Simulating Interactions Between Varied Predators & Preys

New Mexico

Supercomputing Challenge

Final Report

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Overview

Throughout history, there have been countless examples of species being introduced into new environments and devastating the local ecosystem. These invasive species are often brought by humans, both accidentally and purposely. Such examples include mongoose in Hawaii, Lionfish in Florida, Kudzu in the American South, and even the diseases brought by Europeans to the New World (Although plants and microorganisms aren't very well covered under my

simulation). History shows that these mistakes are quite costly and often unexpected. So, if we had some method of roughly predicting how a species would interact with the fauna of a different ecosystem, it could very well help us understand how these incidents occur, how we can prevent them, and help to teach others about what makes these species so dangerous to different animals.

This is where the project aims to help remedy this problem. By having a highly customizable, real time simulation to compare how two different species interact with each other, one designated as a prey species and the other a predator, we are able to, at the very least, educate people about how species can interact with each other, and model future growth of two existing species. But in the long term, this program could even be used to model how two different species, with no prior contact, control the other's population.

To accomplish this hefty goal, this project uses Bevy, a newer, low-level game engine written in the Rust programming language, due to its advantages. The engine gives the program a highly configurable, modular design that retains speed and human readable code.

Introduction

The Issue

Invasive species are classified as any sort of living organism that harms an environment that it's not native to. These organisms are one of the biggest threats to native wildlife as 42% of endangered species alone are at risk from these invasive species. (National Wildlife Federation) Many examples of human introduced invasive species have become famous amongst local populations for how they affected the ecosystem such as the emerald ash borer, a type of beetle

that is destroying populations of ash trees across the U.S. and was likely brought on trading ships from Asia. (Duguid and Kuebbing) While this example was likely an accident on humanities part, with these accidents causing a large majority of invasive species introductions (National Wildlife Federation), there are examples of humans introducing an invasive species to an area. One famous example is Kudzu. It was introduced to the U.S. and advertised to farmers for its positive properties on soil, but it soon took over the south east. Cane toads, brought into Australia to control cane beetles, are yet another example of human imported invasive species. (Duguid and Kuebbing) Historically speaking, whether intentional or unintentional, humans introducing invasive species causes many problems to that ecosystem. So, having a tool that could help us understand and/or prevent this problem would be very useful.

The Solution

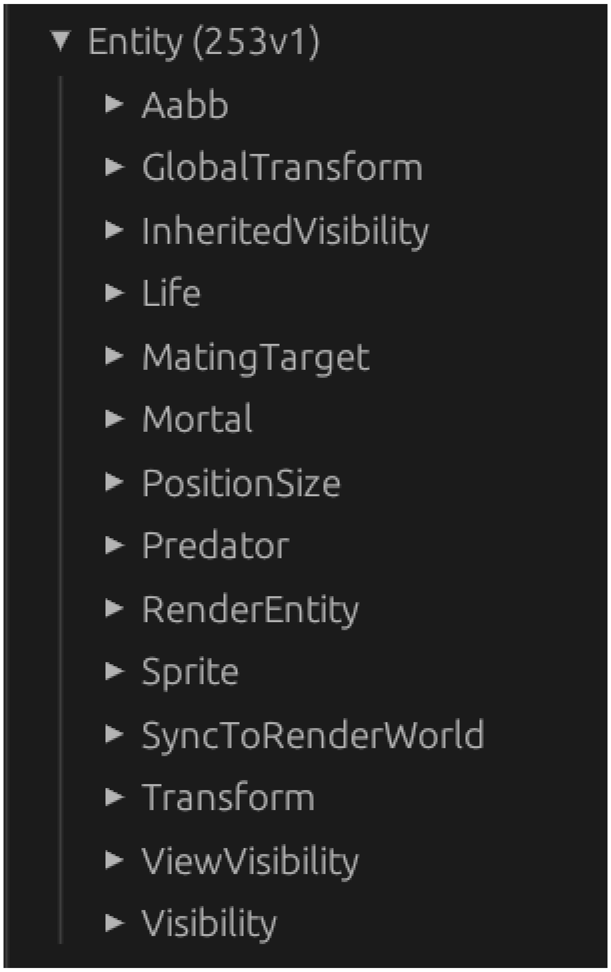
This is where my program would come in. It will be a highly customizable program that simulates one population of prey and one of predators in an environment. The customizability of the program will allow you to plug in different parameters to represent two different species together. You'll be able to see in real time how the populations interact with each other with the option to export graphs of the simulation data. With this combination of features, the program could be used by professionals to predict the outcome of two species interacting to see which relationship the two develop. The tool could also be used in an educational setting to teach about invasive species and, more generally, about different types of relationships between species. This is the optimistic future of the project.

