Assignment 7

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In an empty room, the following strategy might (sometimes) be reasonably effective:

1. From the initial state, move forward until you hit a wall.
2. Turn randomly left or right.
3. Move forward until you hit a wall.
4. Turn left if the wall is on your right side, and vice versa.
5. Repeat the pattern from 3. until you find the square in front of you to be painted.
6. Turn away from the wall and move forward until again you encounter a painted square in front of you.
7. If there is a painter square either to the left or right, turn away from it. If neither is painted, then turn randomly left or right.

Of course, without considering more cases, the effectiveness of this strategy is highly dependent on the starting position; if the painter gets *really* lucky and starts out in a corner, it will result in 100% coverage. Even with just 54 states and 4 actions, it is very difficult to come up with good heuristics, but I suppose that is the whole point of machine learning...

I have implemented a basic selection algorithm with single point crossovers and random mutations as follows:

1. Let C_n be the set of chromosomes in generation n, and $f : C \to (0, 1],\ c_i \mapsto \bar{s}_i$ the fitness function.
2. Sample c_1, c_2 randomly without replacement, using $\left(\sum \bar{s}_i\right)^{-1} f(C)$ as the probability distribution.
3. Perform uniform single point crossover between c_1 and c_2, and mutate one randomly selected gene in each resulting chromosome with probability p_m.
4. Repeat from 2.

Staring with 50 random chromosomes and evolving them over 200 generations, running 50 simulations with each chromosome in each generation, I have plotted the average fitness and a measure of genetic diversity. The results with empty and furnished rooms are shown in fig. 2 and fig. 3 respectively. The mutation rate p_m was set to 0.01.

Genetic diversity in a set C of chromosomes is measured as the average of the total number of positions at which each chromosome differs from the other chromosomes, divided by the maximum possible value:

$$\frac{1}{n}\sum_{c_i \in C}\left[\frac{1}{g(n-1)}\sum_{c_j \in C} c_i \neq c_j\right]$$

where $n = |C|$ and g is the length of the gene sequence.

The overall inverse correlation between average fitness and genetic diversity as the model converges is pretty clear. However, we also see at some points that small jumps in fitness coincide with small jumps in diversity. This might indicate points where random mutations lead to strategic innovation. If I had had time, I would have liked to play around with the mutation rate to see how it affects this measure of diversity.

Fig. 1 illustrates the increased complexity when adding furniture to the room. The highest score in the best generation was about 0.58 with furniture, compared to 0.772 in the empty room.

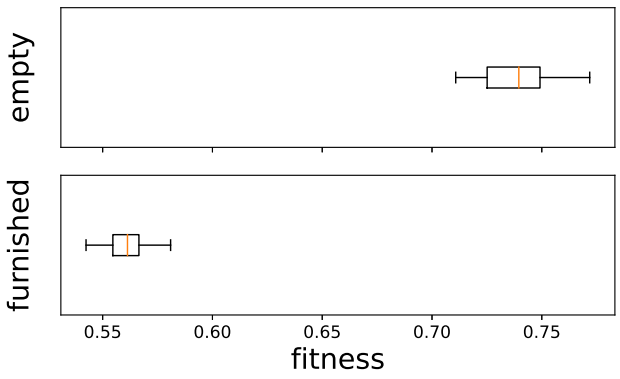

Figure 1: *Min, max, median and quartile fitness of the best performing generation*

The best performing generations with empty and furnished rooms were 198 and 109 respectively.

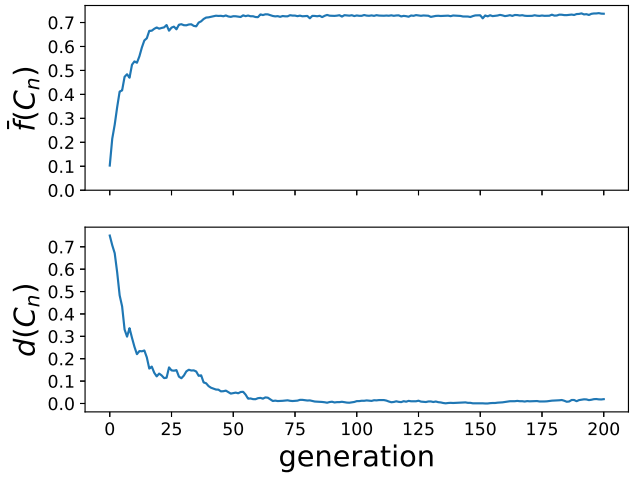

Figure 2: *Average fitness and genetic diversity with empty room*

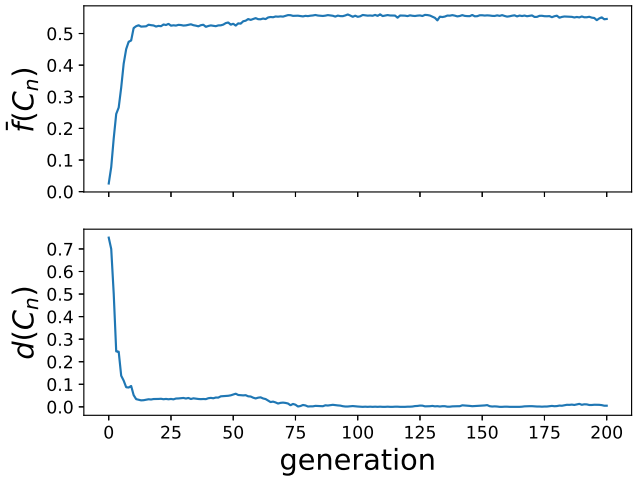

Figure 3: *Average fitness and genetic diversity with 10 randomly generated furnished rooms (100 furniture squares)*

