Wavy Line Search Problem
CS 221 Final Project — Final Report
Fall 2017

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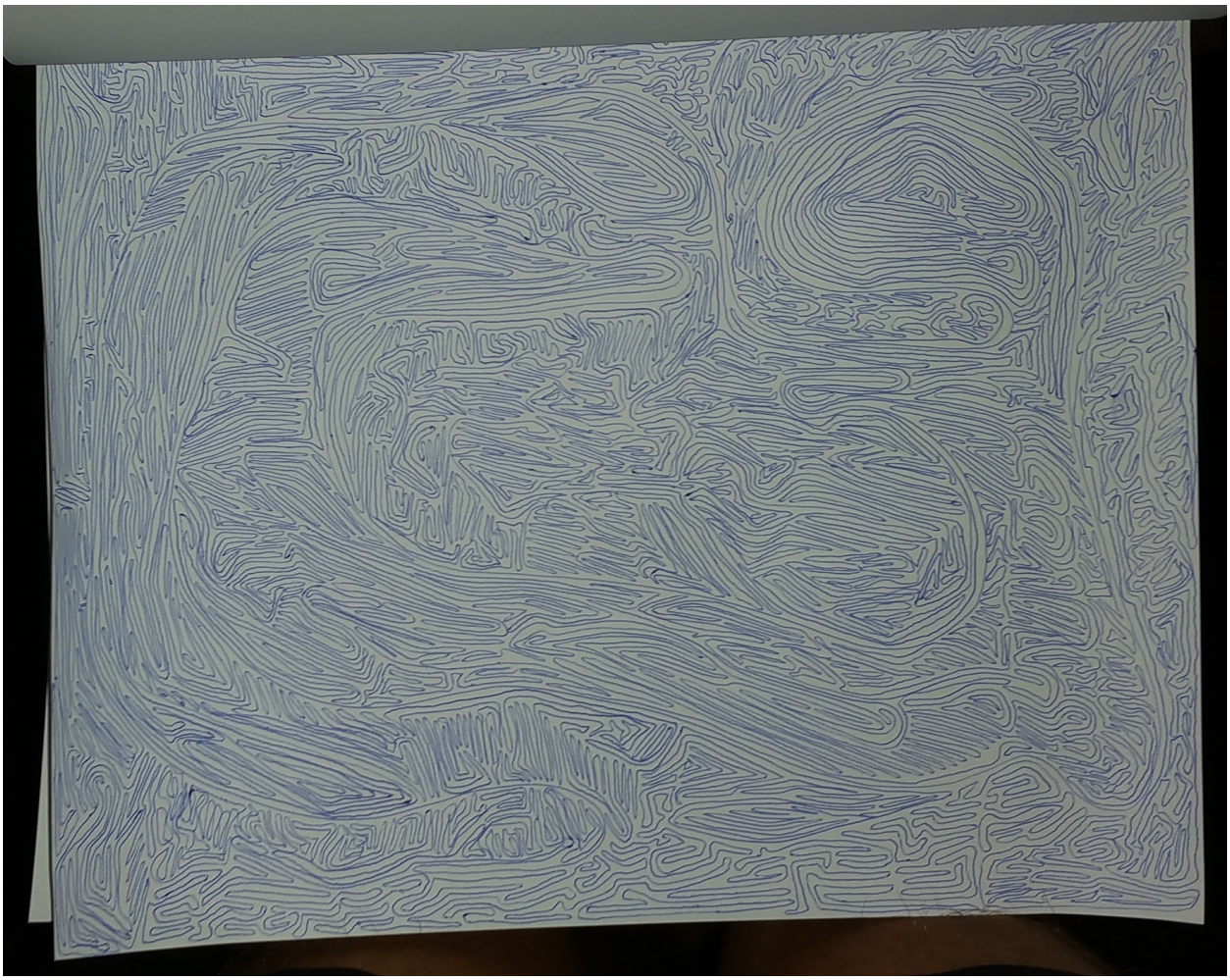

Task Definition
My system generates a "wavy line." Shown above is a wavy line drawn with a pen. It covers the entire page with a single line. To approximate this, my system draws a single line through a grid of points. The task of my system is to fill as much of the grid as possible with this line. As the merit of this work is artistic, resulting outputs are evaluated by humans.

Infrastructure
I chose to use Processing in Python for my project.

Approach
As my project title suggests, I chose to model this task as a search problem. I defined the search problem as follows:

- *Start state:* 2-D array of grid locations, starting point
- *Actions:* Move forward, left, or right
- *Cost:* Based on several deterministic factors, as well as some randomness to make the path interesting (explained below)
- *Successor state:* A new 2-D array of grid locations, with the last current point updated to point to the new current point
- *End state:* True if all surrounding points have been visited

The element of experimentation in this project came with composing the cost function for the search problem. /* TODO */ This is further discussed in this paper's Error Analysis section.

At one point, per the suggestion of CA Steven Mussman, I attempted to formulate the problem as having two actions: Move clockwise or move counterclockwise around the starting point. At each step taken, with some probability the line would begin moving in the opposite direction. The idea was that this would cause the line to emanate from the starting point by wrapping back and forth around itself in a circular fashion. To encourage the line to fill the rectangular page, costs could be assigned based on how square the resulting line pattern would be after taking an action. I unfortunately did not get around to fully implementing the search problem in this way.

After several discussions with the CAs I found the most appropriate search algorithm to be depth-first search with iterative deepening (DFS-ID). My implementation composes a wavy line of segments found using DFS-ID with a fixed depth. The search runs to a depth d, selects the lowest-cost path of those with the greatest length (at most d), and then repeats, beginning at the endpoint of the selected path.

I should also mention that the size of the state for my search problem was prohibitive to the use of certain algorithms. Because the state includes the entire grid of points, my search problem does not lend itself well to, for example, uniform cost search, which would need to compare entire grids in order to check whether a state has already been explored.

The oracle for this task is a hand-drawn line that fills an entire page and achieves aesthetic beauty. The baseline is a basic line that is aesthetically interesting, but does not fill the entire page.

Literature Review
From what I could find, this is the first attempt to build such a system. There is work on maze generation, but the mazes generated are not composed of a single, non-branching line, which is what distinguishes my system's task.

Procedural generation is an umbrella term used in game development and other related spheres to randomly generate graphics that appear as if they were created by a human. I could not find any work within procedural generation that related specifically to my system's task of working with a single line.

Error Analysis

In this section I will walk through the progression of my approach to solving the wavy line search problem, as documented in the Appendix section.

