Plant Ecosystem Simulation using Artificial Life System

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1 Introduction

In theoretical ecology and biology, understand Plant Ecosystem (PES) is very important and also a long standing and challenging problem. PES also has a lot of important applications in computer graphics modeling of outdoor scenes and landscapes.
Therefore, several research works had been undergoing in both fields. However, most of them fall into two categories:

- Generating the CG scenes of PES by methods that yield no insight of the PES.
- Study PES empirically using various statistical methods with data collected from real fields and/or modeled them mathematically.

In this research, we propose a framework for binding them together using bottom-up, synthesis approach based on Artificial Life system. This framework can potentially be used to study the spatio-temporal processes in PES and, at the same time, generating realistic distribution of plants for CG applications. This approach is illustrated as in figure 1.

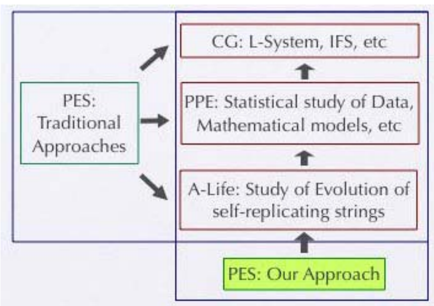

Figure 1: Illustration of the proposed method

2 Spatial Pattern Formation in PES

PES are three-dimensional entities. However, as the vertical dimension is the height of the horizontally-arranged plant bodies, *spatial pattern* in PES is therefore referring to the two-dimensional projection of the plant bodies onto the earth's surface.

Understanding spatial patterns in PES had been a long-standing challenge in theoretical ecology and plant population biology. This is due to several natures of PES itself. For instance, scale-dependency of patterns, dynamical nature of PES, and environmental noises. In this research, PES is considered to be a complex system [2] where the spatial pattern is an emergence result of *Self-Organizing* of internal processe, most notably natality and resources competition. For detail discussions on these topics, see [3].
For modeling PES accordingly, we propose a bottom-up modeling and simulation method using the Artificial Life system.

3 Artificial Life

Artificial Life (ALife) is a new way to study evolution by modeling a large number of *individual* self-replicating entities which are competing against each other for resources required for replication.

3.1 The *Avida* System

The world in *Avida* is an $N \times M$ grid. Each position in the grid hold either an unoccupied space, or a self-replicating string (a *program*).

Programs in *Avida* compete against each other for resource their need for self-replication, that is the CPU time. Default amount of CPU time is given to all programs, with extra amount given to programs that adapt to the environment better by learning to perform logical operations. This is done through *mutation*, which is the key to adaption in Darwinian manner. An *Avida* world, the embeddedness of the individuals and the scope of local interactions are graphically illustrated in figure 2. According to the figure, we can clearly see why *Avida* is suitable for modeling plant communities and we can instantly draw close analogies between *Avida* system and real plant ecosystems.

4 Artificial Life Framework for Modeling Plant Communities

As we can see, there are a lot of conceptual similarities between Avida world and PES, for instance:

- Mobility of individuals. Both are immobile.

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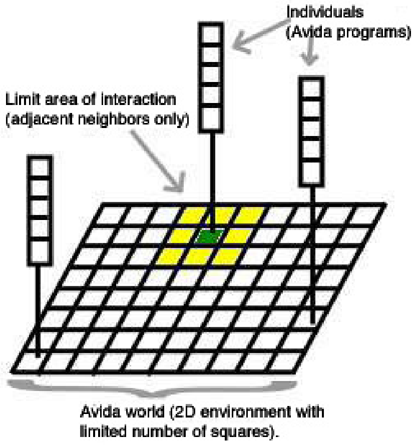

Figure 2: Graphical illustration of *Avida* world.

- Interactions are local to surrounding neighbors.
- Vertical dimension has effects on competition.
- Adaptation (fitness)-based selections (evolution).
- Power-law in population density [1][5].

From these conceptual similarities, it is therefore possible and reasonable to construct a model based on *Avida* for modeling natural plant communities and generating their spatial patterns.

5 Results

In this section, we show a spatial pattern of programs in *Avida* taken during an *Avida* run. *Avida* was configured to analogically reflect a real plant community as much as possible. For details on configuration of *Avida*, see [4]. The spatial pattern generated in *Avida* is showed here in figure 3, while a corresponding graphically rendered image is showed in figure 4.

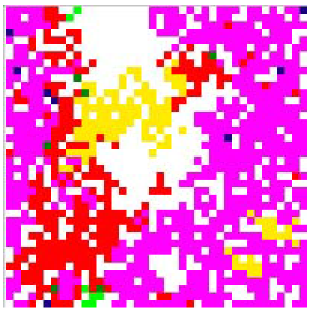

Figure 3: Spatial distribution in *Avida*

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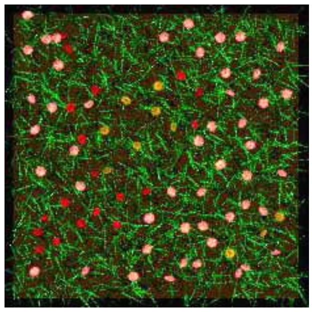

Figure 4: Plant community with spatial distribution pattern generated by*Avida* (figure 3).

6 Summary and Future Research

In this research, we proposed an approach of using an auto-adaptive, evolvable, self-organizing Artificial Life system to generate spatial patterns of plant communities for CG applications and as a tool for studying them theoretically. The spatial pattern generated looks realistic, but we still cannot judge the realness of the pattern yet as the statistical analysis had not been performed.

For future works, we've therefore planned to apply this method in modeling and simulation of some PES and applying L-System for its real-time visualization.

References

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