Analyzing Agent Field of View and Implementing Hexagonal Cells in an Artificial Society

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1 Introduction

1.1 Background

The term "artificial society" is used in the context of this paper to describe a discrete-event simulation model with a given set of characteristics. The model used here is an agent-based simulation in which the agents' environment is a landscape that they can move about by following some rules defined for the model. The motivation for this work is presented in *Growing Artificial Societies* by Joshua M. Epstein and Robert Axtell. The basis for this work comes from the implementation of the Epstein and Axtell artificial society by Barry G. Lawson and Steve Park in "Asynchronous Time Evolution in an Artificial Society Model."

1.2 Goals

The goal of this work is to extend the artificial society implemented by Lawson and Park to determine the implications that changing the pattern of each agent's field of view has on the model. To do this, many variations on the original model were run to determine what effects the various parameters of the agents had on the model. The method for accomplishing a change in the field of view of an agent is to allow the agents a broader field of view that extends in eight directions rather than the four implemented by Lawson and Park. In another instance, a bounding box specified by an agent's field of view will be examined. Further, this paper will demonstrate the effects of landscape cell shape on the model. This is done through an implementation of hexagonal cells, using the model presented by Nicol for a battlefield simulation board. The hexagonal model tests two separate fields of view. The first allows the agent to move in any of the six directions specified by the sides of the hexagon. The second allows the agent to move in any direction they wish within a bounding hexagon specified by their field of view.

1.3 Outline

The following is an outline of the remainder of this paper. In section two, the artificial society as presented by Epstein and Axtell and implemented by Lawson and Park is briefly discussed along with the results that it produces. Section three discusses the eight directional and “bounding box” fields of view that I implemented and the results they produced. Section four discusses the landscape modeled with hexagonal cells which allow agents to move in six directions or on a “bounding hexagon,” and the results produced by these hexagonal models of the society. Section five presents conclusions ascertained from the changes made to the artificial society model and suggestions for future work.

2 The Artificial Society Model

2.1 Epstein and Axtell

The Epstein and Axtell model uses the artificial society model to “apply agent-based computer techniques to the study of human social phenomena” [EA96]. The basic model, as defined by Epstein and Axtell, consists of agents that interact with an environment and coexist by some set of behavioral rules. The important attribute of this model for the purposes of my research is the vision attribute that each agent possesses. As defined by Epstein and Axtell for a landscape consisting of agents confined to square cells at a given time step on a square landscape, agent vision is restricted to moving in one of four directions. More specifically, agents are restricted from movement in diagonal directions. Agent movement is also restricted by the rule that a cell may not be occupied by more than one agent at a given time. An agent’s vision also defines across how many cells an agent can “see,” which is important because an agent can only move to cells that are within its vision. Agents will always move to the most fertile cell within their field of view. When two cells have the same amount of resource, the agent will always choose the closer cell. The aforementioned rules and restrictions will apply to all models discussed in this paper. Figure 2-1 illustrates an agent’s vision with black squares, with white squares indicating cells that an agent cannot see. This paper will explore what happens if you allow an agent’s vision to extend beyond this basic four directional view.

2.2 Lawson and Park

The Lawson and Park implementation of the basic Epstein and Axtell model is used as the basis for study of new fields of vision in the artificial society model [LP00]. An important note is that the Lawson and Park model allows for asynchronous time evolution, in addition to the synchronous time evolution presented in the Epstein and Axtell model. The Lawson and Park implementation was used both synchronously and asynchronously and the attributes were initialized with random variates $Uniform()$ and $Equilikely()$ defined by Leemis and Park [PL99]:

$$\begin{aligned}
&\phi = Equilikely(1,6)\\
&\mu = Uniform(1,4)\\
&\alpha = Uniform(12,15)\\
&\lambda = Uniform(60,100)\\
&\omega = Uniform(50,60) \text{ (for males)}\\
&\omega = Uniform(40,50) \text{ (for females)}\\
&\eta = 0
\end{aligned}$$

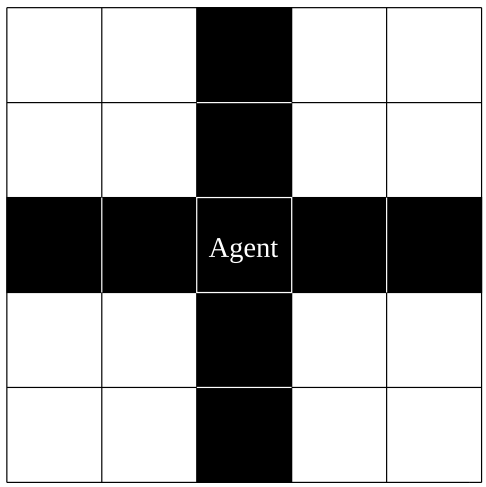

Figure 2-1: Basic four directional vision for an agent with $\phi = 2$.

2.3 Results

The main goal of the Lawson and Park implementation is to determine the effects of asynchronous versus synchronous time evolution in an artificial society. Their tests use several different values of T, the time at which the simulation terminates. However, all of the values show that synchronous time evolution produces much more oscillatory behavior in the carrying capacity of the four directional landscape than does asynchronous time evolution. Further, for large values of T, the synchronous time evolution was shown to continue producing oscillatory behavior for carrying capacity, while the asynchronous case produced stable agent populations in most cases. The model produced by Lawson and Park also allows for use of random initial ages for each agent. This feature attempts to remove any bias that may result from all agents starting at age zero. Using random initial ages produces stable agent populations in the asynchronous case for T values as small as 500 in their implementation. Figure 2-2 shows the synchronous case for the one peak and a random landscapes. Figure 2-3 shows the same landscapes in the asynchronous case. This paper will examine the effects of agent field of view and cell shape in both the synchronous and asynchronous cases.