Appendix

Changes in conditions between figures are indicated by *italicized text.*

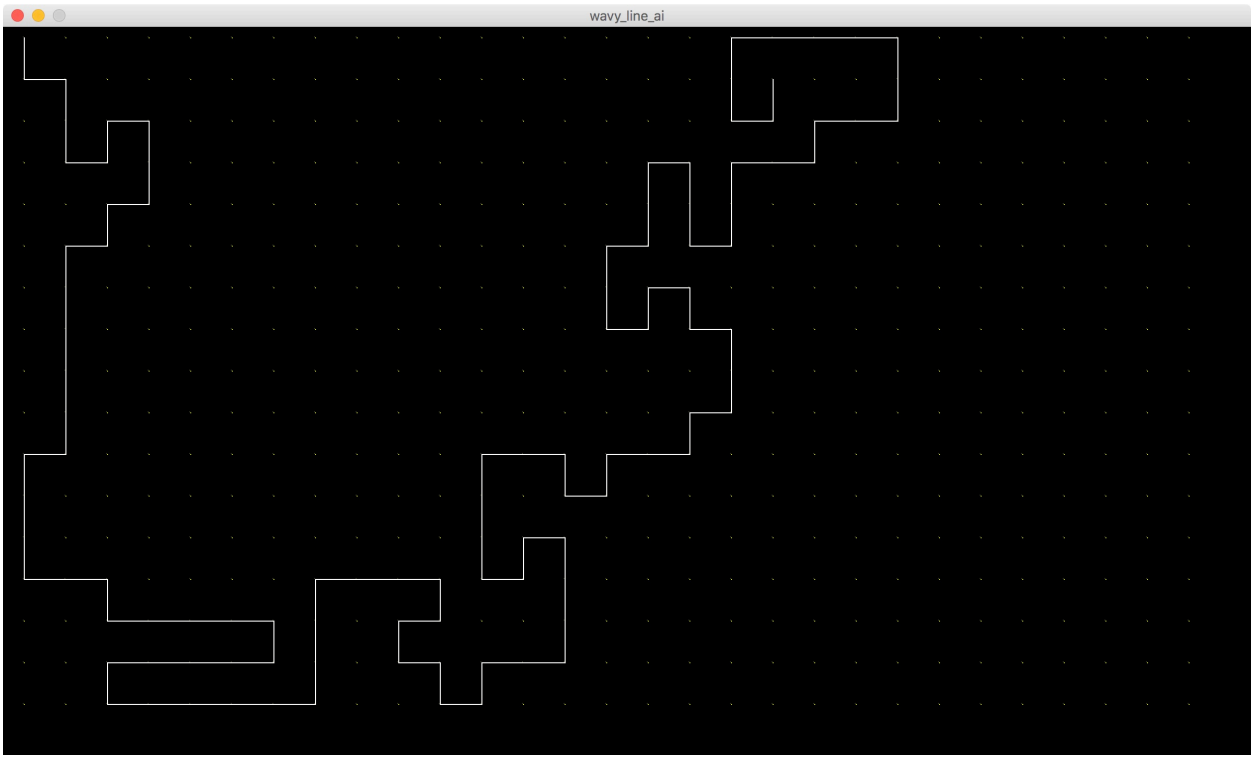

Figure 1: Random costs; search depth of 5.

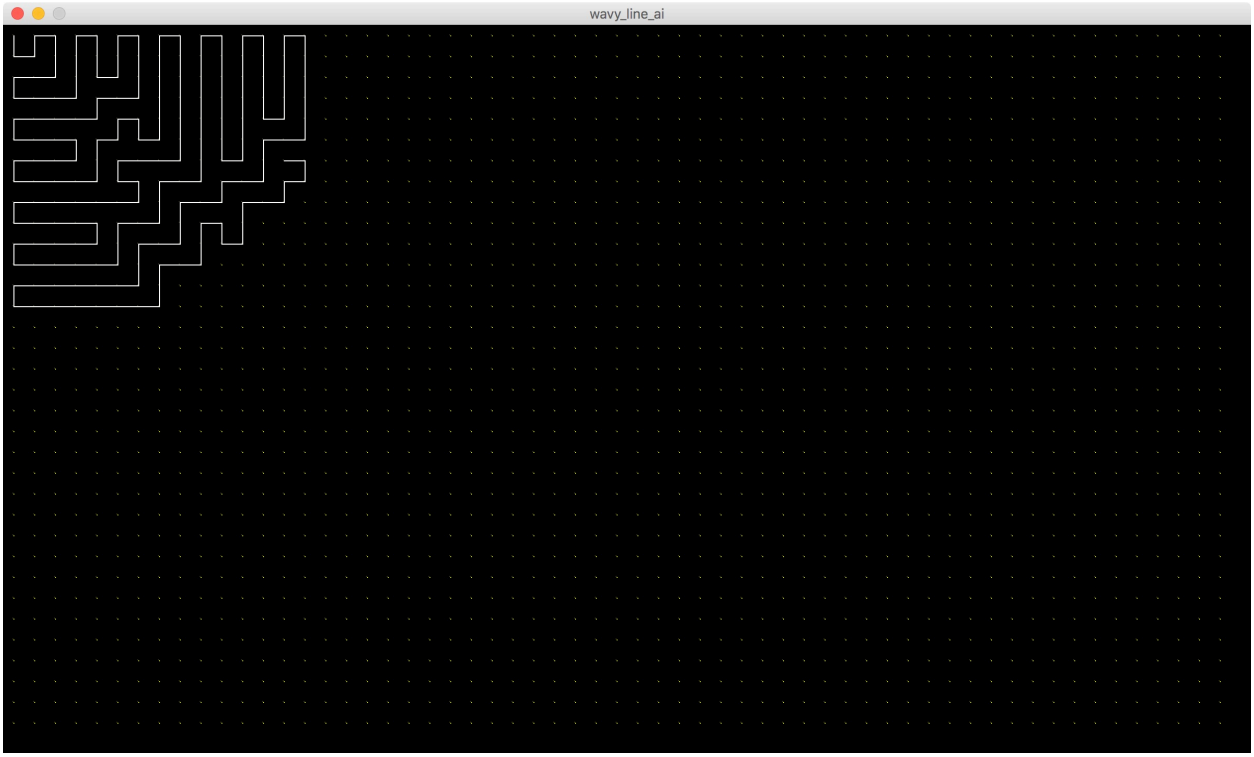

Figure 2: Cost equal to the distance from the starting point (top left); search depth of 3.

