RBE550 - Wildfire Homework

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The wildfire simulations were done in Python using Pygame and additional Libraries such as Numpy, time, and Math. Two versions of the simulation were made. One version is a combinatorial planner that uses a path planning algorithm, A*. The other version is a sampling based planner that uses a Probability Roadmap (PRM) path planner to navigate the obstacle field and a simple A* plath planner to plan local paths between nodes in the PRM as described in [LaV06]. For the fire truck in the simulation, the truck's movement was restricted by its holonomic constraints. As such, each positional node only has six options, where the truck's turning radius is restricted to either 0m or 15m, and its drive is either forwards or backwards as seen in Fig. 1. The A* path planner does provided efficient routes, but heuristic costs of moving straight and turning do not differ so many of the paths have some unnecessary zig-zaging. While each version of the simulation is shown in the following, please refer to the video accompanying this report for a visualization of the path planning implementation.

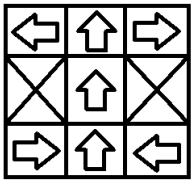

Figure 1: Firetruck Node Expansion (6 possibilities from center position)

Figure 2 shows summed (or averaged) metrics across both simulations (each repeated 5 times with varying obstacle fields). The initial metric reflects the percentage of surviving shrubbery out of all of the shrubbery. Unfortunately, between the fire spreading and the arsonist lighting new fires, no shrubbery remained intact for any of the simulations (A* or PRM) and hence the metric was repeatedly 0. For the second metric, the average extinguished-to-burned ratio was taken across all five simulations for each version. The A* had consistently higher extinguish rates then the PRM. Lastly, the computation time was recorded and summed across all five simulations for each version. In this metric, the PRM used significantly less processing and planning time then A*, but at the cost of more burned shrubbery. Details on each method are described in the following sections.

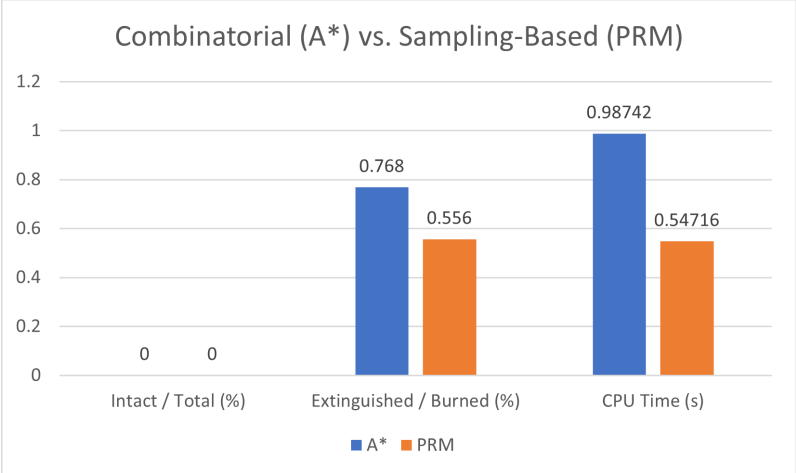

Figure 2: Summed (or Averaged) Results

Combinatorial Path Planner

The A* Path Planner provides a simple and direct path for the firetruck thanks to the simplification of state vectors shown in Fig. 1. As a derivative of Dijkstra's method, A* uses more advanced heuristics to always guide the truck in an efficient path. Unfortunately, I forgot to add in heuristic cost for turning, so while some paths may look inefficient, they are still adequate paths. An example path is shown in Figure 3.In this example, the truck is being driven from the extinguished fire on the left to the extinguished fire on the right. Take note that the diagonal lines are not true to the path but are indicative of when the truck moves from its center position to a far corner position as shown in Fig. 1. The combinatorial method, A*, proved to be more effective then PRM as it effectively extinguished over 80% of the fires in 4 out of the 5 trial runs. The downside to this method, its processing time, was greater then PRM's processing time, but at the cost of higher fire extinguishing efficiency.