The scope of the project at the moment intends to have the simulation only simulate between two populations. The project looked to use data about the grey wolf population in New Mexico as there seems to be some data available to aid (Maestas), but I wasn't able to gather the data alongside develop the program. This means that the program currently has no real-world data to verify it as of April 2nd, 2025. However, there might be data available by the time the conference comes around.

The program is written in Rust and uses Bevy, a data-driven, game engine library that uses an entity component system (ECS) for its logic. (Bevy Contributors) This library is being used as it's general enough for the project's needs, it has good performance, is very human readable, has a modular design (thanks to that ECS), and I've never programmed with an ECS and wanted to gain experience with this technology.

Making a Predator Prey Simulation

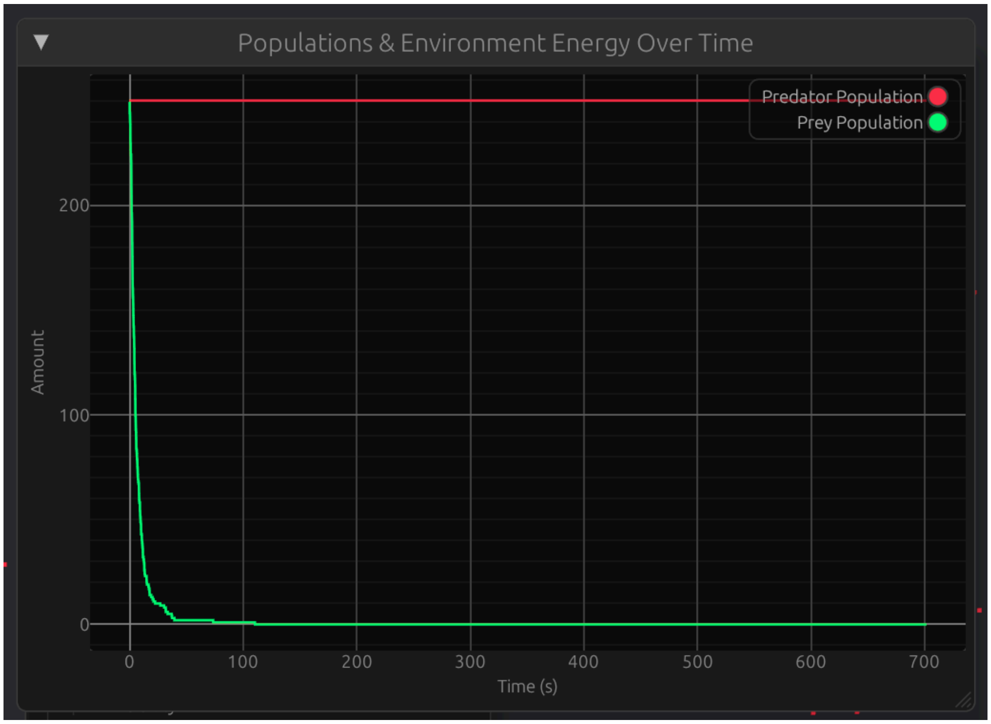
Bevy has been used for this project for the primary reason that it's a fast entity component system. To illustrate the uses of this technology, we'll see how it's used in our program. First, a rough explanation on how ECS works. A program that uses ECS is composed of entities, components, and systems.