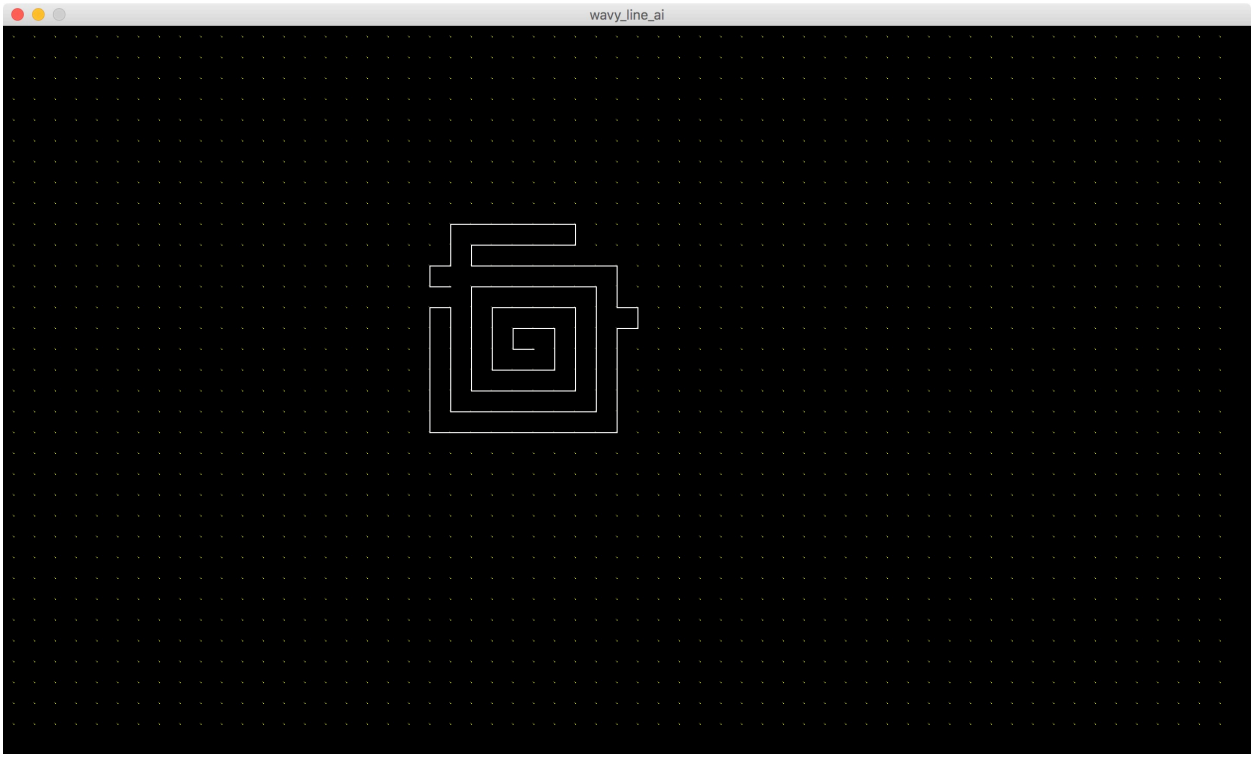

Figure 3: Cost equal to the distance from the starting point *(near center)*; search depth of 3.

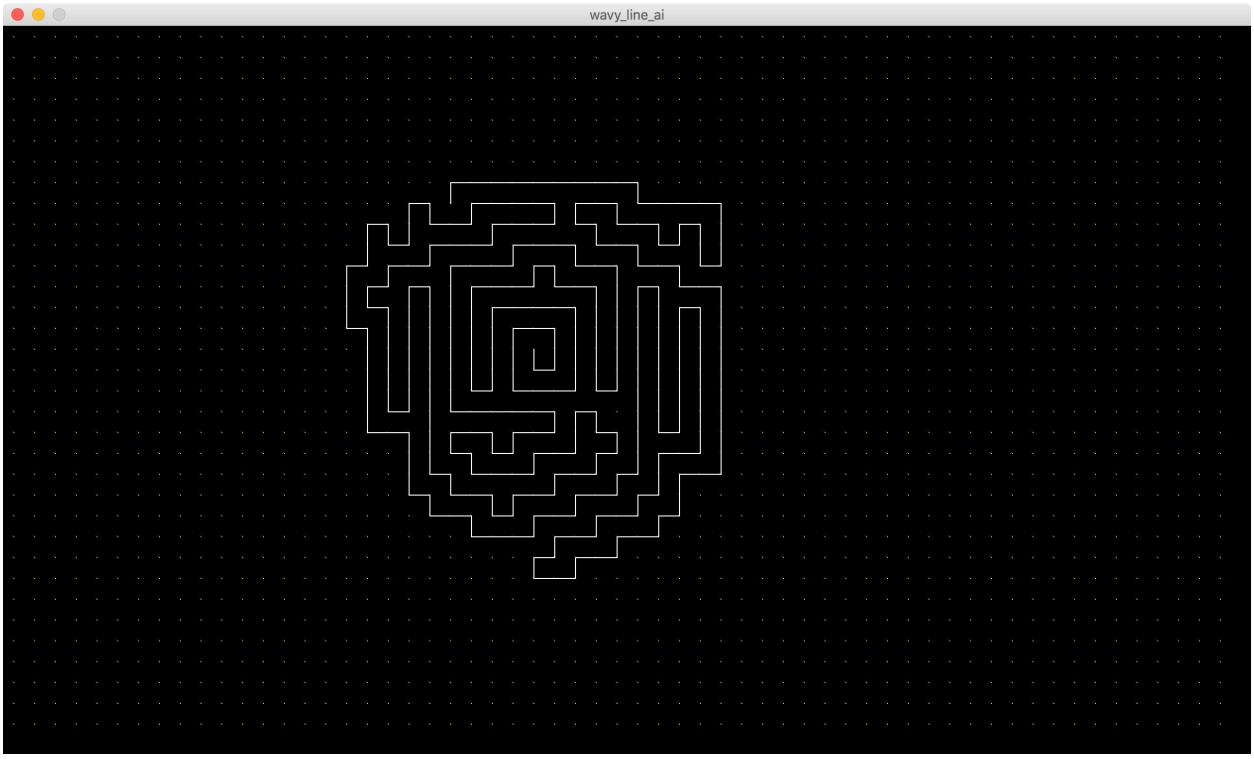

Figure 4: Cost equal to the distance from the starting point (near center), *plus a random number in the range of the average of the width and height of the grid divided by 50;* search depth of 3.

