CX 4230
Project 3, Part B
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Orca Communication and Behavior

A little about orcas

Orcas are mammals, a type of dolphin to be specific. They live in a rather complex matriarchal family structure which consists of pods of closely related individuals. For a variety of reasons, orcas extensively use vocal communication consisting of three distinct sound types for a variety of reasons, including food processing after a successful hunt (aka butchering whale carcass). Groups (e.g., pods) of orcas have even been known to develop dialects distinct from that of other groups, and it is for this reason that I am interested in orca behavior and communication.

Literature Review / Annotated Bibliography

1. Whitney B. Musser, Ann E. Bowles, Dawn M. Grebner, and Jessica L. Crance. *Differences in acoustic features of vocalizations produced by killer whales cross-socialized with bottlenose dolphins*. The Journal of the Acoustical Society of America, 2014 DOI: 10.1121/1.4893906.

    This is just a little bit of extra information about orca communication and adaptability. Although orcas sometimes eat their fellow dolphins, the former sometimes befriend the latter in some situations. This article goes to show that killer whales are capable of adapting their communication patterns to accommodate certain aspects of their environment.

2. Christensen, V. and C. J. Walters. 2004. *Ecopath with Ecosim: methods, capabilities and limitations*. Ecological modelling, 172(2), 109-139. http://www.ecopath.org/about.

    Ecopath with Ecosim (EwE) is a simulation framework for ecological systems, particularly marine ecosystems and fisheries. As one could easily imagine, an agent-based simulation could easily become far too complicated and computationally intensive to run. Consequently, this simulation framework approaches species populations as biomasses and uses ordinary differential equations to model the interactions among these populations. The mathematical approach is interesting, but the granularity is not appropriate for my project at this point. I am interested in the individual interactions among orcas and between the orca population and its prey.

3. Gerum, R. C., Fabry, B., Metzner, C., Beaulieu, M., Ancel, A., & Zitterbart, D. P. (2013). The origin of traveling waves in an emperor penguin huddle. *New Journal of Physics*, *15*(12), 125022.

    In this study, the behavior of chilly Emperor penguins is simulated. The goal is to reproduce the cascading patterns of penguin movement as the penguins try to huddle away from the cold as seen in video footage from previous studies. To reproduce this behavior, the authors designed an agent-based model in which 1) every penguin seeks to

stay warm given a threshold for cold-tolerance and 2) an individual penguin's movement could influence the movements of their neighbors. The authors compared the behavior to a traffic jam, except in this case multiple directions were involved because penguins could have up to six neighbors. The simplicity of this model is to be admired. However, the behavior of orcas complicates my model because the orcas are adapting their *behavior* over time, not just their *state* as in the penguin huddle model.

4. Mock, K. J. and J. W. Testa. 2007. *An agent-based model of predator-prey relationships between transient killer whales and other marine mammals*, University of Alaska Anchorage, Anchorage, AK, May 31, 2007, Available online at http://www.math.uaa.alaska.edu/~orca/.

The authors here sought to model orca behavior and movement with great detail. Like my project will be, their simulation is agent-based. However, I am not interested in this level of detail (at least not yet) and I am more interested in the language aspect.

5. Riesch, R. and V.B. Deecke. 2011. *Whistle communication in mammal-eating killer whales (Orcinus orca): further evidence for acoustic divergence between ecotypes*. Behavioral Ecology and Sociobiology, 65(7), 1377-1387. http://www.marinemammal.org/wp-content/pdfs/riesch.pdf.

This paper discusses how two types of orcas (pescatarian orcas and mammal-eating transient orcas) differ in language patterns. To be specific, mammal-eating orcas tend spend more of their time silent when compared to fish-eating orcas. This is believed to be the result of differences in diet; mammal-eating orcas must contend with the fact that their prey is capable of hearing the orca's verbal communications since the predator and prey share the same hearing range. Prey could eavesdrop on orca conversation and take the necessary evasive maneuvers. These transient orcas would go hungry if they kept chitchatting while hunting. I wish to explore the development of this difference; thus this paper is the foundation of this project.

Project goals

I would like to reproduce the behavior described in (Riesch & Deecke, 2011). Following the example of (Gerum et al., 2013), evaluation will be more qualitative in that I am trying to reproduce a specific type of behavior: the seemingly learned silence of transient orcas. Like (Mock & Testa, 2007), my simulation will be agent-based, but I do not intend to model the same level of detail as this group. Furthermore, I am interested in observing a specific phenomenon related to language. Data for sound frequencies may be important. (Riesch & Deecke, 2011) provide some information in this vein.

Who would be interested in such as simulation? Marine biologist have obviously spent a significant amount of time studying orca behavior, possibly even the authors Riesch and Deecke. This simulation would help bolster hypotheses about orca communication; in the case of (Riesch & Deecke, 2011), it would provide some support of their theory. Although simulation cannot replace direct observation, it is a useful tool for exploring theories.

Conceptual model

- Agents
    - *Orcas*
        - The agents of interest.
        - Goal function: maximize fat, communal relations
        - Maximizes fat by eating food.
        - Maximizes communal relations (and hunting success) by communicating.
        - Learning ability is represented by a classifier.
    - *Mammal prey*
        - The intelligent agents that serve as a fat-source for the hungry orcas.
        - Capable of hearing the sounds that the orcas emit. Hearing range is variable though, and the range will be altered to study whether orcas learn to use frequencies outside of the animals hearing.
        - Learning ability is also represented by a classifier.
    - *Fish prey*
        - Also fat-providing agents.
        - Distinguished from mammal prey by the fact that they cannot hear the orcas communication.
        - No real learning ability. They just sort float around and try to avoid orcas. Their movement may be characterized by randomness.
- Environment
    - *Open ocean:*
        - Area in which both prey and orca can maneuver.
        - Conducts sound signals given off by orcas.
        - Conducts sensory information which orcas can use to detect prey.
        - Represented by a collection of discrete cells.
    - *Beach/safety area:* Completely inaccessible by orcas (not really, but for the sake of this simulation they are) and thus safe for mammals.
    - *Ice floes:* Areas that offer minimal safety to mammal prey. Orcas working together still have a (reduced) chance of successfully catching the prey.
    - *Sound:* Agents may emit sound for various reasons as outlined above.
        - Sounds are stochastic variables with a mean frequency complete with a variance.
        - Sounds have a limited distance they may travel.
- (a few) Assumptions
    - The world is a two-dimensional grid.
    - There are no distinctions among agents; agents do not age, die, sleep, or mate.
    - Only one orca pod is observed at one time.
    - The orcas do not add new types of signals over time.

- Transient orcas do not become pescatarians, and pescatarian orcas do not become transient.
- Fish are represented as a single “school of fish”. Individuals are not modeled.
- Happiness is being fat and having good friends.