ECE 313 – Section B (R. Iyer)

- **Meeting time and Place:**
  - **11:00 - 12:20 Tuesday and Thursday**
  - **1304 Siebel Center for Computer Science**
- **Instructor:**
  - **Professor Ravi K. Iyer**
  - **Office: 255 Coordinated Science Lab (Phone: 333-9732)**
  - **Email: rkiyer@illinois.edu**
  - **Office Hours: 12:30pm-2:00pm, Tuesdays and Thursdays after class and by appointment**
- **Teaching Assistant:**
  - **Homa Alemzadeh**
  - **Office: 246 Coordinated Science Lab**
  - **Email: alemzad1@illinois.edu**
  - **Office Hours: TBD**

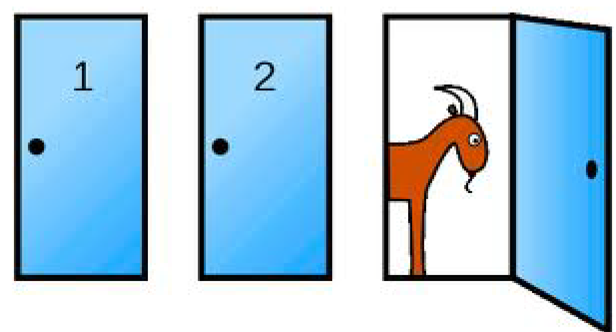
General Information

- **Text Book:**
  - **Sheldon Ross, *A First Course in Probability*, 9th edition, Pearson, 2012.**
- **Further Reading and Problems:**
  - **Sheldon M. Ross, *Introduction to Probability Models*, 10th Edition, Academic Press, 2010 (Chapters 1-5).**
- **Class Website:**
  - **http://courses.engr.illinois.edu/ece313/SectionB/**
  - **Please check the class web site for all announcements (e.g., homework and projects, corrections to homework problems) on a regular basis.**
  - **Lecture notes will be posted on the class web site weekly in pdf format under Lectures.**