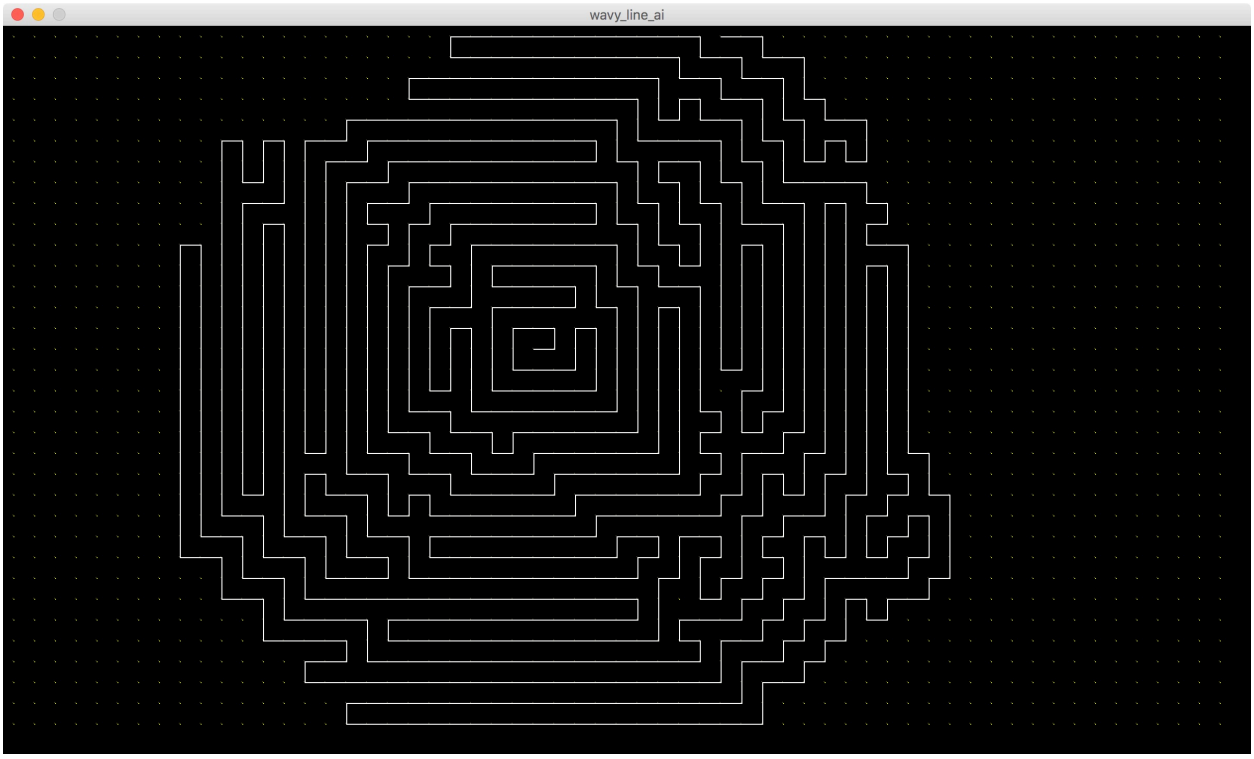

Figure 5: Cost equal to the distance from the starting point (near center) *multiplied by 1.5,* plus a random number in the range of the average of the width and height of the grid *divided by 30;* search depth of 2.

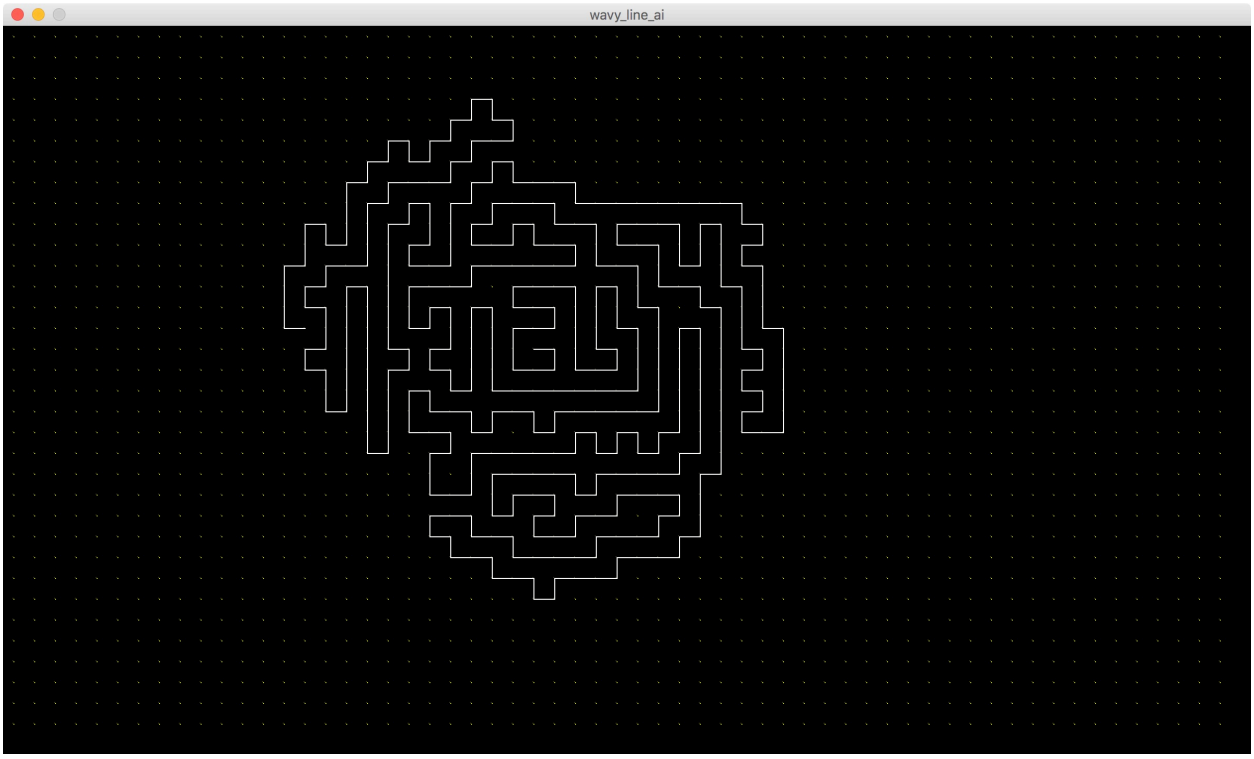

Figure 6: Cost equal to the distance from the starting point (near center) *multiplied by 0.75,* plus a random number in the range of the average of the width and height of the grid divided by 30; search depth of 2.

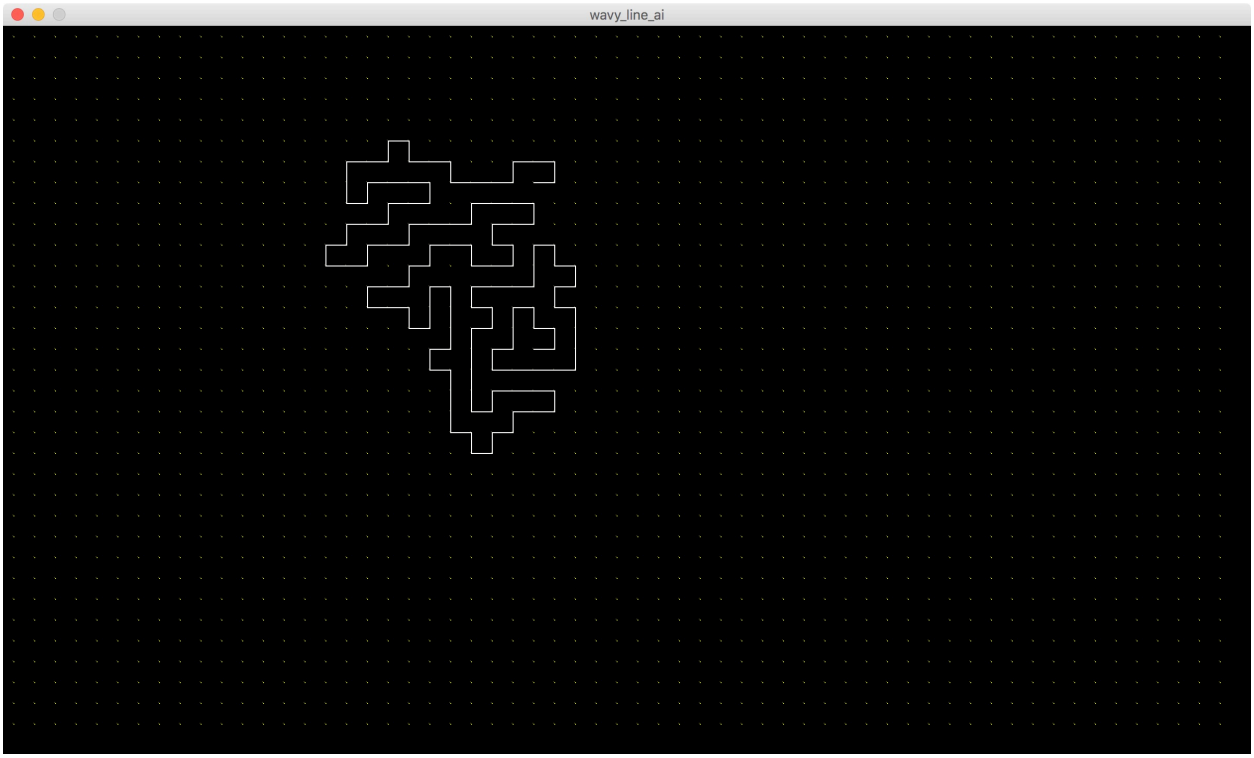

Figure 7: Cost equal to the distance from the starting point (near center) *multiplied by 0.5,* plus a random number in the range of the average of the width and height of the grid divided by 30; search depth of 2.

