

# Discrete Probability

## The Big Ideas:

- We want to model uncertainty, so we can build systems that address it, and are robust against it
- Probability can be used to model uncertainty. Joint and conditional distributions represent relationships between information
- Manipulating these distributions and relationships using the calculus of probability allows us to model uncertainty over the passage of time.
- Stochastic State Machines are state machines that do not have directly observable state; instead, it has a (possibly different) distribution over possible states at each timestep.
- State Estimation uses the observations and actions of a system to estimate the current state of that system in its environment.

## Introduction

Last week, we concluded the circuits module with Thevenin equivalence and superposition. This week, we switch gears entirely; we've been talking about how to analyze and design systems, but we haven't talked about how to make systems robust under uncertainty. In fact, we haven't even talked about how to model uncertainty.

In this module, we'll address the problem that systems we design may have to operate under uncertainty, and that we may want those systems to be able to search the world for possible solutions to problems. We'll introduce the basics of probability and search, and apply those concepts to our design challenges.

## Vocabulary

In order to engage the material, be able to communicate about the topic with others, and in particular ask questions, we encourage familiarity with the following terms:

### Theory

- Probability theory
- Event
- Atomic event
- Mutually exclusive
- Factored event
- Collectively exhaustive
- Sample space  $U$
- Random variable
- Probabilistic Axioms:
  - Non-negativity
  - Scaling/Normalization
  - Additivity
- Distribution

- Conditional distribution/normalization
- Bayes' rule
- Bayesian update
- Joint distribution
- Marginalization
- law of Total Probability
- Hidden Markov Model
  - Initial distribution
  - State transition model
  - Observation model

## Practice

- `module dist`
  - `class DDist`
  - `class MixtureDist`
  - `bayesEvidence`
  - `totalProbability`
  - `incrDictEntry`
- Observation update
- Transition update
- noise model
- Delta distribution
- Square distribution
- Uniform distribution

## Check Yourself

Theory: you should understand:

- Basic probability: the axioms, different laws, and the difference between joint and conditional distributions
- The general idea of State Estimation

Practice: you should be able to:

- Use the 6.01 software to create and manipulate probability distributions
- Marginalize, Normalize, and Bayesian Update the appropriate distributions

## Resources

Theory:

Chapter 7 of the 6.01 Course Notes is the official assigned reading for this week.

Practice:

The 6.01 Software Documentation will come in handy, in particular modules `dist` and `ssm`.

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6.01SC Introduction to Electrical Engineering and Computer Science  
Spring 2011

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