Comparing the strategies in fig. 4 and 5, it seems that the empty-room painter has developed a kind of compound strategy that revolves around circling outward for as long as possible and then going back and forth, hugging the already painted area. This is not unexpected. The starting and ending positions are marked with ∘ and × respectively.

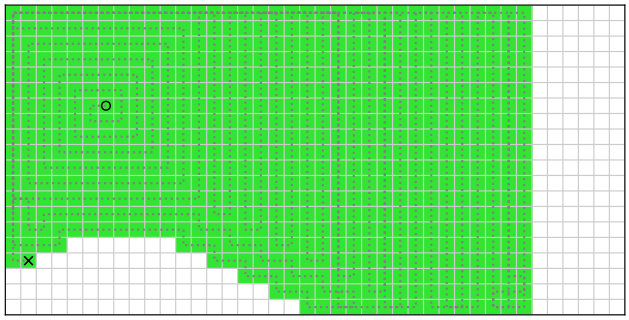

Figure 4: *Example trajectory of best performing empty-room painter.*

The furnished-room painters strategy seems to be more about moving along as far as possible turning as necessary. It is difficult to discern any master plan here, other than *'keep moving along and try to avoid painting twice'*.

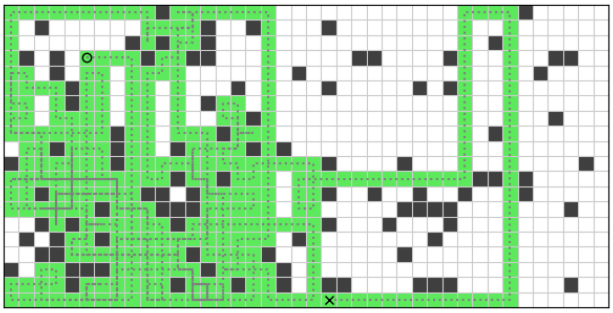

Figure 5: *Example trajectory of best performing furnished-room painter.*

From the best generation evolved with the empty room, I took the chromosomes with an average fitness at or above the 95:th percentile, and evaluated those over 100 simulations on 50 randomly generated furnished rooms. The average score was about 0.208. The corresponding evaluation of the best chromosomes from the furnished room on an empty room yielded an average score of about 0.66. The discrepancy is not surprising, since basic sensible behavior such as turning away from obstructions and not painting the same area twice applies in both an empty room and a furnished one, whereas all the tricky cases from a furnished room are completely new to the empty-room painter.

Fig. 6 and 7 show examples of how the best performing chromosome from the empty room fails when it gets itself stuck in between furniture. Such cases, when both the front, left and right squares are impenetrable, cannot occur in an empty room. Thus the painter has no strategy to deal with them.

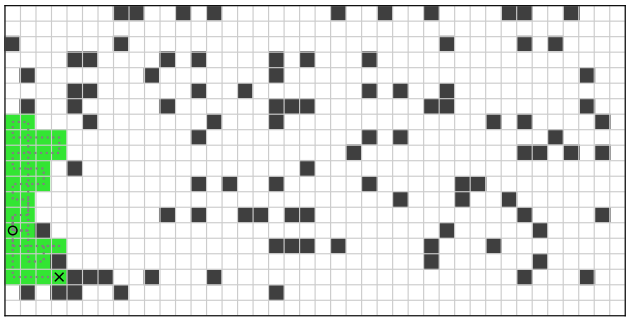

Figure 6: *Example trajectory of best performing empty-room painter in a furnished room.*

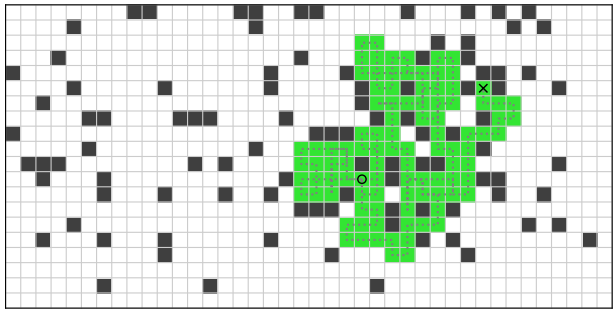

Figure 7: *Example trajectory of best performing empty-room painter in a furnished room.*

A Code

All the code can be checked out at
`https://github.com/Fredrik-M/BERV-MCS/tree/master/MCS/lab_7`