Algorithms for Robotics

or: An Unofficial Companion Guide to the Georgia
Institute of Technology's **CS7638**: *Artificial Intelligence for Robotics*

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(*Draft*)

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Preface

> *I read that Teddy Roosevelt once said, "Do what you can with what you have where you are." Of course, I doubt he was in the tub when he said that.*
>
> — Bill Watterson, *Calvin and Hobbes*

Before we begin to dive into all things robotics, here are a few things I do in this notebook to elaborate on concepts:

- An item that is **highlighted like this** is a "term;" this is some vocabulary or identifying word/phrase that will be used and repeated regularly in subsequent sections. I try to cross-reference these any time they come up again to link back to its first defined usage; most mentions are available in the Index.
- The presence of a **`TODO`** means that I still need to expand that section or possibly to mark something that should link to a future (unwritten) section or chapter.
- An item in a maroon box, like. . .

  Boxes: A Rigorous Approach

  . . . this example, often represents fun and interesting asides or examples that pertain to the material being discussed. They are largely optional, but should be interesting to read and have value, even if it's not immediately rewarding.

- An item in a blue box, like. . .

  Quick Maffs: Proving That the Box Exists

  . . . this example, is a mathematical aside; I only write these if I need to dive deeper into a concept that's mentioned in lecture. This could be proofs, examples, or just a more thorough explanation of something that might've been "assumed knowledge" in the text.

Introduction to Probability

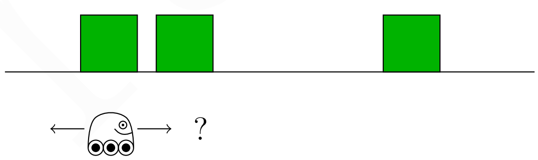
> *73.6% of all statistics are made up and 90% of quotes are misattributed.*
>
> — Abraham Lincoln, *The Internet*

We'll open our discussion of algorithms for robotics applications by discussing probability. However, we'll take an example-based approach, working up to a method for **localization** using basic probability theory.

Localization is the need to determine where you are in the world. This is an important skill for humans and robots alike and can be achieved to varying degrees of success; some of us just have a "bad sense of direction." Given a layout of some area, a robot should be able to determine where it is based on sensor readings or other measurements.

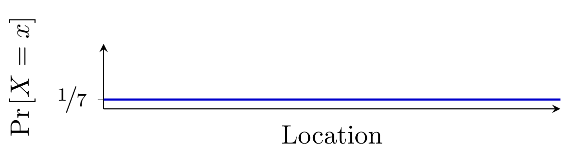
1.1 Localization

Suppose a robot is in a simple hallway with three doors:

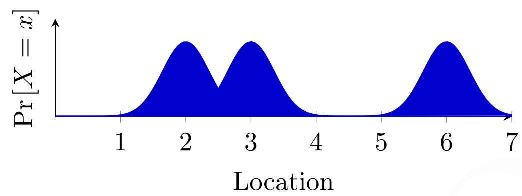


We see that it's in front of the first door, but the robot doesn't know that. Instead, it has a **probability distribution** representing its confidence at each point in the hallway. For the sake of simplicity, suppose we discretize the hallway into 7 spots; then, we can say that X represents the distribution of probabilities for each position in the hallway. Since the robot knows nothing about its location yet, this is a **uniform distribution**:

$$X = \{1/7, 1/7, 1/7, 1/7, 1/7, 1/7, 1/7\}$$

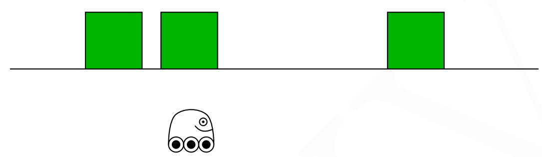


For the robot to increase its certainty about the situation, it needs to perform a *measurement*. The distribution before the measurement is called the **prior** or **belief** distribution; afterwards, it's called a **posterior**. Suppose the robot measures, with some doubt, that it's in front of a door. Naturally, we'd expect its location probability distribution to now peak at doors.

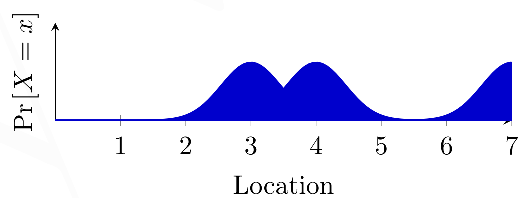


The reason why we don't have hard spikes is because of uncertainty in our measurement: sensors are never perfect, so we need to take into account the fact that it's possible we measured "door" when there in fact wasn't one.

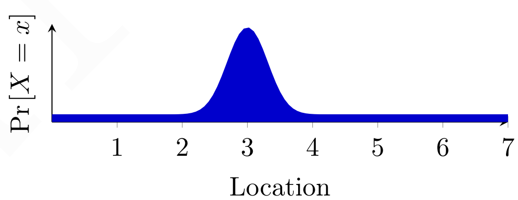
We continue iterating on the localization process by doing this again after a movement. Suppose we move one step to the right:



Our prior (pre-measurement) belief distribution should shift accordingly, but it also flattens out a bit because again, movements are not perfect, so we need to take into account the possibility of not moving exactly 1 unit.



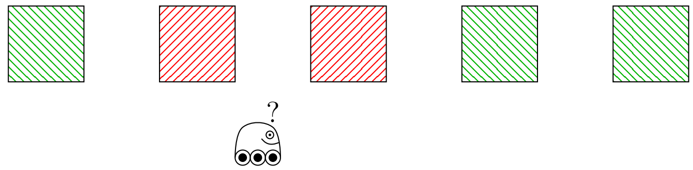
Our robot takes a measurement and determines it's in front of a door again. Well, there's only one place in our map in which you can measure a door, move right, then *still* measure a door, and our posterior distribution reflects this:



If you followed this logic, you understand probability and localization!

1.2 Probability

With this intuition under our belt, let's make things a little more concrete. We'll work with a simpler example, keeping our little robot friend around. We have a map of five tiles, each of which is either red or green.



To be continued...

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