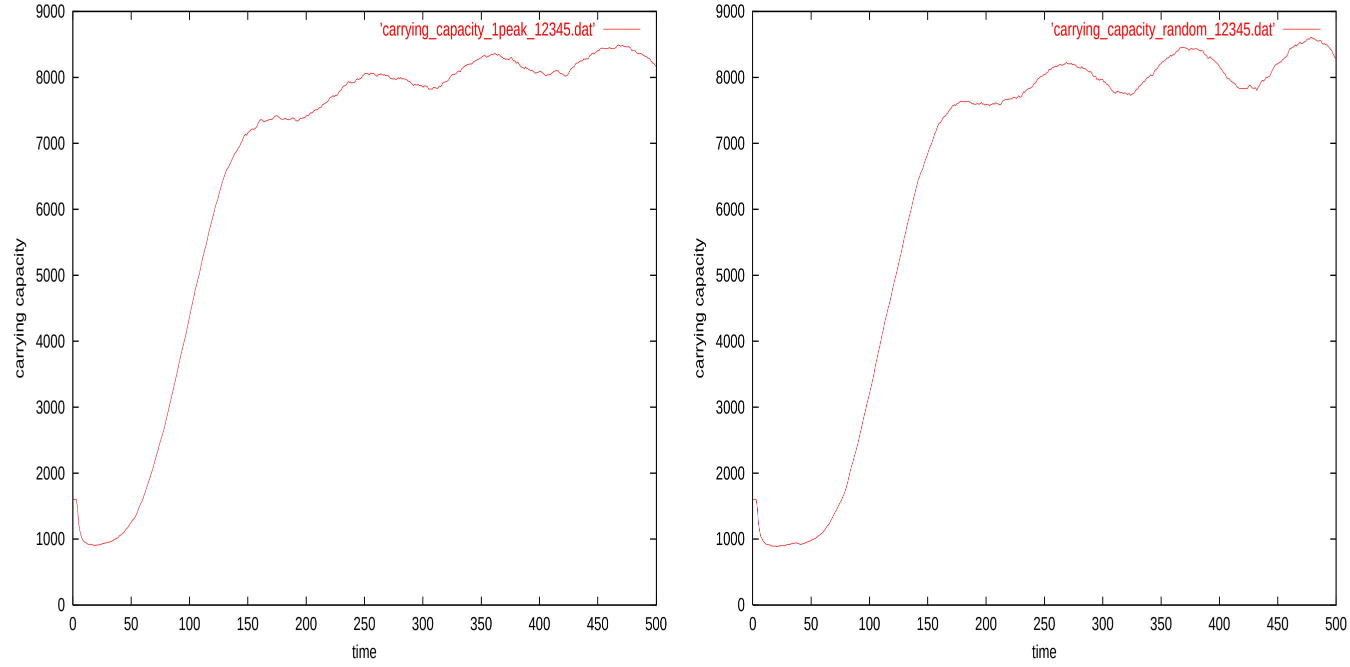

Figure 2-2: Carrying capacity for synchronous time evolution on a 1 peak landscape (left) and random landscape (right).

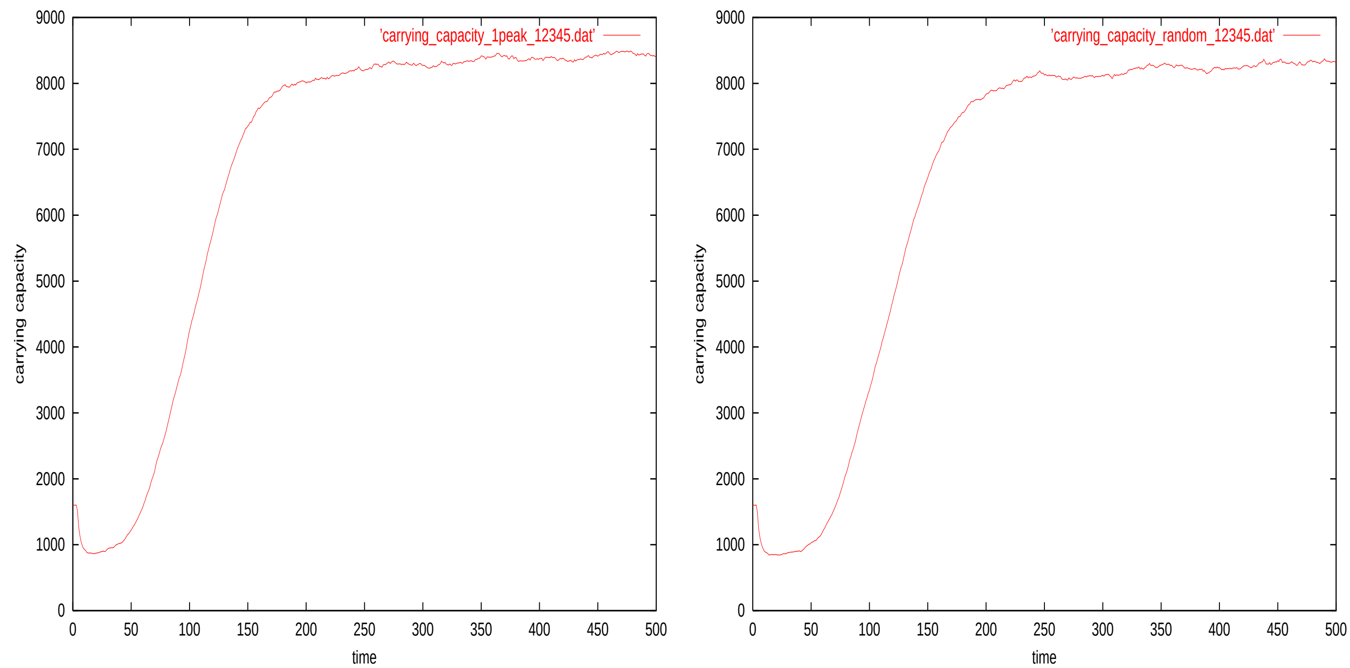

Figure 2-3: Carrying capacity for asynchronous time evolution on a 1 peak landscape (left) and random landscape (right).

3 Introducing New Fields of View: Increasing the Agent's Options

3.1 Eight Direction Field of View

The eight direction field of view is an extension of the four direction field of view used in Lawson and Park. This field of view allows an agent to move within its Moore Neighborhood. Figure 2 illustrates an agent's field of view with black squares for agent field of view in eight directions. The same restrictions apply to more than one agent occupying the same cell as in the Epstein and Axtell model.