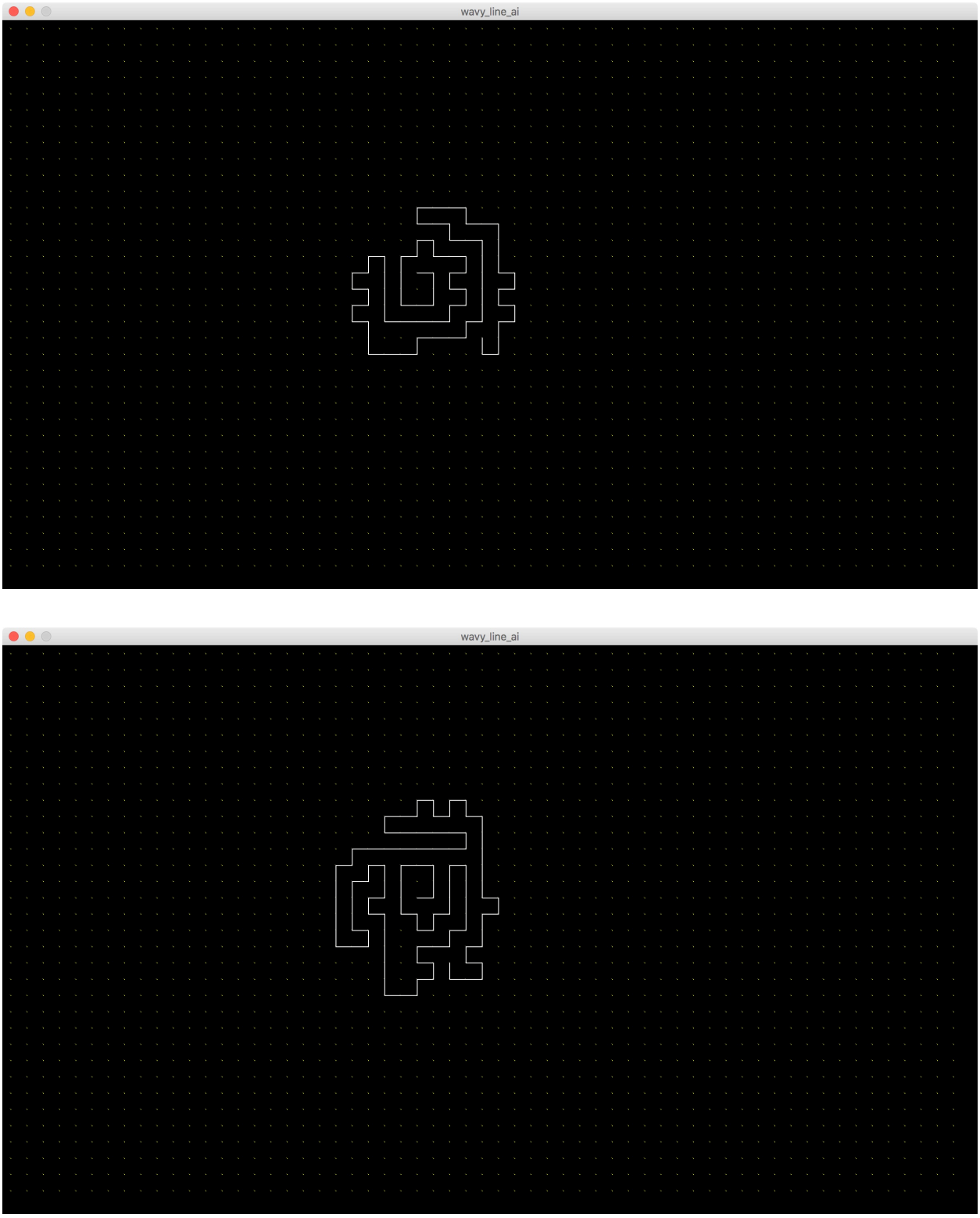

Figure 8: Same conditions as Figure 7.

