Alex Book, Max Donovan, Katrina Siegfried
CSCI-5314 S'22 Semester Project Proposal
03.28.2022

Integrated Pest Management for Prairie Dogs

Problem significance

The City of Boulder owns extensive agricultural lands to the North, South, and East of the City (the "Green Belt") that is leased to smallholder farmers under certain conditions of land-management. One such condition is that pest management be minimally invasive and centered on relocation. The relocation of Black-tailed prairie dogs (*Cynomys ludovicianus*) – an agricultural pest listed as a threatened species by the US Fish and Wildlife Service that desertifies grasslands, compacts and burrows soil, and eats crops – has been particularly challenging. We propose the development of a simple relocation model incorporating group movement in response to attractants (like gardens and open fields) and repellents (like tall grasses and fungal toxins). Possible extensions would include ecosystem impacts of relocation. Xeric tallgrass prairies and grasshopper sparrows suffer in competition with prairie dogs, and healthy prairie dog populations are essential for the reintroduction of the endangered black-footed ferret.

Background and related work

Boulder Open Space and Mountain Parks has done extensive work documenting the behavior of prairie dog colonies and the integrated management systems that economically conserve both the prairie dog populations and agricultural lands. These non-invasive interventions include gradual tall-grass seeding, introduction of visual barriers, use of mild fungal toxins, vaccinations against plague, introduction of contraception, and physical relocation ("Prairie Dog Conservation and Management", 2022).

A study from the Northern Prairie Wildlife Research Center proposes the use of satellite imagery to monitor the development and movement of prairie dog colonies across prairies and grasslands using the lifecycle of the prairie dogs to inform time-step. Active colonies are currently being identified without image-processing algorithms by monitoring the establishment and occupation of burrows as well as the reduction of xeric tallgrass and desertification of prairies (Sidle et al, 2002).

The primary system currently in use for monitoring prairie dog colony movement is post-hoc analysis of satellite images as noted above. Very few predictive approaches have been proposed which use historical data to predict colony development and movement. The two primary approaches for predicting how these colonies will change over time are regression and predictive image analysis. While not yet applied in the study of prairie dog colonies, flocking models have successfully been used to model the colony behavior of other species.

Yoder et al used a linear-regression-type approach using detailed demographic information about colony composition (2008). Additionally, Gaston et al studied the colony foraging ranges of arctic birds where the birds occupy a small number of discrete colonies using a similar – though more complex – regression technique (2013). Another ML-technique was applied by Brennan et al who utilized random forest models to classify colony extent based on satellite images (2020). However, all these approaches fail to account for the complex inter-organism interactions which can be highly dependent on external and internal factors such as rainfall, disease and immigration/emigration.

Though a literature review did not reveal any published studies using flocking or multi-agent models specifically for prairie dog colonies, it has been applied to other organisms including ants (Drogoul and Ferber, 1994; Nave et al, 2020; Ramirez, 2018; Sangita et al, 2014). The components of the models in these studies such as affinities to nest/burrow, orientation to/from chemical stimulus, cohesion between organisms in the colony, bio-physical rules of motion, attraction to food, repulsion from undesirable environment or predators, etc, translate across species to the prairie dog, and therefore have the potential to yield promising predictive models which could enhance the understanding and management of prairie dog colonies.

Plan of execution

We aim to use NetLogo to model the movement of a coterie/clan of prairie dogs given factors such as an initial population and a set of attractants and repellents of varying strengths. There will be a defined set of rules guiding the interactions between prairie dog individuals and the environmental factors, as well as between individuals themselves, allowing us to tweak attraction/repulsion to see how the group reacts to varying conditions. Depending on the time scales we want to study, we may add some degree of prairie dog life cycle, allowing expansion/shrinkage of groups of prairie dogs based on birth/death rates. This will likely look somewhat similar to the problem explored in Homework Set 3, in that we will see flocking behavior largely based on interactions with the environment (similar to - yet expanding on - the ideas introduced in the homework). Should we encounter any odd issues with NetLogo that cannot be remedied on a reasonable time scale, we are comfortable implementing such a model using Python and/or Matlab, although ideally we will stick with NetLogo alone.