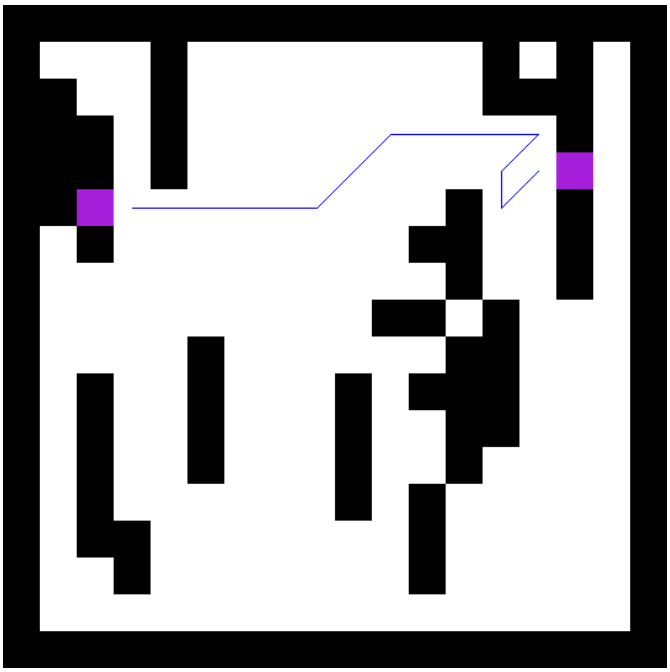

Figure 3: A* Driven Path

Sampling Based Path Planner

For the Probabilistic Roadmap (PRM) method, several configurations in free space were randomly chosen as acting nodes. Using a local planner, these nodes were connected to form a "roadmap" of the obstacle field. As an example, Figure 4 shows the nodes in the PRM of a particular simulation case. Twenty-one nodes are present (the green node is the initial starting point) and a map was built from these nodes. Unfortunately, the trucks access to new fires is limited by the amount of accessible nodes in the PRM. As such, several sections of the obstacle field are unreachable, leading to unquenchable fires and lost shrubbery.Additionally, this caused the extinguished-to-burned ratio to be significantly lower then the other method. The one advantage to this method is that it did save time in execution. Processing time was reduced but without additional nodes in the "roadmap", the method was not as efficient as the A* planner.

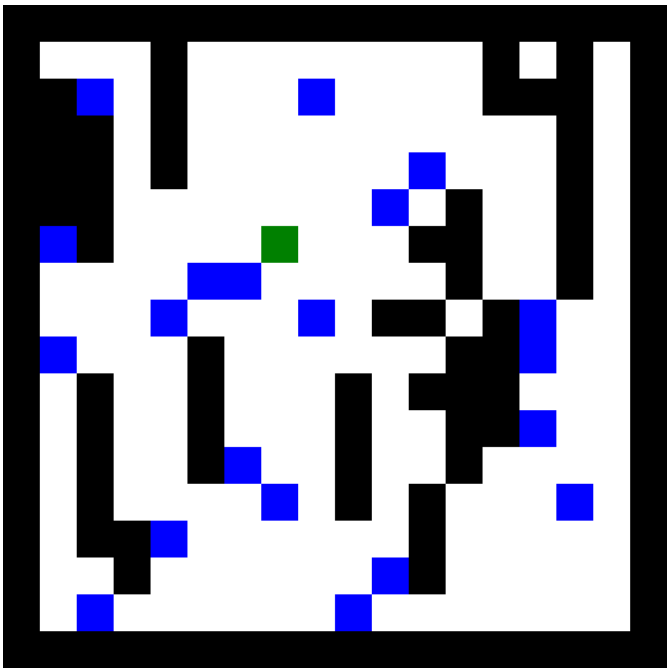

Figure 4: Probability Road Map (PRM)

Appendix

Both Pythons codes for the A* Wildfire Simulation and the PRM Wildfire simulation are included in this homework's accompanying folder. Additionally, pdf's of the code are provided.

References

[LaV06] Steven LaValle. *Planning Algorithms*. Cambridge University Press, 2006. ISBN: 9780511546877. URL: %7Bhttps://doi-org.ezpv7-web-p-u01.wpi.edu/10.1017/CBO9780511546877%7D.