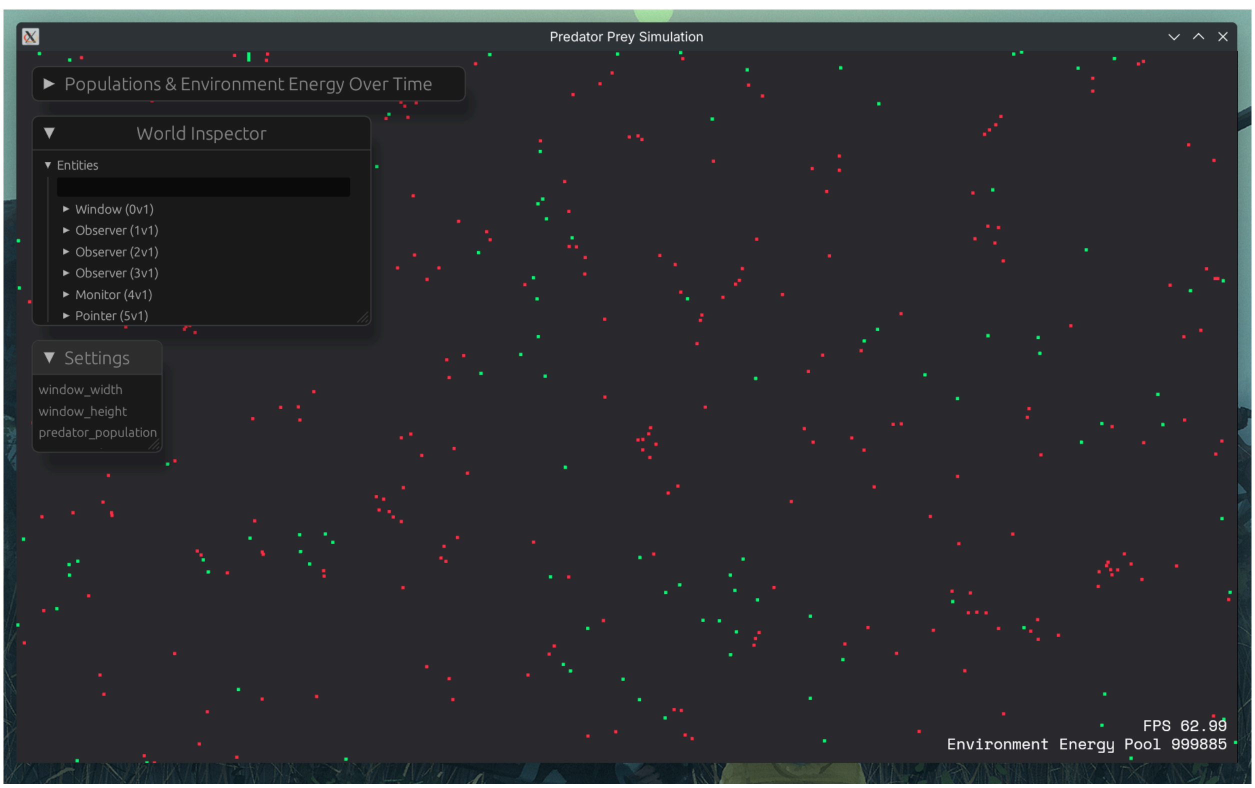
Components are traits that store data. In this project, they're used to store position and size data, the "life" of an individual, if they're dead or not, and if an individual is a predator or prey. Then, these components can be added to an entity. Entities are all but blank except for these components. Entities are built up from these components in a way. In my project, there are entities for the predators and prey, the environment, and even the user settings. Then there are systems that make queries for entities that have certain traits. For example, the project has one system that queries for an entity that contains an environment component, and slowly regenerates the simulated vegetation of that environment.

Using this entity component system, this project slowly built up systems that killed prey if they were touching predators, got all entities to wiggle around idly, made entities search for a mate nearby when they had enough energy, etc.

The other part of the project was UI. The program features 3 different available panes: a settings pane to adjust some settings in realtime, an ECS pane to view and edit data about all the entities and components in real time, and a graph pane to show population over time for both species.



The Graph Pane



Overall Program

Results of the Project & Conclusions

I've failed to get results for the scope I wanted. I haven't been able to get data about the grey wolf population, and the program still has bug fixes, optimizations, and minor features (like an export to .csv option to import data into spreadsheets). I'm happy with the work I've done, but the obstacles I've hit due to working with such a new library in a relatively new language has tremendously slowed down progress. I'm still very glad I used this technology as I find it quite enjoyable compared to alternatives, but the results of using it means I haven't reached the scope of this project. At least, not by April 2nd, 2025.

There is still some time until the conference and I hope that I wrap up some of these features and invest more time into gathering real world data to tweak my simulation against. Hopefully by the time the conference comes, the program will have reached its scope.

While the project has had slower development than competing solutions (one suggestion was to rewrite the project in NetLogo), the advantages of an ECS are still evident in this rough program. An unoptimized build of the program can run on laptops with hundreds of thousands of prey (predators reduce performance significantly as more are added) and still be usable for gathering data and viewing the simulation in real time.

I've concluded that using an ECS for the task of helping with tasks involving simulating invasive species, and fauna in general, is very favorable for a more long term program that can simulate populations in their entirety. But this isn't the end of this program as it's being hosted on Github with the MIT license to allow for use by commercial and public actors alike.

Acknowledgements

I'd first like to thank my mentor, Clint Hubbard, for giving me advice on how to modify my scope to give this project use to science and academia. And for giving me advice on the fundamentals of the simulation. I'm very thankful for my judges during the February presentation, Patricia Meyer and Maximo Lazo for their words of encouragement/interest, and incredibly helpful resources and advice given to me. I'd also like to thank my teacher, Mrs. Jocelyne Comstock, for helping me out with resources related to the Supercomputing Challenge and reminding me of deadlines (such as this one). I'd like to thank family and friends for when I was pulling my hair out over bugs in my code. I'd finally like to thank you, reader, for taking the time to read this document. Although I haven't completed my scope (and this final report is relatively unfinished as well, I hope you found some interest in the topic of invasive species, entity component systems, or computer simulations in general. Thank you very much for your time.

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