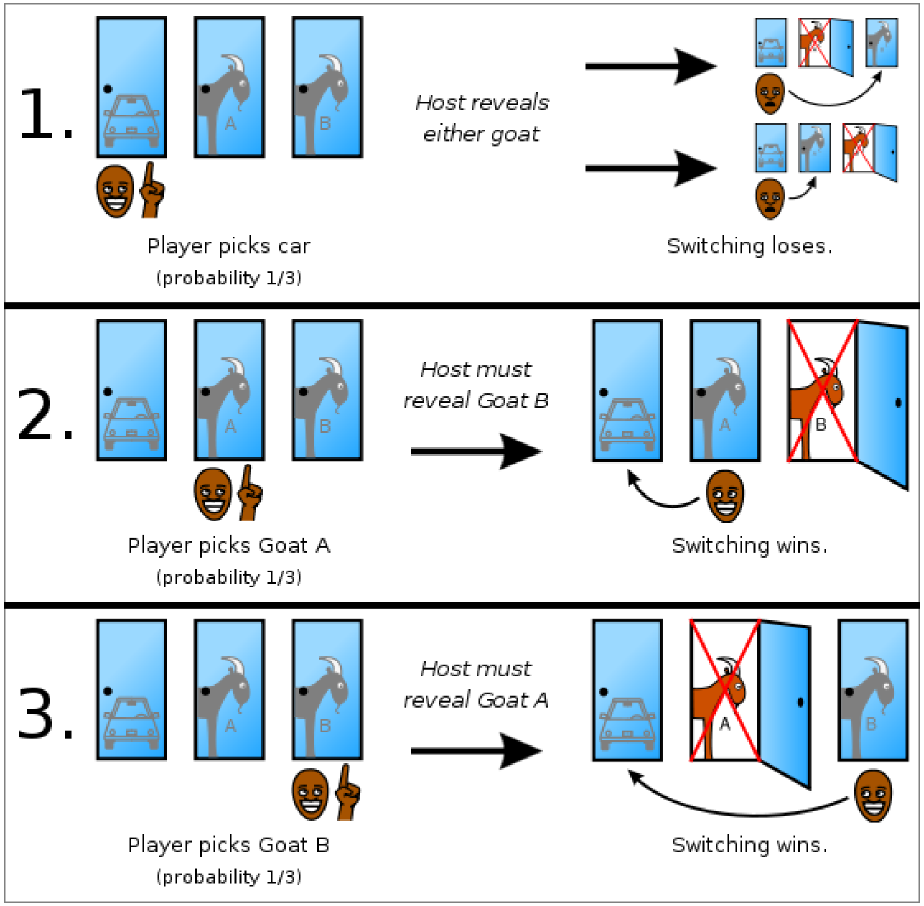
Monty Hall Problem

- The "Let's Make a Deal" game.
- Popular game show in the 1970's.

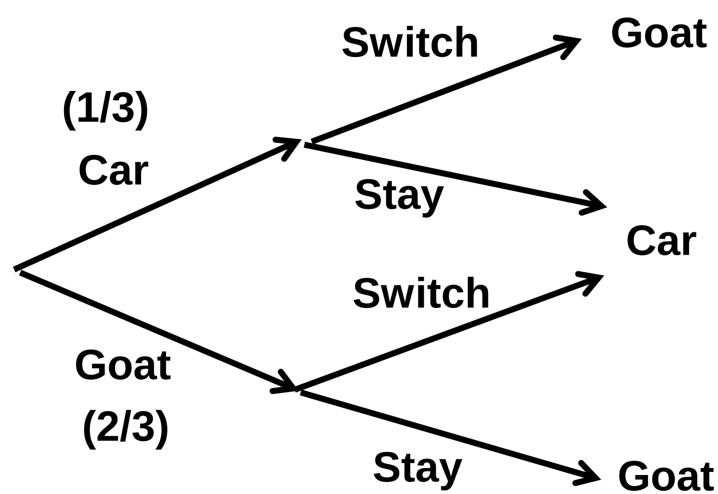
- Suppose you're you're given the choice of three doors: Behind one door is a car; behind the others, goats. You pick a door, say No. 1, and the host, who knows what's behind the doors, opens another door, say No. 3, which has a goat. He then says to you, "Do you want to pick door No. 2?" Is it to your advantage to switch your choice?



Monty Hall Problem



Probability Tree Diagram



More Reading at: http://en.wikipedia.org/wiki/Monty_Hall_problem

Grading Policies

- **Homeworks will be handed out or posted on the class website under <u>Problem Sets</u> weekly on Thursdays and will be due the following Thursday before the class.**
  - **<u>No late homework will be accepted.</u>**

- **There will be three mini-projects and a final project to provide hands-on experience with applications of probability in analysis of computer systems.**
  - **Project descriptions and due dates will be posted on the class web site under <u>Student Projects</u>.**
  - **Please check the <u>Resources</u> for tutorials and hints related to projects.**

- **Project: 20%**
  Final: 35%
  Homework: 20%
  Midterm Exam: 20%
  Class Participation: 5%

Course Outline

I. Introduction

- Motivation
- Course objectives/outline
- Probability theory, models and their uses, examples
- Definitions: sample space, elements, events
- Algebra of events (union, intersections, laws/axioms)
- Probability axioms and other useful relationships
- Basic procedure for problem solving and an example
- Combinatorial problems
- Introduction to measurements

- **Mini Project 1: Failure data analysis for Software-as-a-Service (SaaS) business application**

Course Outline

II. Conditional Probability and Independence of Events

- Definitions of conditional problems, multiplication rule
- Example
- Independent events and associated rules
- Application to reliability evaluation:
  - Series systems
  - Parallel redundancy
  - Example: series-parallel system evaluation
- Theorem of total probability, Bayes' Formula
- Examples:
  - Error-prone communication channel
  - Non-series-parallel system
  - Application to system reliability