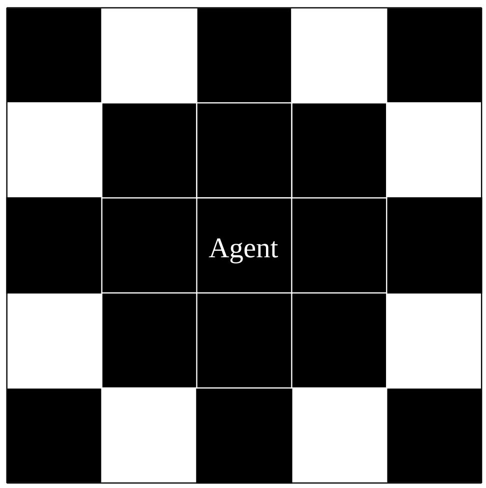

Figure 3-1: Eight directional Moore Neighborhood vision for an agent with $\phi = 2$.

3.2 Agent in a Box Field of View

The "agent in a box" field of view expands further upon the four direction field of view. The box shaped field of view is implemented by allowing agents to move in more than one direction in the Moore Neighborhood. If we define a step as movement by an agent from one cell to any cell in its Moore Neighborhood, then we can define the box field of view as taking no more than ϕ steps from the current cell. This view of stepping creates a box that includes all cells within ϕ rows and ϕ columns of the current cell. An agent may then move, in accordance with the model, to the most fertile cell in that block that is not occupied by another agent. Figure 3-2 illustrates the agent in a box field of vision.

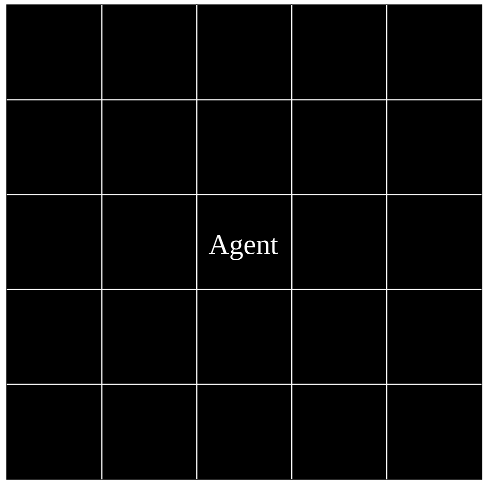

Figure 3-2: Agent in a Box field of vision with $\phi = 2$.

3.3 Results

The two fields of view presented yield interesting results when using a landscape with one peak, where a peak is an area of the landscape with more resources. In the case of the eight direction field of vision, the asynchronous case had little change in carrying capacity from the four direction field of vision. The pattern followed was very close to that of the standard four direction field of view, with the carrying capacity reaching a stable value in most cases. However, the oscillatory behavior of the synchronous case was clearly diminished by the eight direction field of view. While there was still some minor visible oscillation, the extent of the oscillations was vastly reduced, yielding behavior very similar to that of the asynchronous case. The box field of view furthers the similarity between the synchronous and asynchronous cases. Figure 3-3 illustrates the eight direction field of view for the synchronous and asynchronous cases, while Figure 3-4 illustrates the synchronous and asynchronous cases for the box field of view, all for the one peak landscape. Clearly, the asynchronous case is relatively unchanged from the four direction field of view, while the synchronous case is very different from the synchronous case shown in Figure 2-2.

The one peak landscape is not a complete assessment, however, because the behavior of the model changes when using a randomly generated landscape. While the asynchronous case is still relatively unchanged from the four direction model, the synchronous case is not as similar to the asynchronous case on this random landscape. The synchronous case is less oscillatory than in the four direction case for both the eight direction and box fields of vision. However, there is still visible oscillation in this case demonstrating that the new fields of view alone do not eliminate oscillations in the synchronous time evolution for all cases. Figure 3-5 illustrates the eight direction field of view for the synchronous and asynchronous cases, while figure 3-6 illustrates the synchronous and asynchronous cases for the box field of view, all for the random landscape.

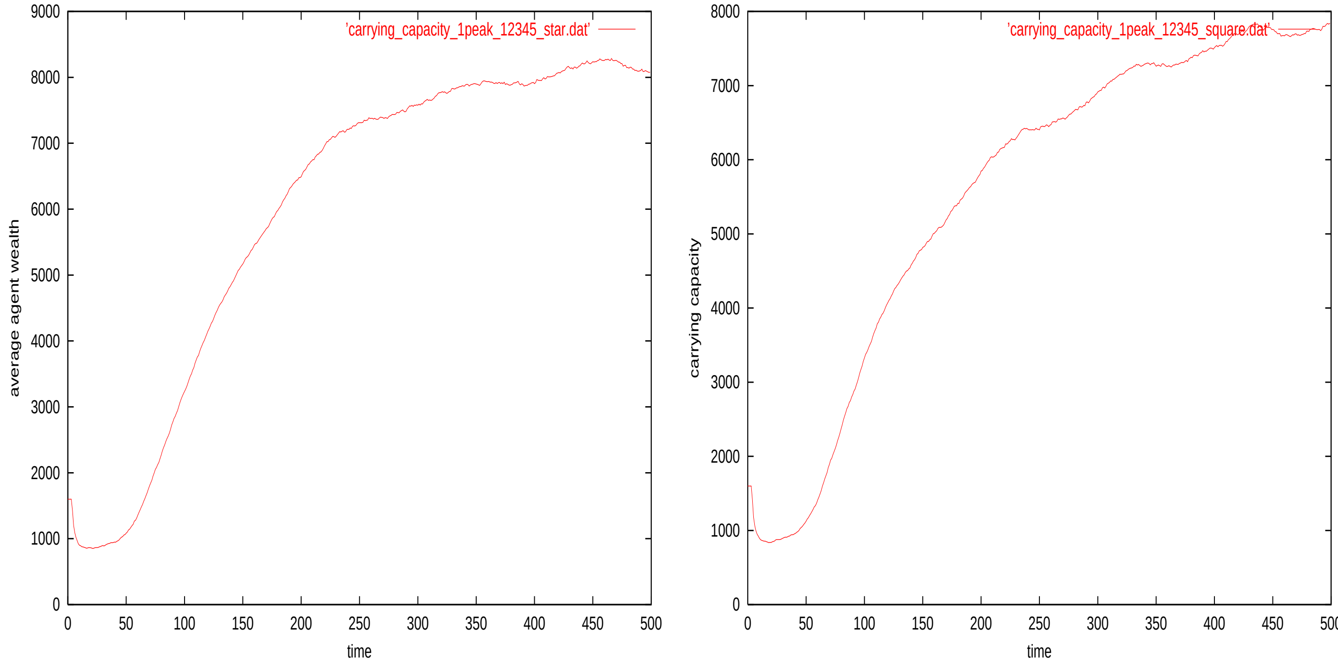

Figure 3-3: Carrying capacity for synchronous time evolution on a 1 peak landscape with eight direction field of view (left) and box field of view (right).