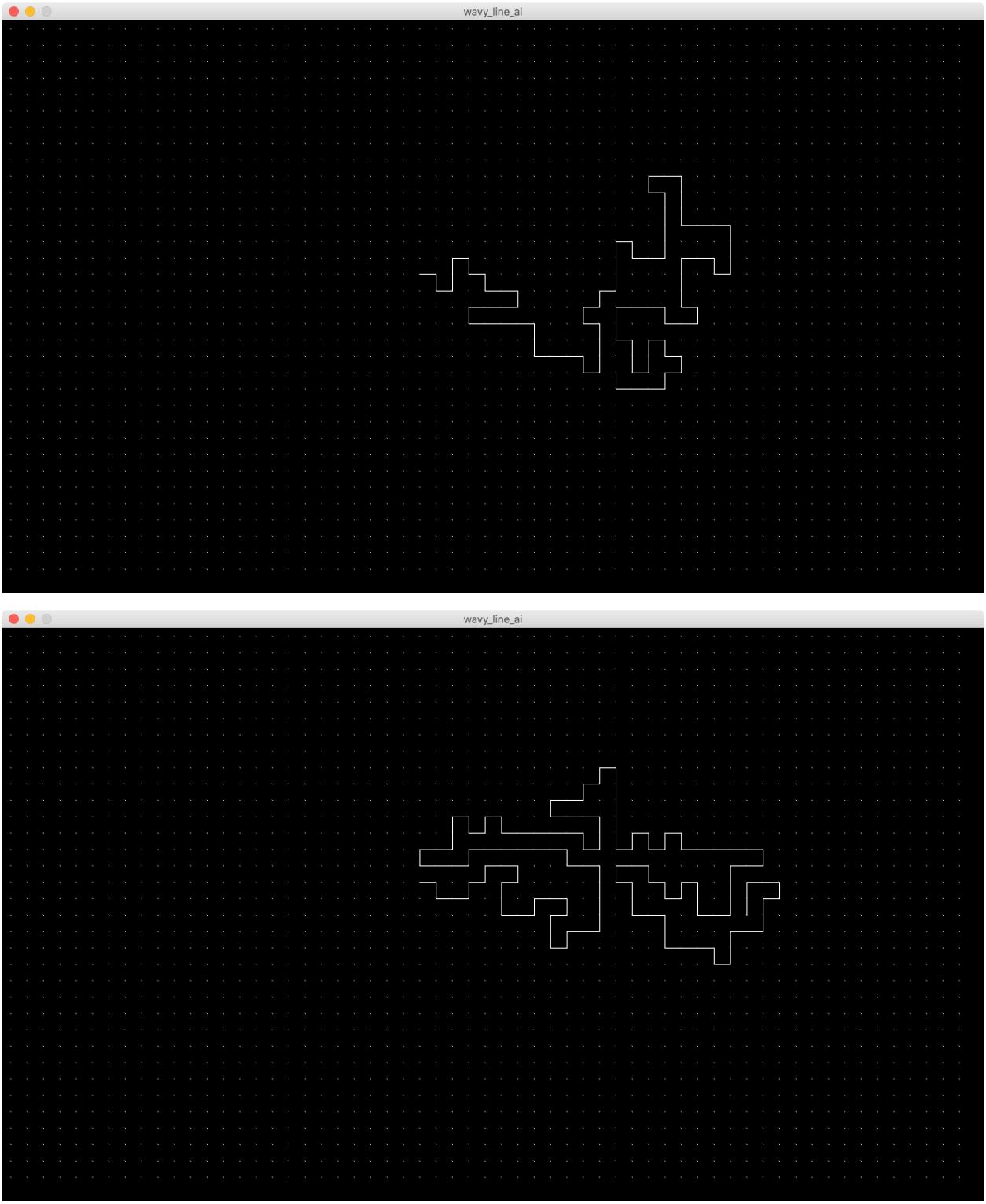

Figure 9: Cost equal to the distance from the starting point (near center) multiplied by 0.5, *plus the distance to the nearest canvas edge multiplied by 0.5,* plus a random number in the range of the average of the width and height of the grid divided by 30; search depth of 2.

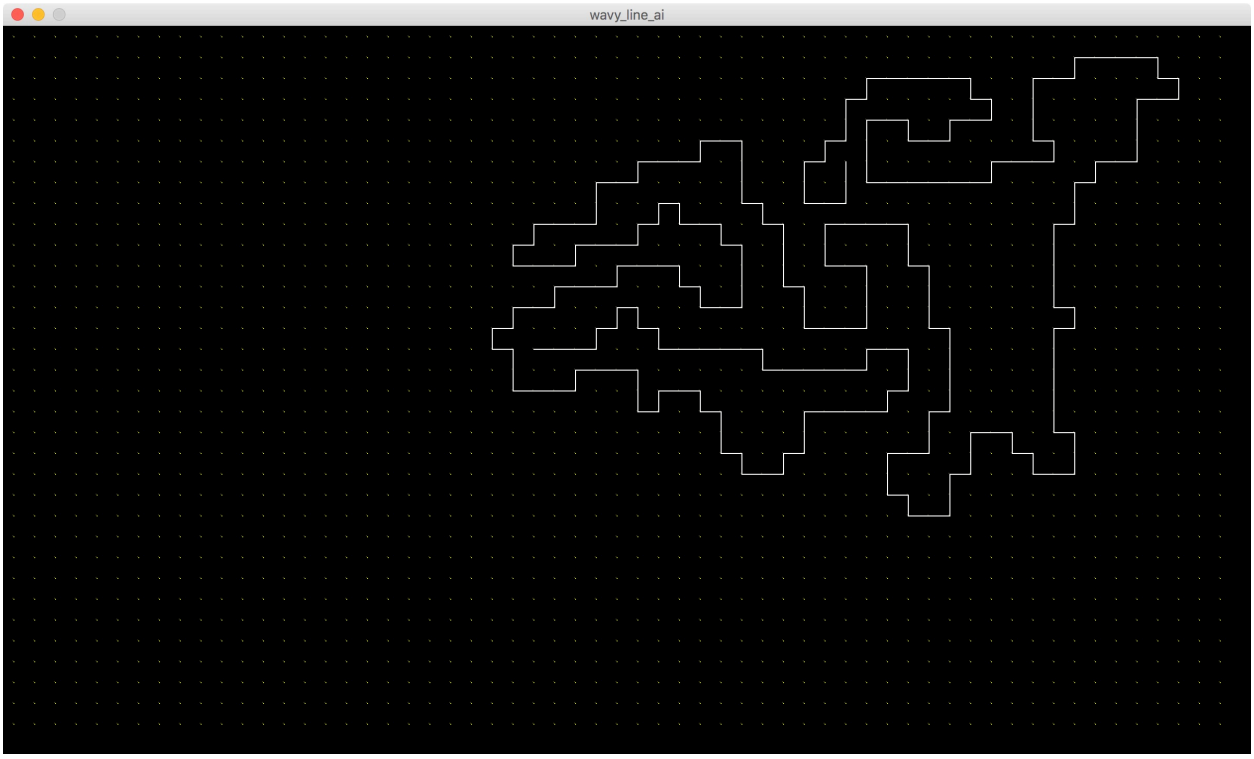

Figure 10: Cost equal to the distance from the starting point (near center) multiplied by 0.5, plus the distance to the nearest canvas edge *multiplied by 0.4, plus a cost for each visited point surrounding the successor state,* plus a random number in the range of the average of the width and height of the grid divided by 30; search depth of 2.

