ECE 340
Probabilistic Methods in Engineering
M/W 3-4:15

Lecture I: Introduction/Motivation

Prof. Vince Calhoun

ECE-340
Spring 2008
Probabilistic Methods in Engineering (3 credits)
M, W 3:00-4:15 PM
Room: Dane Smith Hall 325

Syllabus

Course Goals: To introduce the student to basic theoretical concepts and computational tools in probability and statistics with emphasis on their role in solving engineering problems.

Course Catalog Description: Introduction to probability, random variables and random processes. Distributions and density functions, expectations and correlation, autocorrelation functions and power spectral densities for wide-sense stationary processes; confidence intervals; transmission of random signals through linear systems.

Prerequisites: ECE314.

Textbook: Probability and Random Processes for Electrical Engineering, 3rd ed., Alberto Leon-Garcia, Addison Wesley, 2008.

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Course Requirements

1) Conduct:

Students are expected to comply with the Student Code of Conduct found in the UNM Student Handbook. In particular, exchange of information during exams and quizzes is strictly prohibited.

2) Verbal and written communication:

Oral and written communications are important in the educational setting. Each student is expected to participate in classroom discussions. Students are also expected to exhibit good writing when working homework assignments, quizzes and examinations.

3) Homework:

Homework assignments will include problems from the text as well as special problems. Some problems may require the use of MATLAB, which is available in the ECE Computer labs. Computer-aided simulation and analysis (using MATLAB) of random phenomena will be an integral part of the course for two reasons: First, simulation of practical problems will provide motivation and give a realistic and enjoyable feel to the concept of chance. Second, it will help develop the basic computer tools necessary for the simulation and analysis of some problems that cannot be solved analytically. Completing homework assignments is a key component of this course, as it will help master the course material and prepare for the exams. Late submissions are generally not accepted unless under extreme conditions. Solutions will be provided when the assignments are graded and returned.

4) Examinations:

There will be two required midterms and a final. Make-up exams are given only under extreme conditions (such as in a medical emergency).

5) Quizzes:

There will be a 5-minute quiz every Wed in the beginning of the class period (with the exception of the first week of class). Each quiz will be on the material covered in the two lectures before the quiz. The purpose is to encourage students to read the class notes and be in synch with the course.

6) Attendance:

Attendance is mandatory. Missing more than two lectures requires the permission of the instructor.

7) Small-group project:

Groups of 2-3 students will be required to work on a small project comprising experimentation (of a random phenomenon) and analysis of results. The specifics of the project will be announced approximately 8 weeks before the due date, which will be on the final class period. Each group will be asked to prepare a brief report. Tools learned in class should be used to complete the design. The use of Matlab will be required to complete the project.

Grading:

10% Completion of homework assignments
10% Weekly 5-minute quizzes every Wednesday at the beginning of class (with the exception of the first week of class)
20% First Exam, **Wednesday, Feb. 27**
20% Second Exam, **Wednesday, Apr. 9**
30% Final Exam**: Wednesday, May 14, 3-5 PM**, Room TBA
10% Project (details to be announced)

Tentative grade assignment:

90-100 (A);
80-89 (B);
70-79 (C);
60-69 (D);
59 or below (F).

Some important dates:

Last day to drop without a grade: Feb 29th
Spring break: March 16-23

ECE 340 Schedule: Spring 2008

Lecture	Date	Topic	Assignment	Other
1	Jan 23	Intro/Ch 1		
2	Jan 28	2.1-2.2		
3	Jan 30	2.3-2.4	Quiz	
4	Feb 4	2.5-2.6	HW1 due	Lecturer Jean Liu
5	Feb 6	3.1-3.2	Quiz	Lecturer Jean Liu
6	Feb 11	3.3	HW2 due	Lecturer Jean Liu
7	Feb 13	3.4	Quiz	Lecturer Jean Liu
8	Feb 18	3.5		
9	Feb 20	4.1-4.3	Quiz; HW3 due	
10	Feb 25	4.4-4.5		
E1	Feb 27		**Exam #1**	
11	Mar 3	4.6-4.7		
12	Mar 5	5.1-5.2	Quiz	
13	Mar 10	5.3-5.4	HW4 due	
14	Mar 12	5.5-5.7	Quiz	
N	Mar 17	NO CLASS		
N	Mar 19	NO CLASS		
15	Mar 24	5.8-5.9	HW5 due	
16	Mar 26	6.1-6.2	Quiz	
17	Mar 31	6.3-6.4		
18	Apr 2	7.1-7.2	Quiz; HW6 due	
19	Apr 7	7.3		
E2	Apr 9		**Exam #2**	
20	Apr 14	8.1-8.2		
21	Apr 16	8.3	Quiz	
22	Apr 21	8.4-8.5	HW7 due	
23	Apr 23	8.6	Quiz	
24	Apr 28	9.1-9.2		
25	Apr 30	9.3-9.6	Quiz	
26	May 5	10.1-10.2	Term Project Due	
27	May 7	TBA		
F	May 14		**Final Exam**	
	May 12-16	FINALS WEEK		