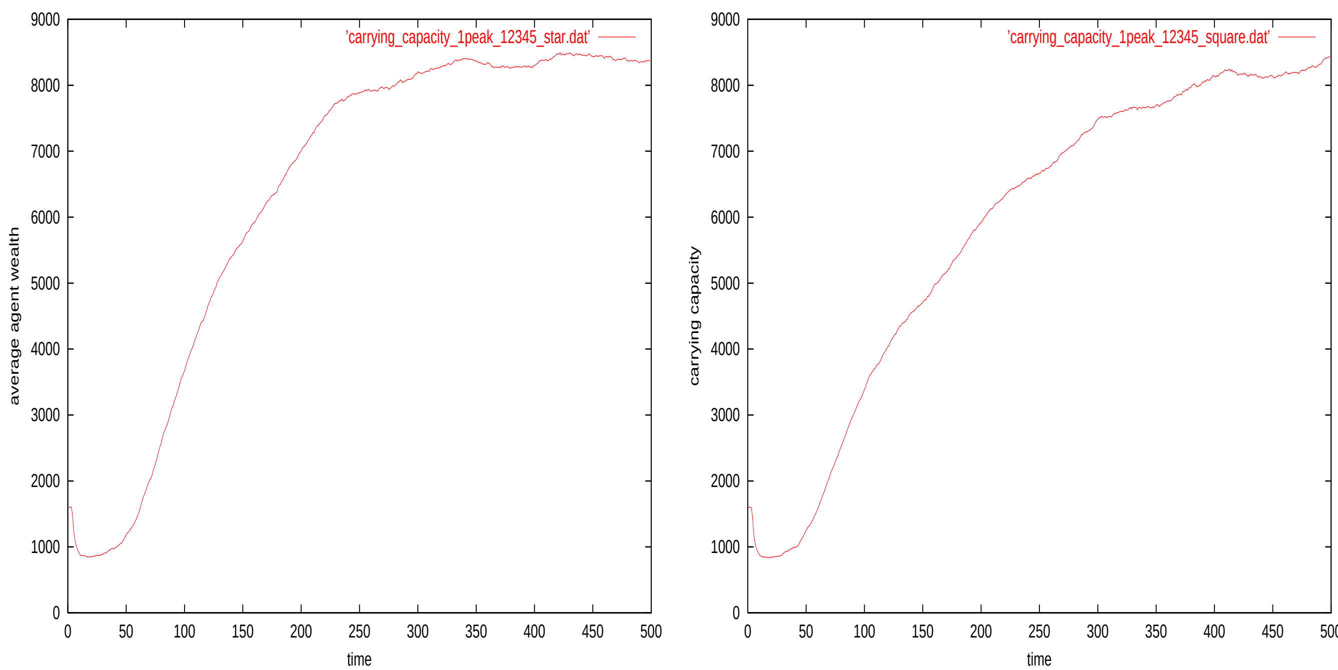

Figure 3-4: Carrying capacity for asynchronous time evolution on a 1 peak landscape with eight direction field of view (left) and box field of view (right).

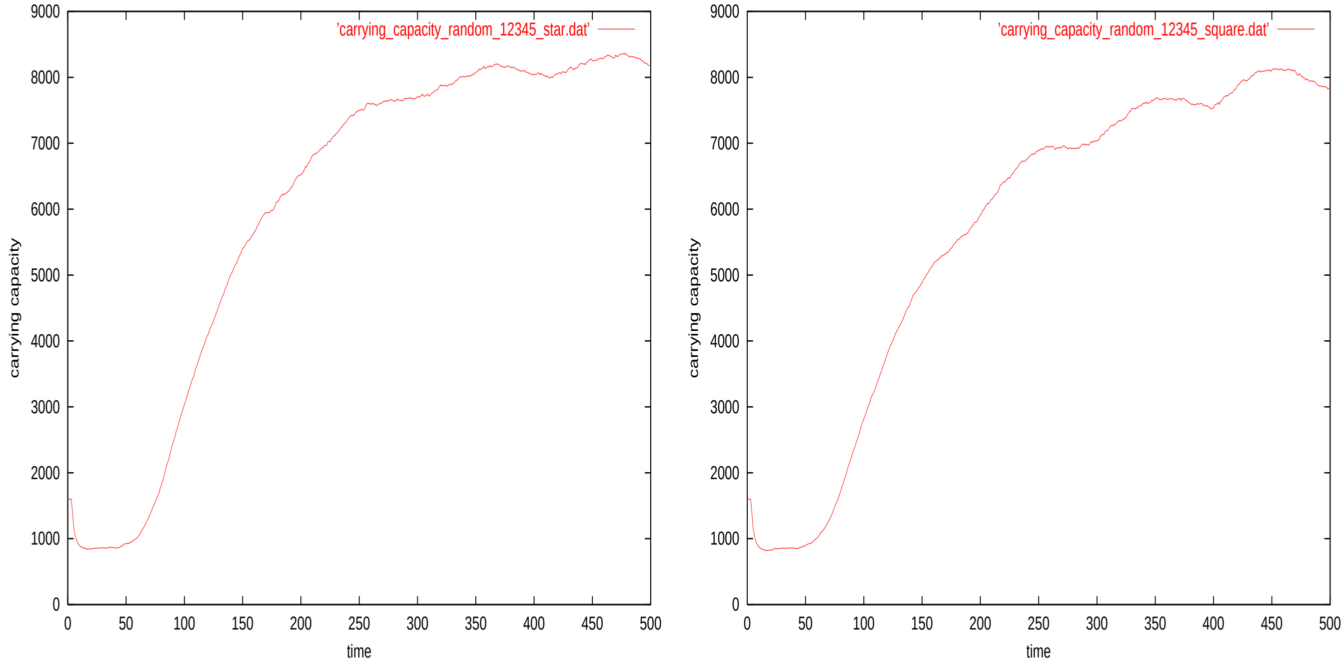

Figure 3-5: Carrying capacity for synchronous time evolution on a random landscape with eight direction field of view (left) and box field of view (right).