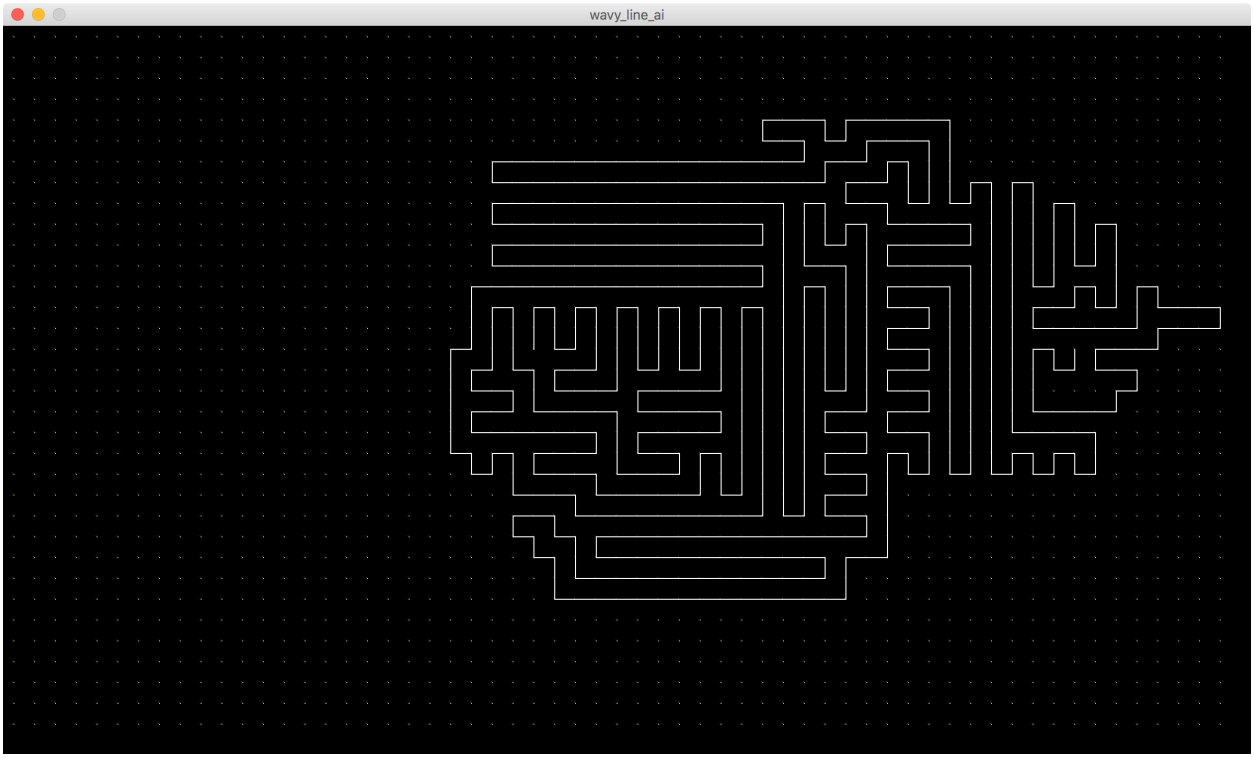

Figure 11: Cost equal to the distance from the starting point (near center) multiplied by 0.5, plus the distance to the nearest canvas edge multiplied by 0.4, *plus the average of the width and height of the grid multiplied by 2 if the successor state has three or more visited points surrounding it,* plus a random number in the range of the average of the width and height of the grid divided by 30; search depth of 2.

Figure 12: Cost equal to the distance from the starting point (near center) multiplied by 0.5, plus the distance to the nearest canvas edge multiplied by 0.4, plus the average of the width and height of the grid *multiplied by 1.75* if the successor state has three or more visited points surrounding it, plus a random number in the range of the average of the width and height of the grid divided by 30; search depth of 2.

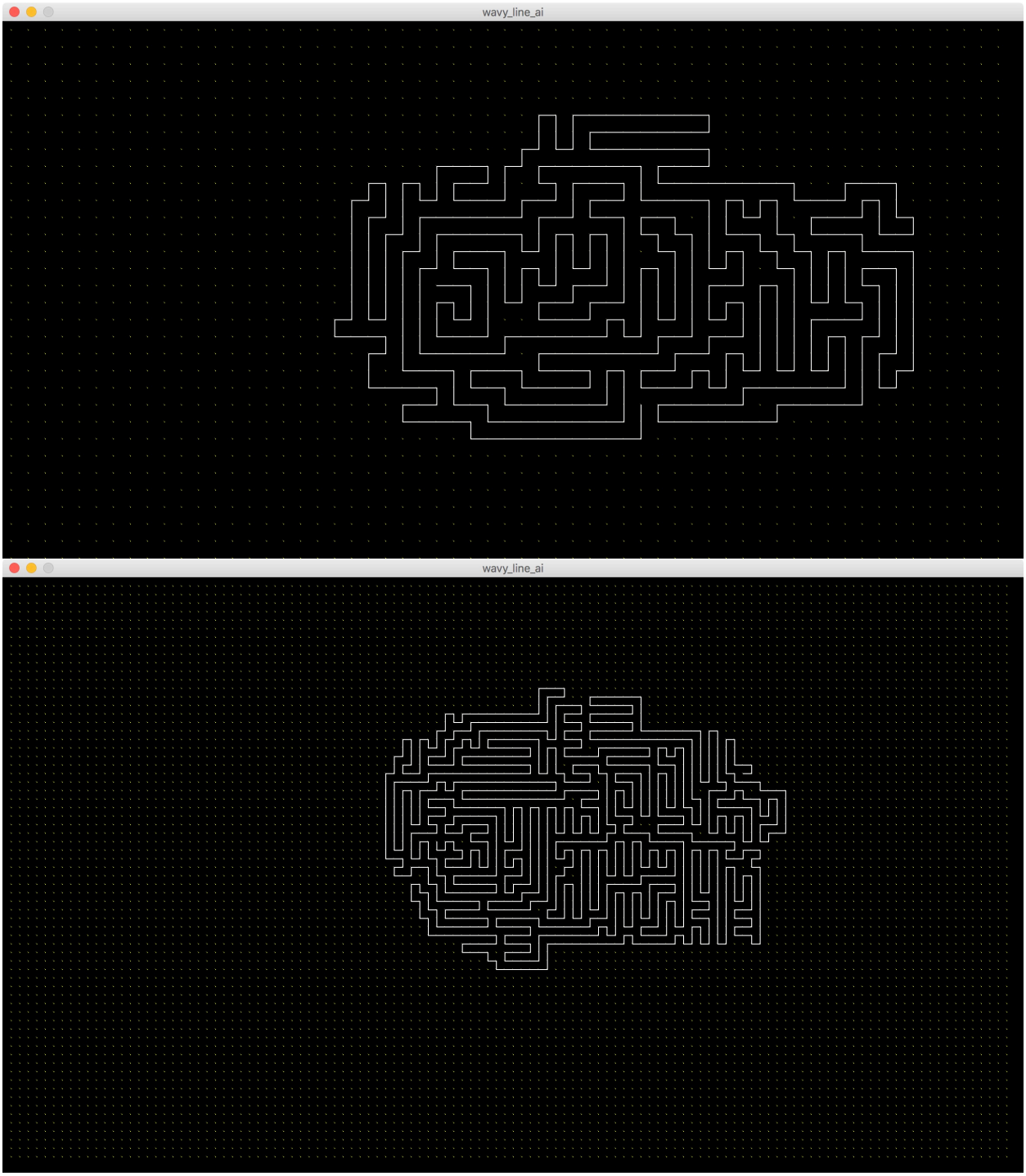

Figure 13: Cost equal to the distance from the starting point (near center) multiplied by 0.5, plus the distance to the nearest canvas edge multiplied by 0.4, plus the average of the width and height of the grid multiplied by 1.75 if the successor state has three or more visited points surrounding it, plus a random number in the range of the average of the width and height of the grid divided by 30; *search depth of 3*.