Reading

- **This class: Section 1.1-1.6**
- **Next class: Section 2.1-2.2**

ECE 340

- Introduction to Probability Theory
  - Models
    - Deterministic
    - Probabilistic
      - Relative frequency
      - Axiomatic approach

ECE 340

- **This course teaches "mathematical tools" that are useful for a wide range of disciplines:**
  - Communications and Networking
    - Information theory, coding, modulation, queuing theory, traffic modeling, etc.
  - Signal, Speech and Image Processing
    - Statistical signal processing, filtering, signal modeling, etc.
  - Many other…
    - Control; other areas in engineering and science

The Engineering Method and Statistical Thinking

- Engineers solve problems of interest to society by the efficient application of scientific principles
- The engineering or scientific method is the approach to formulating and solving these problems.

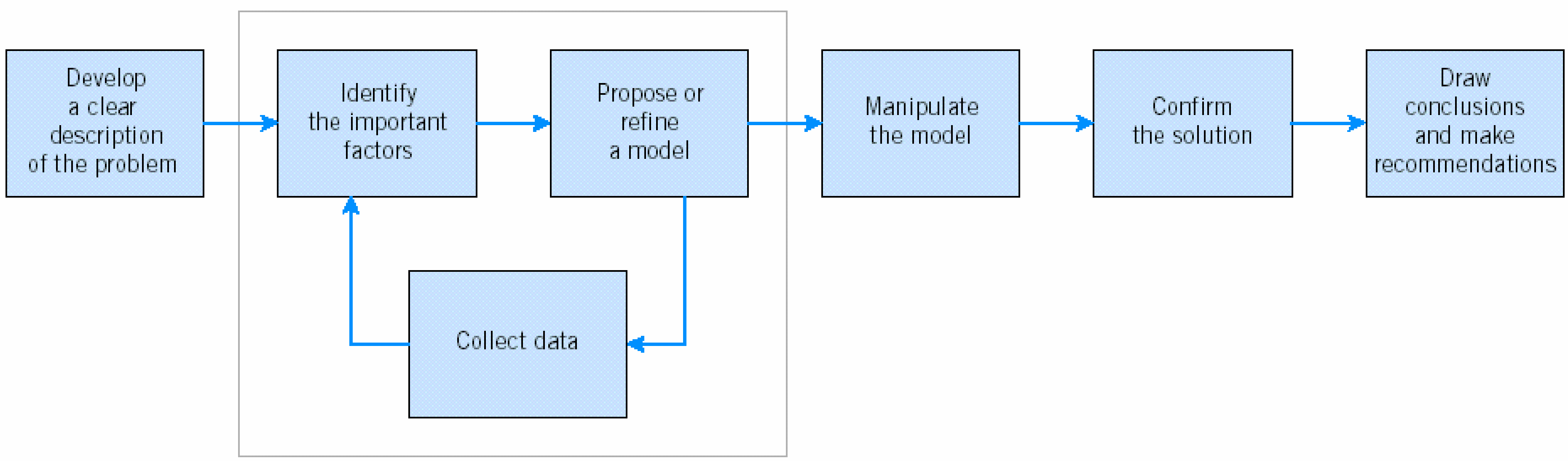


Figure 1-1 The engineering problem-solving method.

The Engineering Method and Statistical Thinking

The Field of Probability

Used to quantify likelihood or chance

- Used to represent risk or uncertainty in engineering applications
- Can be interpreted as our degree of belief or relative frequency

The Field of Statistics

- Deals with the collection, presentation, analysis, and use of data to make decisions and solve problems.

