoc, and Nathan Jackson. 2013. "Wildlife–vehicle collision mitigation: Is partial fencing the answer? An agent-based model approach," *Ecological Modelling* 257 (2013) 36–43