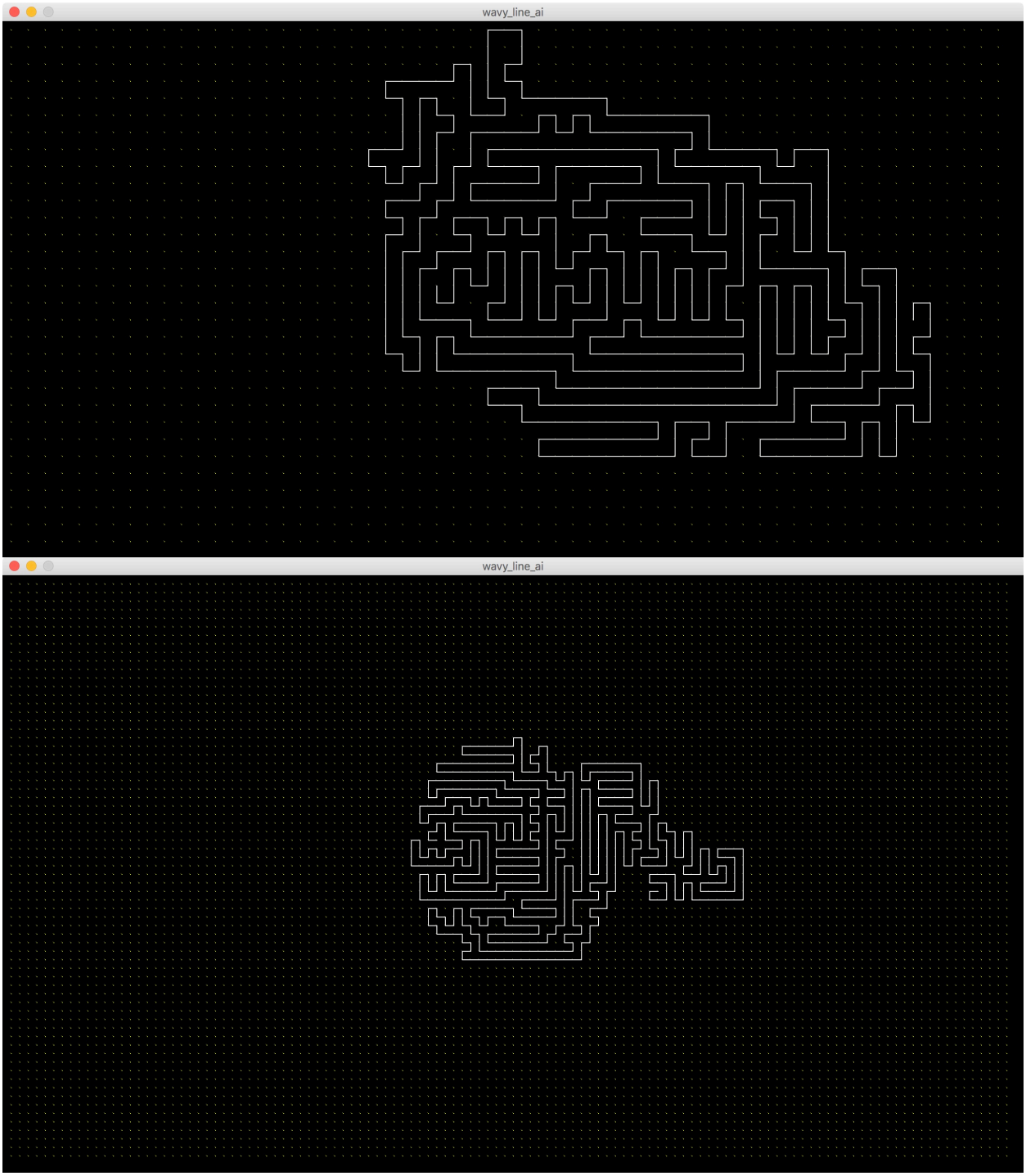

Figure 14: Cost equal to the distance from the starting point (near center) multiplied by 0.5, plus the distance to the nearest canvas edge multiplied by 0.4, plus the average of the width and height of the grid multiplied by 1.75 if the successor state has three or more visited points surrounding it, plus a random number in the range of the average of the width and height of the grid divided by 30; *search depth of 4*.

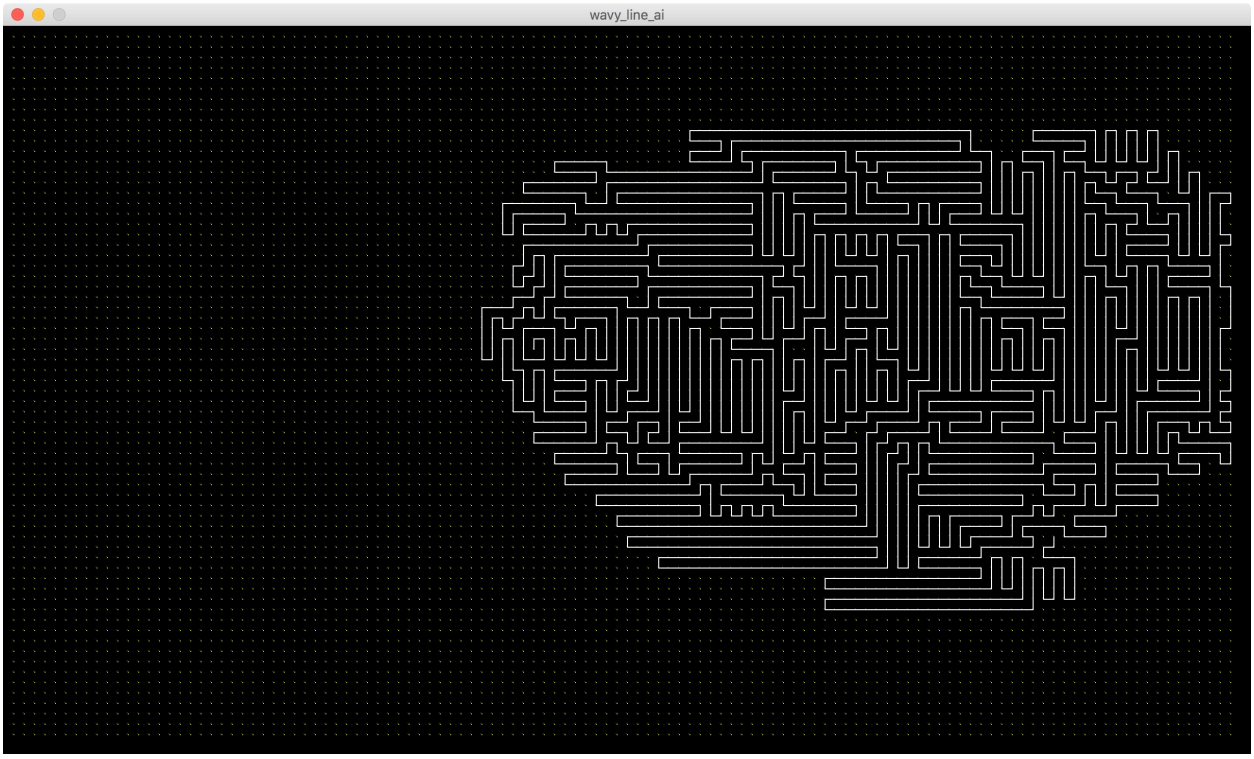

Figure 15: Cost equal to the distance from the starting point (near center) multiplied by 0.5, plus the distance to the nearest canvas edge multiplied by 0.4, plus the average of the width and height of the grid *multiplied by 2.25* if the successor state has three or more visited points surrounding it, plus a random number in the range of the average of the width and height of the grid divided by 30; search depth of 4.

Figure 16: Cost equal to the distance from the starting point (near center) multiplied by 0.5, plus the distance to the nearest canvas edge multiplied by 0.4, plus the average of the width and height of the grid *multiplied by 4* if the successor state has three or more visited points surrounding it, plus a random number in the range of the average of the width and height of the grid divided by 30; search depth of 4.

Figure 17: Same conditions as figure 16, but on a larger grid.

Figure 18: Cost equal to the distance from the starting point (near center) multiplied by 0.5, plus the distance to the nearest canvas edge multiplied by 0.4, plus the average of the width and height of the grid *multiplied by 6* if the successor state has three or more visited points surrounding it, plus a random number in the range of the average of the width and height of the grid divided by 30; search depth of 4.