

Traversing and Expending Limited Resources in Treacherous Environments: a Probability-Based Approach

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Motivation: In search-and-rescue, disaster recovery and other similar situations, the successful use of robots (including those yet to be developed) depends in large part on their ability to traverse unpredictable, often dangerous environments without human assistance and, in certain contexts, on their prudent use of finite resources (e.g. distributing a limited supply of first-aid packages, or perhaps using a built-in reservoir of fire extinguisher for use in key areas, such as areas with people in imminent danger of catching fire) for maximum efficiency and/or minimizing risks of loss.

There have been studies that explore navigation by service robots in pre-defined environments,¹ efficiency of different robot designs at performing various disaster recovery tasks in real-life settings,² the parsing of natural language directions for pathfinding,³ and navigation in populated urban settings aided by interaction with passersby.⁴ The scope of this study will instead focus on a more restricted 2-D setting, and will gauge the effectiveness of a simulated robot in getting to the desired destination by traversing environments filled with traps (which the robot must avoid) as well as other dangers (which the robot may choose to either avoid or, if possible, expend its finite resources to eliminate), based on certain cues in the environment which the robot is able to sense.

That the robot be able to autonomously sense and make these decisions is important because human intervention / direction may not be available in certain rescue operations, and also because time is often of the essence, meaning the robot may need to balance the benefits of an aggressive strategy (i.e. spend resources as soon as possible and try to take the shortest route, even at the cost of increased risk of failure) with its counterpart (i.e. conserve resources whenever possible, and minimize danger of falling into a trap from which it cannot recover, resulting in automatic failure).

Proposed Methodology: This will be a simulated experiment in a semi-randomized 2D environment, without a corresponding hardware component. For simplicity, I plan to break up the 2D environment into discrete grids, some of which are filled with fatal traps (which must be avoided altogether) and some with other dangers (which may be dealt with via the robot's use of resources, assuming the resource hasn't been exhausted). I'm thinking of assigning at least two goals (primary and secondary) to the robot, respectively: 1) get to the destination without "dying"; and 2) do so in the least number of time-steps as possible. I may have the robot start at either a fixed or a random grid (which will always be a safe, non-destination grid). The robot will have no idea where the destination is, and will have to rely on cues from the surrounding environment to plan its next move. It will also have to judiciously use its

¹ See, e.g., Azenkot, et. al. [Enabling Building Service Robots to Guide Blind People](#) (2016).

² Yanco, et. al. [Analysis of Human-Robot Interaction at the DARPA Robotics Challenge Trials](#) (2015).

³ Kollar, et. al. [Toward Understanding Natural Language Directions](#) (2010).

⁴ Wollherr, et. al. [The ACE Project – Mobile Robot Navigation in Highly Populated Urban Environments](#) (2009)

limited resources to deal with certain dangers in the environment. Multiple trials will be recorded, with the environment being randomized each time.

The exact details regarding the dangers, environmental cues and robot's resources are still being developed, but they will likely involve something similar to the following: the dangers might consist of pits, fires or other hazards, environmental cues might be in the form of scents temperature readings or the like, and the robot's resources might be some type of disabler with limited "ammo". The robot will consider information about where it has travelled combined with these environmental cues to probabilistically determine its move that will hopefully minimize risk of failure and maximize efficiency.

Proposed Evaluation: Multiple iterations of the experiment will be run, and at least two objective measures will be taken: the rate of success (in terms of reaching the destination), and the number of time-steps needed to get to the destination in the event of a successful run. Additionally, I would like to experiment with slightly different variations of the robot (in terms of whether it implements an "aggressive" or more "conservative" strategy, as discussed on the previous page) and compare their performances in terms of the aforementioned measures. My hypothesis at this time is that employing a more aggressive strategy will decrease the rate of success, but increase efficiency for those times when the robot is successful.

Finally, and this is sort of a long shot (esp. if I end up working on this by myself), but I may look into performing some type of survey with human subjects in which they manually control the robot, and compare their performances with those of the automated robot. I'm also curious about what strategies the humans would employ if told that this is a simulated rescue-operation situation as opposed to being told that this is just a simple game. However, doing all this may end up being too time-consuming and introduce too many variables, diluting the focus of the study...

Proposed Grading Rubric:

System Component	Grade %
Implementation of the software is largely as described	50%
Hypothesis is clearly presented and the experiment (notwithstanding its artificial constraints) either confirms or denies the hypothesis	25%
The findings of the experiment are presented clearly and in an accessible manner	25%
Human survey is performed and the results outlined	???