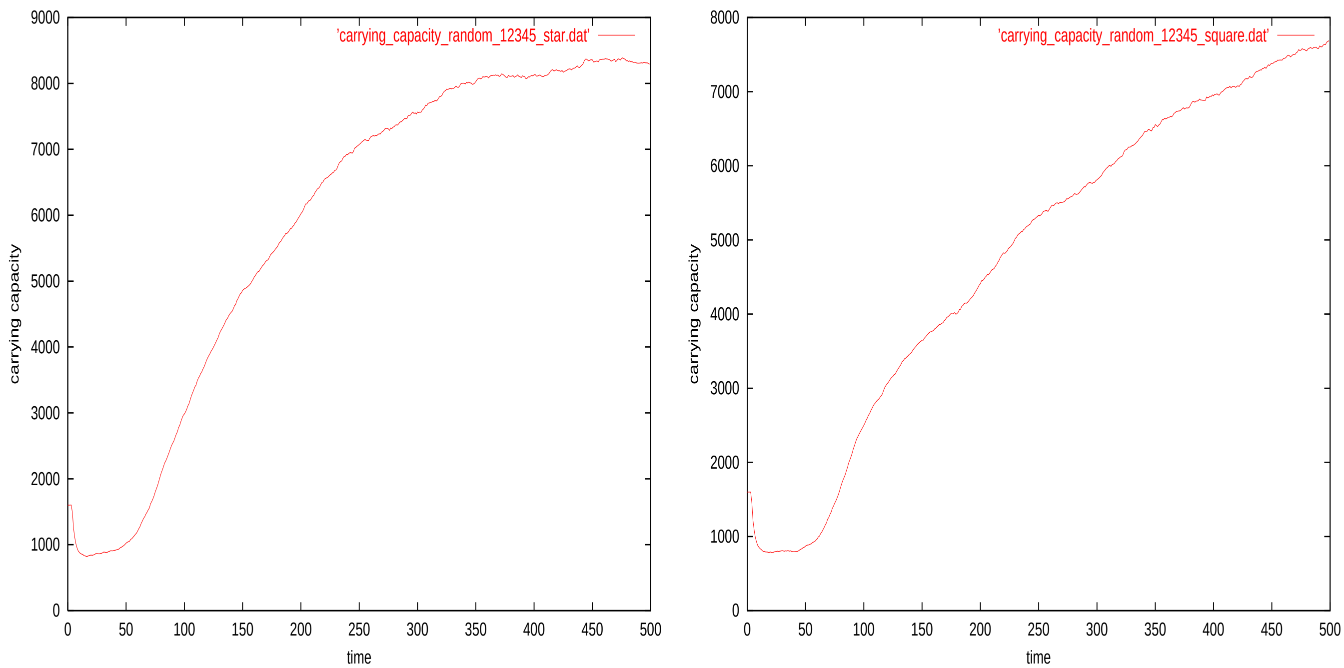

Figure 3-6: Carrying capacity for asynchronous time evolution on a 1 peak landscape with eight direction field of view (left) and box field of view (right).

4 Modifying the Cell Shape: The Hexagon Model

4.1 Nicol's Battlefield Simulation Model

The basis for this extension of the field of view comes from Nicol's battlefield simulation model [Nic87]. The model presents a battlefield simulation with cells that are hexagonal in shape. The implementation of this model is rather straightforward to accomplish by understanding the indexing of an array structure which holds the cells. Whereas cells are simple to index for square shaped cells, the joining of hexagonal cells can be a little more difficult. The cells are still stored in an array and the rows of the hexagons are still indexed in the same way. However, the columns have jagged edges due to the shape of the hexagons. For example, the first cell in each row is still the zeroth element, even though it is not located directly below the zeroth cell in the row above it. The structure of the array is best illustrated by Figure 4-1. These hexagonal cells will be used as the cells in the artificial society model in place of square cells. The reason for this is to determine whether allowing an agent a broader range of movement will have an effect on the carrying capacity of the landscape. I examine two different implementations of this hexagonal model: movement in six directions and movement bounded by a hexagon.

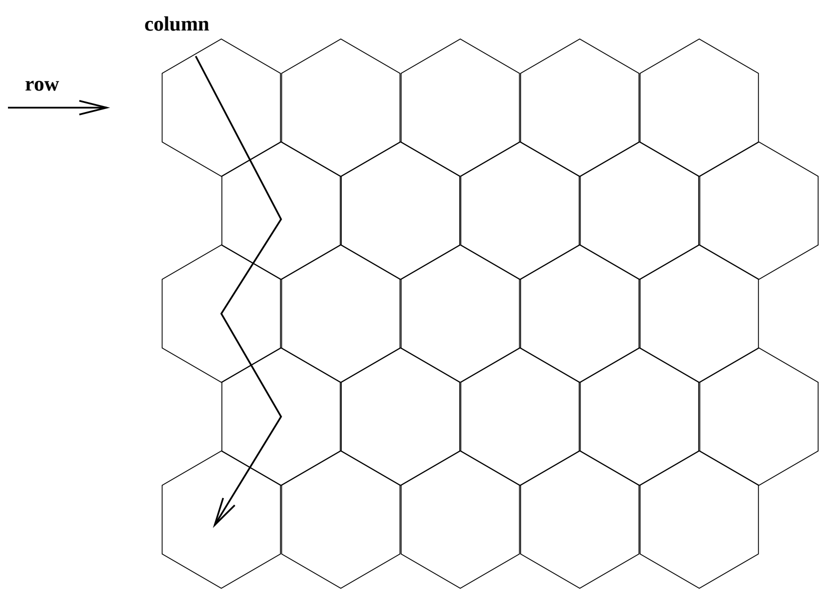

Figure 4-1: A 5 X 5 array of hexagonal cells.

4.2 Six Direction Field of View

The six direction field of view is almost as straightforward as implementing a four directional field of vision for a square. An agents field of view extends ϕ cells in six directions, where the six directions are defined by the sides of the current cell. The visible field of an agent is illustrated in Figure 4-2, where black hexagons denote the visible cells.

