Incorporating Habitats in Conceptual Models and Agent-Based Simulations

Expanding the Virtual Ecological Research Assistant (VERA)

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ABSTRACT

The Design & Intelligence Laboratory at Georgia Tech is expanding the capability of its on-demand agent-based simulation generator to enable users to divide components into separate habitats. The Virtual Ecological Research Assistant (VERA) currently provides a concept map creator to designate biotic organisms and abiotic factors with their relevant relationships which then feed parameters into a compiler that generates server-side NetLogo code that is runtime compiled and executed and then outputs to the end user for a line graph displaying the population cycles of the organisms involved. The software enables easy access to generate multiple simulations by changing parameters and settings to meet user chosen goals such as more correctly emulating realistic natural environments or testing potential solutions to a problem. In reality, organisms and abiotic factors are often divided into separate habitats by a variety of factors such as a wall or by their very nature such as an ocean being separate from a landmass. With the additional feature of habitats to the VERA project, we can enable experiments that will show the viability of this approach to create more accurate models.

CCS CONCEPTS

• Computing methodologies ~ Modeling and simulation ~ Simulation theory

KEYWORDS

agent-based simulation, conceptual modeling, ecological modeling, modeling, simulation

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VERA

The Virtual Ecological Research Assistant (VERA) is an AI-based web application for modeling ecological phenomena. VERA (http://vera.cc.gatech.edu) was developed by and is maintained by Georgia Tech's Design & Intelligence Lab (https://dilab.gatech.edu/) in collaboration with Smithsonian's Encyclopedia of Life (EOL) project.

VERA supports inquiry-based modeling. It enables learners to create parameterized concept models of ecological phenomena and simulate the models. VERA uses EOL for retrieving information about biological species in the given ecosystem and to select the values of the simulation parameters. The goal of the project is to make complex modeling and simulation available to a wide audience of non-experts including students and citizen scientists who not only want to collect data on their local environments, but also need to build evidence-based conceptual models of them thereby utilizing virtual assistants to increase access to information [An et al. 2018; An et al. 2020]. Presently, VERA models consist of biotic and abiotic components without the ability to form higher level abstractions of these components such as assigning them to habitats. The addition of habitat components addresses this gap and adds topological relationships thereby enriching the modeling vocabulary and capability.

Learning

Earlier research on a previous version of VERA called MILA showed that it enabled statistically significant learning gains in ecological domain knowledge in middle school science as well as undergraduate biology [Joyner Goel & Papin 2014; Agarwal, Hartman & Goel 2018]. More recently, VERA has been successfully used in multiple undergraduate biology classes [An et al. 2021]. Preliminary results indicate that VERA enables significant gains in ecological domain knowledge.

Semantics

To add Habitats, their semantics must be clearly defined. In the following italicized words denote elements of the semantics.

Habitats

- *Components* describe a set of related *Instances.*
- Each *Component* has a fixed set of *Parameters.*
- *Instances* have *Values* for their *Parameters.*
- There are three non-overlapping types of *Components: Habitats, Biotics* and *Abiotics.*
- A Habitat may contain a set of other *Components*, including sub-*Habitats.* Leaf *Habitats* contain only *Biotic* or *Abiotic Components.*
- The set of *Habitats* in a model form a tree, where the sub-*Habitats* of a *Habitat* inherit their parent's *Parameters.*

Relations

- Three built-in Relations are *Contains*, *Adjacent* and *Affects.*
- There is a binary *Relation* between *Habitats* and non-*Habitat* (*Biotic* or *Abiotic*) *Components* called *Contains.*
- Instances of *Biotic* and *Abiotic Components Contained* in a *Habitat* are also *Contained* in all ancestor *Habitats.*
- Within a *Habitat*, two direct sub-*Habitats* may be *Adjacent* to each other (participate in the binary *Adjacent Relation*).
- On any simulated clock tick, an Instance of an *Abiotic* or *Biotic Component* can migrate between *Adjacent Components.*
- There is a functional (one way) Relation between *Components* called *Affects.* If two *Components* participate in an *Affects Relation*, the *Values* of the *Parameters* of *Instances* of the independent one may influence one or more *Parameter Values* in the *Instances* of the dependent one on each clock tick.
- A non-*Habitat Component* can only *Affect* a non-*Habitat Component* in its own or sub-*Habitats.*

Extending Learning Potential

The addition of habitats to VERA enables current simulations to produce a richer learning environment by having the habitat parameters alter the parameters of the contained components.

Habitats have been initially developed with three parameters:

1. area,
2. oxygen concentration; and
3. temperature.

In the model shown in Figure 1 a wet, dry, and green habitat each consisting of predator, prey, and plants biotic components is shown.

Temperature affects the lifespan of a biotic component, area its movement velocity, and oxygen concentration its respiratory rate. Figure 2 shows a three-month simulation of how the biotic components' populations differ depending on if and which habitat they are in.

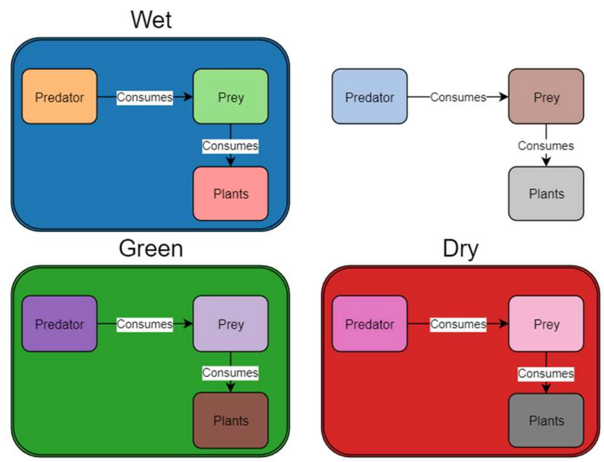

Figure 1: **Simulation canvas with three components inside three different habitats and outside of a habitat.**

Plants are shown to populate at a faster rate in the green habitat more than any other state and slower in the wet habitat - corresponding to the fastest growing rate of prey in the wet habitat and the prey consuming plants.

Predator and prey observations can be seen by the two groups of increasing lines that begin to slope upward after the second month of the simulation. These observations are also affected by the prey's ability or not to consume plants.

Various other observations can be extracted via the given relationships shown in the model in Figure 1 and the output of the model simulation in Figure 2.

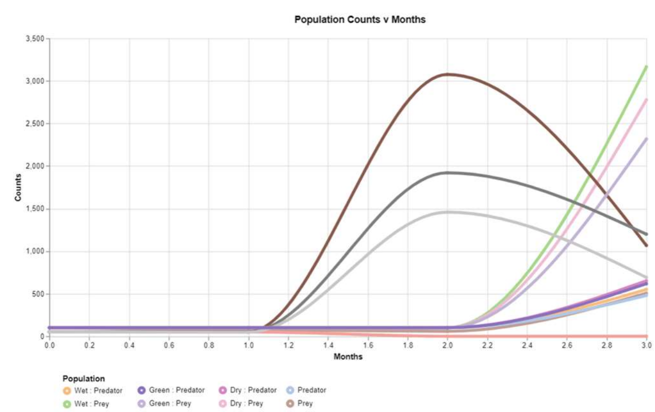

Figure 2: **Simulation results showing the difference between a component being in a habitat or not.**

CONCLUSIONS

VERA is a proven tool for ecological learning on a large scale. Upcoming implementations of habitats will provide an opportunity to extend the current learning capabilities of users by exponentially expanding the possible conceptual models to simulate and enrich VERA with a new source of information upon which to build future features.

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