Milestones

- To be completed by our presentation slot time (April 7)
    - Work flow framework - Git repo, transfer milestones to todo list, identify models from other systems.
    - Sign up for presentation slot
    - Identify NetLogo model(s) for colony behavior (attractants, repulsions, and cohesion)
        - Flocking library is a promising lead
        - May be fairly simply to add static attractants/repulsives, unsure how complex dynamic adversaries would be (i.e. predators)
    - Put together basic model with monthly / lifecycle timestep
    - Put together and record presentation - reach out to Orit about accommodations

        - Presentation aims to present a framework of our model and a general overview of the problem, then gather feedback from Orit/class to guide the work we do as it pertains to our final model (and thus the final paper)
- To be completed by the paper turn-in date (May 4)
    - Flesh out model with further specifics
        - More granular attractants/repulsions
        - Introduce randomness into movement, search, and behavior
        - Introduce reproduction into colony development
        - Introduce seasonality and multi-modal behavior - spring: searching, summer: burrowing, fall: reproduction, winter: hibernation (stop activity)
- “Reach” goals (to be completed only if time allows)
    - Include an analysis and/or integration of available geospatial datasets

Alex Book, Max Donovan, Katrina Siegfried
CSCI-5314 S’22 Semester Project Proposal
03.28.2022

Bibliography

Brennan, Jameson R., et al. “Comparing Stability in Random Forest Models to Map Northern Great Plains Plant Communities in Pastures Occupied by Prairie Dogs Using Pleiades Imagery.” *Biogeosciences*, vol. 17, no. 5, 2020, pp. 1281–1292., https://doi.org/10.5194/bg-17-1281-2020.

Drogoul, Alexis, and Jacques Ferber. “Multi-Agent Simulation as a Tool for Modeling Societies: Application to Social Differentiation in Ant Colonies.” *Artificial Social Systems*, 1994, pp. 2–23., https://doi.org/10.1007/3-540-58266-5_1.

Gaston, Anthony J., et al. “Modeling Foraging Range for Breeding Colonies of Thick-Billed Murres Uria Lomvia in the Eastern Canadian Arctic and Potential Overlap with Industrial Development.” *Biological Conservation*, vol. 168, 2013, pp. 134–143., https://doi.org/10.1016/j.biocon.2013.09.018.

Nave, Gary K., et al. “Attraction, Dynamics, and Phase Transitions in Fire Ant Tower-Building.” *Frontiers in Robotics and AI*, vol. 7, 2020, https://doi.org/10.3389/frobt.2020.00025.

“Prairie Dog Conservation and Management.” *City of Boulder*, 2022, https://bouldercolorado.gov/services/prairie-dog-conservation-and-management.

Ramirez, Jorge M, et al. “Modeling Tropotaxis in Ant Colonies: Recruitment and Trail Formation.” *ArXiv: Populations and Evolution*, 1 Nov. 2018.

Roy, Sangita, et al. “Nature-Inspired Swarm Intelligence and Its Applications.” *International Journal of Modern Education and Computer Science*, vol. 6, no. 12, 2014, pp. 55–65., https://doi.org/10.5815/ijmecs.2014.12.08.

Sackett, Loren C., et al. “Connectivity of Prairie Dog Colonies in an Altered Landscape: Inferences from Analysis of Microsatellite DNA Variation.” *Conservation Genetics*, vol. 13, no. 2, 2011, pp. 407–418., https://doi.org/10.1007/s10592-011-0293-y.

Sidle, John G, et al. “Monitoring Black-Tailed Prairie Dog Colonies with High-Resolution Satellite Imagery.” *Wildlife Society Bulletin*, vol. 30, no. 2, 2002.

Yoder, Christi , et al. “Population Modeling of Prairie Dog Contraception as a Management Tool.” *Proceedings of the Vertebrate Pest Conference*, vol. 23, 2008, https://doi.org/10.5070/v423110509.