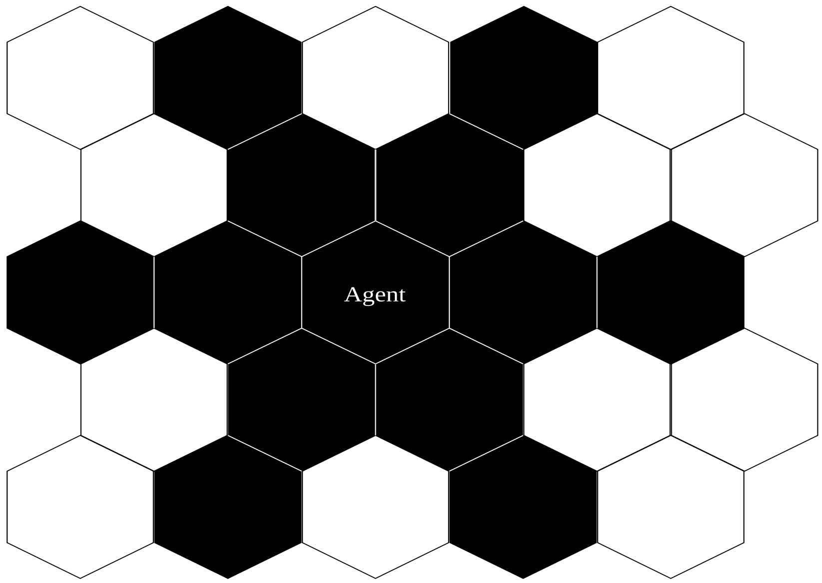

Figure 4-2: A 5 X 5 array of hexagonal cells with six direction field of view and $\phi = 2$.

4.3 Agent in a Hexagon Field of View

The "Agent in a Hexagon" field of view is similar in nature to the "Agent in a Box" field of view. In this case, we define a step as movement by an agent from a cell to one of its six neighboring cells. We allow the agent to take up to ϕ steps from the original cell. Interestingly, this creates a hexagon shape as the field of view for the agent. The black hexagons in Figure 4-3 illustrate the visible cells to a given agent.

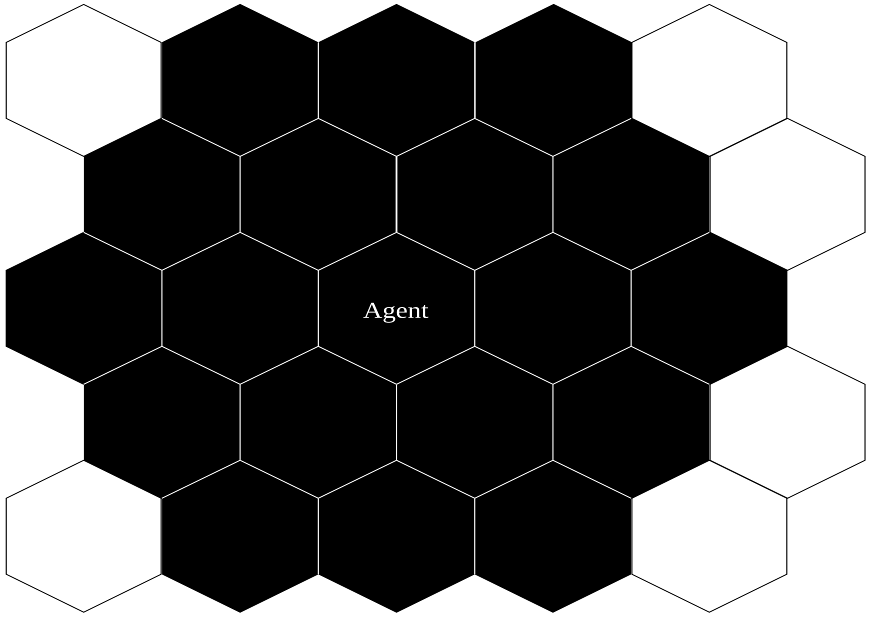

Figure 4-3: A 5 X 5 array of hexagonal cells with an agent in a hexagon field of view for $\phi = 2$.

4.4 Results

For a one peak landscape, using six direction field of view, the behavior of the synchronous case does not display much difference in carrying capacity over time from the four direction field of view. However, the carrying capacity in the asynchronous case tends to oscillate, a behavior that is not seen in the four directional model. Using the random landscape, both sychronous and asynchronous time evolution tend to reach a stable carrying capacity with a limited amount of oscillation. This is unexpected behavior from the synchronous case because synchronous time evolution has generally led to larger oscillations on a random landscape than on a landscape with a single peak. The behavior of the synchronous time evolution for the two landscapes is pictured in figure 4-4 and asynchronous time evolution is pictured in figure 4-5.

For hexagonal cells with the bounding hexagon field of vision, the one peak landscape shows carrying capacity that is close to the four direction field of view model. In the case of synchronous time evolution, the carrying capacity oscillates more as time progresses. In contrast, the carrying capacity in the asynchronous case reaches a stable value without distinct oscillating behavior, but takes much longer to reach this value than in the four direction case. The asynchronous case exhibits similar behavior with the random landscape, as expected. However, the synchronous case exhibits behavior similar to the asynchronous case, rather than the oscillating behavior that was present in the one peak landscape. The behavior of the synchronous time evolution for the two landscapes is pictured in figure 4-6 and asynchronous time evolution is pictured in figure 4-7.