- Mini Project 2

Course Outline

III. Bernoulli Trials

- Triple Modular Redundant (TMR) system with voter
- Multiple failure modes

IV. Random Variables (Discrete)

- Introduction: random variables and associated event space
- Probability mass function
- Special discrete random variables and their distribution:
  - Binomial
  - Geometric
  - Poisson
  - Uniform
- Application to program/algorithmic analysis
- Performance measurements using SPEC and other benchmarks

Course Outline

V. Random Variables (Continuous)

- Mean, median, variance models
- Distribution function, probability density function
- Exponential distribution
- Application to reliability evaluation
- Memory less property and simple Markov model
- Other important distributions: Normal, Hyper/Hypo Exponential, Weibull
- Expectations:
  - Mean, median, variance, covariance, correlation
  - Expectation of function of random variables
  - Mean time to failure, Failure rates, and Hazard function
  - Conditional expectation
  - Inequalities and limit theorems
  - Fault coverage and reliability

- Mini Project 3

Course Outline

VI. Joint Distributions

- Joint CDFs and PDFs
- Jointly Gaussian random variables
- Functions of many random variables
- Law of large numbers
- The Central Limit Theorem

- **Final Project**

VI. Summary and Overview

Introduction: Some Basic Concepts

ECE 313

Probability with Engineering Applications

Lecture 1

Professor Ravi K. Iyer

University of Illinois

Motivation

- Examples of the need for probability and statistics in computer engineering
  - Tools to analyze computer systems and the algorithms that execute on them (worst case vs. average behavior)
    - distribution of inputs
    - arrival patterns of tasks
    - computer resources (CPU, memory, I/O, network)
    - distributions of resource requirements of jobs
    - effect of hardware/software failures (random phenomena, environmental effects, software failures, aging)
- Theory of probability is important for evaluating the system design and its performance using measures like:
  - throughput
  - response time
  - reliability, availability

Motivation (cont.)

- A popular evaluation techniques
  - performance benchmarks - (SPEC, LINPACK
  - parallel benchmarks (NAS, Livermore Loops, PARKBENCH)
  - Possible benchmarks for Security, Resilence, and Fault Tolerance
- Experimental analysis
  - Need to specify various probability distributions
  - where do these distributions come from?
  - collect data during actual operations
  - measurements using Hardware and Software monitors
  - Analyze and interpret this data to estimate relevant parameters/distributions
  - Mathematical Statistics ==> provides the tool

Introduction

- Probability theory studies random phenomena (i.e., phenomena for which the future behavior cannot be predicted in a deterministic fashion)
- A "Probabilistic Model" is used to abstract the real-word problems or situations
  - the model consists of a list of possible inputs and their outcomes and an assignment of their respective probabilities
  - the model is only as good as the underlying assumptions (probability assignments and distributions)
  - the model must be validated against actual measurements on the real phenomena

Introduction
Example 1

Example 1:

Predicting the number of job arrivals at a computer center in a fixed time interval (0, t)

- a common model is to assume that the number of job arrivals in this period has a particular distribution, such as Poisson distribution
- a complex physical situation is represented by a simple model with a single unknown parameter - the average job arrival rate λ

Introduction
Example 2

Example 2:

- Consider a computer system with automatic error recovery capability.
- Model: probability of successful recovery is c (Coverage) and probability of an abortive error recovery is unsuccessful) is (1- c).
- Estimate parameter c in this model: we observe N errors out of which n are successfully recovered.

Introduction
Example 2 (cont.)

- A reasonable estimate of c ==> "Relative Frequency" n/N. we expect this ratio to converge to c in the limit $N \rightarrow \infty$.
- Note that this limit is a limit in a probabilistic sense, i.e.,

$$\lim_{N \rightarrow \infty} P(\left| \frac{n}{N} - c \right| > \varepsilon) = 0$$

Introduction
Example 2 (cont.)

- This is different from the usual mathematical limit: $\lim_{N \to \infty} \frac{n}{N}$
- Thus, given any small $\varepsilon > 0$, it is not possible to find a value M such that (as would be required for the mathematical limit).

$$\left| \frac{n}{N} - c \right| < \varepsilon \qquad for\ all\ N > M$$