Overall:

Statistics is a set of methods used to collect and analyze data. Those statistical methods help people identify, study, and solve a variety of problems. Statistics help people make good decisions about uncertain situations. Probability is used to describe events that do not occur with certainty.

The Engineering Method and Statistical Thinking

Statistical techniques are useful for describing and understanding variability

By variability, we mean successive observations of a system or phenomenon do *not* produce exactly the same result.

- Statistics gives us a framework for describing this variability and for learning about potential sources of variability.

Probability: Basic Ideas

- Terminology:
  - Trial: each time you repeat an experiment
  - Outcome: result of an experiment
  - Random experiment: one with random outcomes (cannot be predicted exactly)
  - Relative frequency: how many times a specific outcome occurs within the entire experiment.

Statistics: Basic Ideas

- Statistics is the area of science that deals with collection, organization, analysis, and interpretation of data.
- It also deals with methods and techniques that can be used to draw conclusions about the characteristics of a large number of data points--commonly called a population--
- By using a smaller subset of the entire data.

For Example…

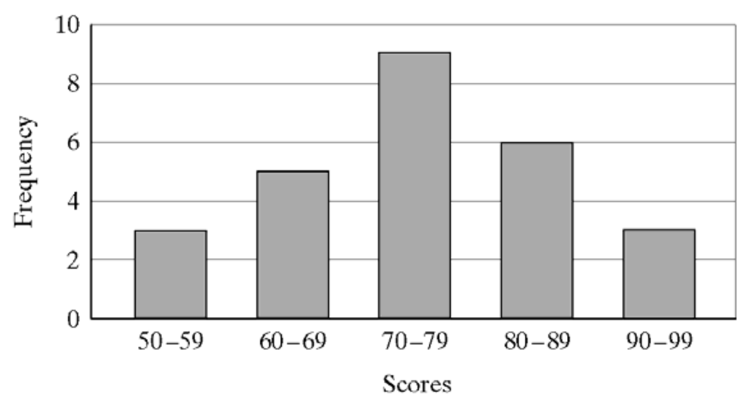
- You work in a cell phone factory and are asked to remove cell phones at random off of the assembly line and turn it on and off.
- Each time you remove a cell phone and turn it on and off, you are conducting a random experiment.
- Each time you pick up a phone is a trial and the result is called an outcome.
- If you check 200 phones, and you find 5 bad phones, then
- relative frequency of failure = 5/200 = 0.025

Statistics in Engineering

- Engineers apply physical and chemical laws and mathematics to design, develop, test, and supervise various products and services.
- Engineers perform tests to learn how things behave under stress, and at what point they might fail.

Statistics in Engineering

- As engineers perform experiments, they collect data that can be used to explain relationships better and to reveal information about the quality of products and services they provide.



Frequency Distribution:

Scores for an engineering class are as follows: 58, 95, 80, 75, 68, 97, 60, 85, 75, 88, 90, 78, 62, 83, 73, 70, 70, 85, 65, 75, 53, 62, 56, 72, 79