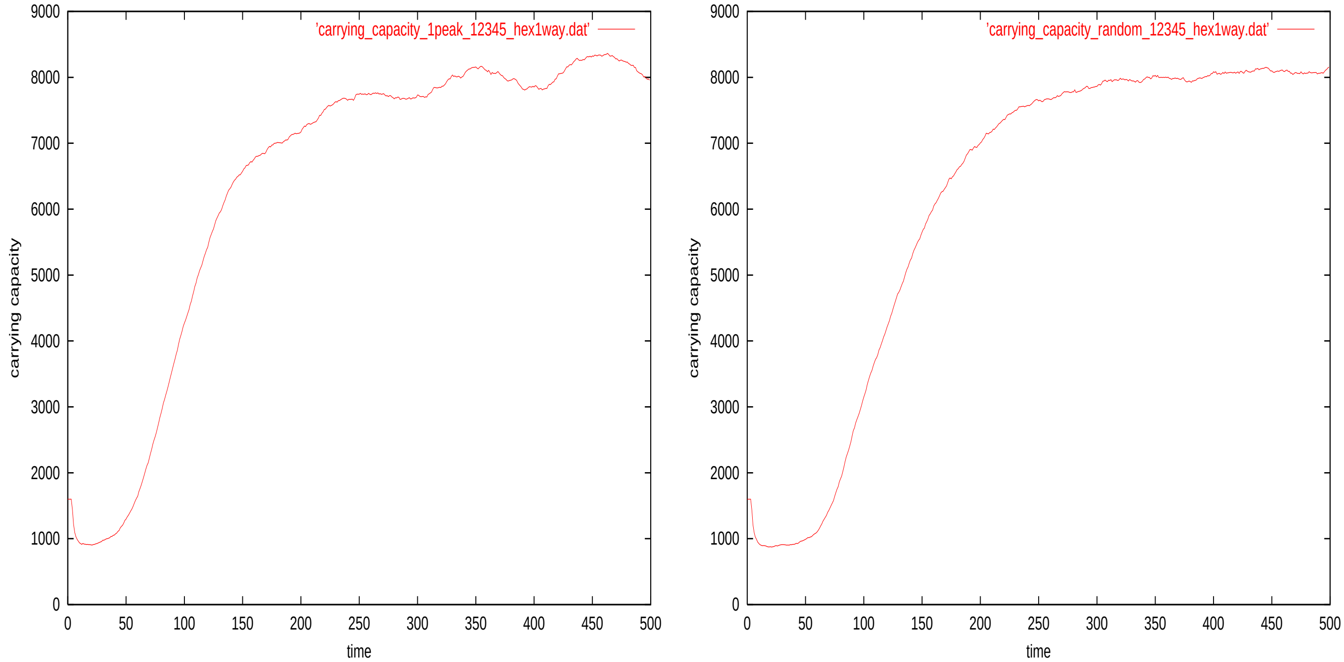

Figure 4-4: Carrying capacity for synchronous time evolution on a 1 peak landscape (left) and random landscape (right) for six direction field of view.

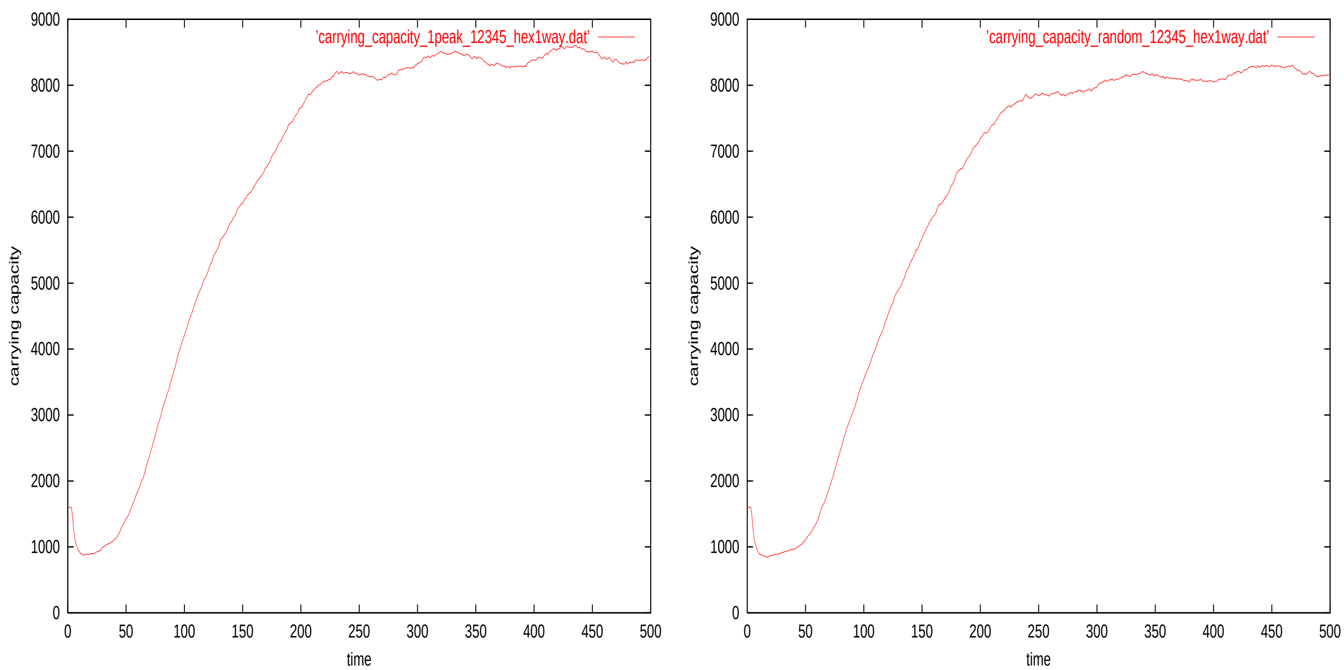

Figure 4-5: Carrying capacity for asynchronous time evolution on a 1 peak landscape (left) and random landscape (right) for six direction field of view.

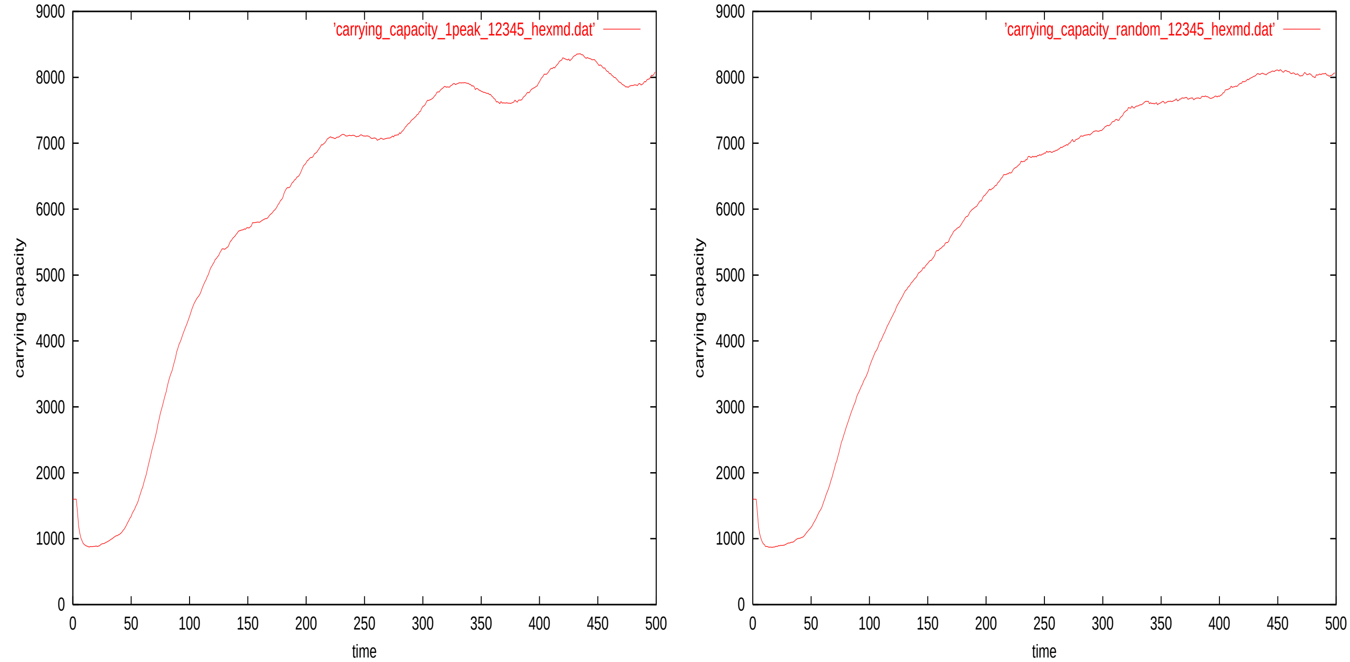

Figure 4-6: Carrying capacity for synchronous time evolution on a 1 peak landscape (left) and random landscape (right) for the bounding hexagon field of view.

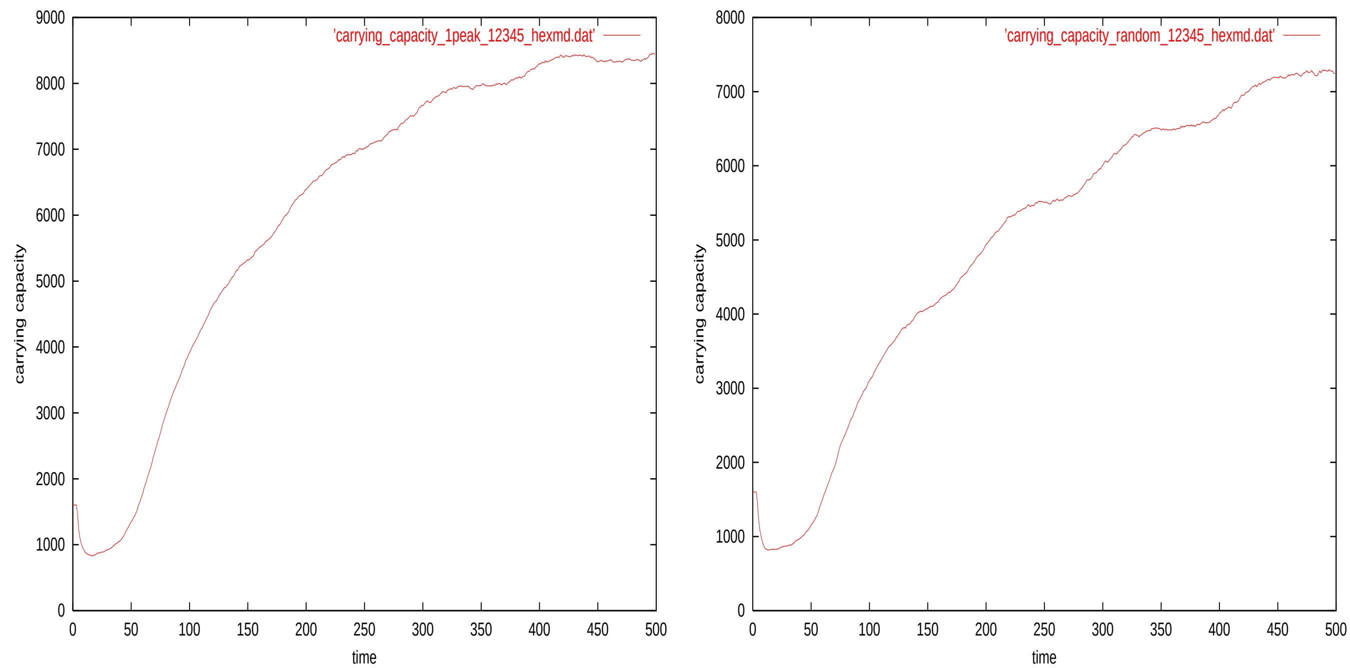

Figure 4-7: Carrying capacity for asynchronous time evolution on a 1 peak landscape (left) and random landscape (right) for the bounding hexagon field of view.

5 Conclusions and Future Work

The new models for field of view present the problem of choosing which is the best field of view and cell shape for implementing the artificial society. It seems that the hexagonal cell model coupled with the bounding hexagon field of view is the best of those discussed. However, as implemented by myself, it lacks the robustness of the other algorithms. Therefore, I would suggest using the box field of vision due to the simplicity of the square cell shape and the ease of creating a bounding box around a given cell. The difference in the results between the hexagonal cells with bounding hexagons and the square cells with bounding boxes is too negligible to merit the extra computing time required to implement the hexagon model. However, this presents one of two areas in which future work would be advised. First, a robust algorithm for the hexagonal model may prove to produce better results within the artificial society, while providing time complexity similar to that of the box model. Also, extensions into other shapes, such as octagons, would be an interesting experiment to see how it builds upon the changes seen in the hexagonal model. A final observation is that the broader an agent's field of view, the longer it takes for the carrying capacity to reach a steady population. One possibility for this occurence is the fact that agents have a better view of cells with a large amount of resource meaning more cells with high resource levels are occupied, thus preventing agents with dwindling resources from increasing their resource as quickly. This would result in less reproduction and more agent death. However, this is beyond the scope of this paper and will require further research to verify.

References

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