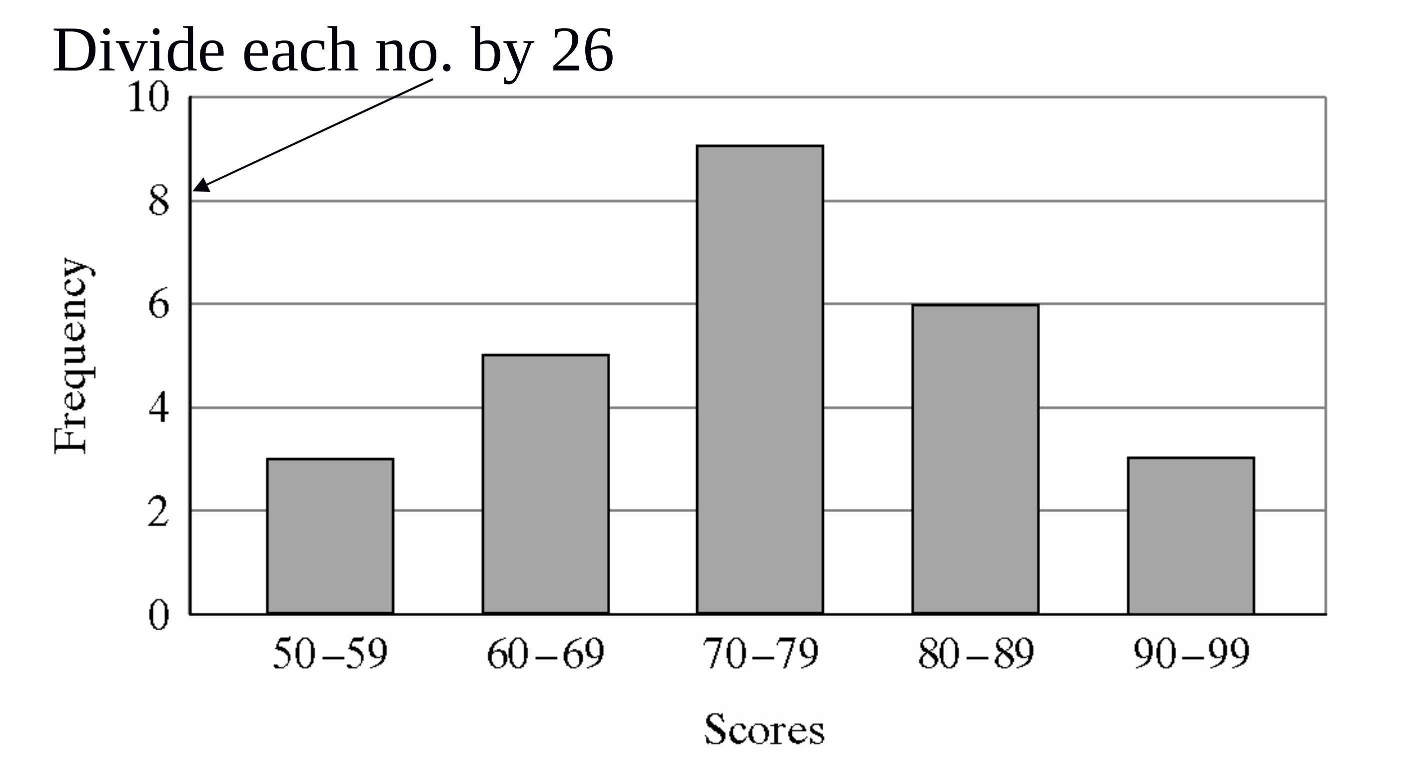
To better assess the success of the class, we make a frequency chart:

TABLE 19.1 Grouped Frequency Distribution for Example 19.2

Scores	Range	Frequency
58, 53, 56	50–59	3
68, 60, 62, 65, 62	60–69	5
75, 75, 78, 73, 70, 70, 75, 72, 79	70–79	9
80, 85, 88, 83, 85, 87	80–89	6
95, 97, 90	90–99	3

Now the information can be better analyzed.

For example, 3 students did poorly, and 3 did exceptionally well. We know that 9 students were in the average range of 70-79. We can also show this data in a freq. histogram (PDF).



Cumulative Frequency

- The data can be further organized by calculating the cumulative frequency (CDF).
- The cumulative frequency shows the cumulative number of students with scores up to and including those in the given range. Usually we normalize the data - divide 26.

TABLE 19.2 Cumulative Frequency Distribution for Example 19.2

Range	Frequency	Cumulative Frequency	
50–59	3	3	3
60–69	5	$3 + 5 = 8$	8
70–79	9	$3 + 5 + 9 = 17$ or $8 + 9 = 17$	17
80–89	6	$3 + 5 + 9 + 6 = 23$ or $17 + 6 = 23$	23
90–99	3	$3 + 5 + 9 + 6 + 3 = 26$ or $23 + 3 = 26$	26

Measures of Central Tendency & Variation

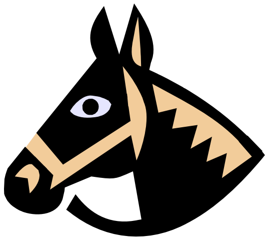
- Systematic errors, also called fixed errors, are errors associated with using an inaccurate instrument.
  - These errors can be detected and avoided by properly calibrating instruments
- Random errors are generated by a number of unpredictable variations in a given measurement situation.
  - Mechanical vibrations of instruments or variations in line voltage friction or humidity could lead to random fluctuations in observations.

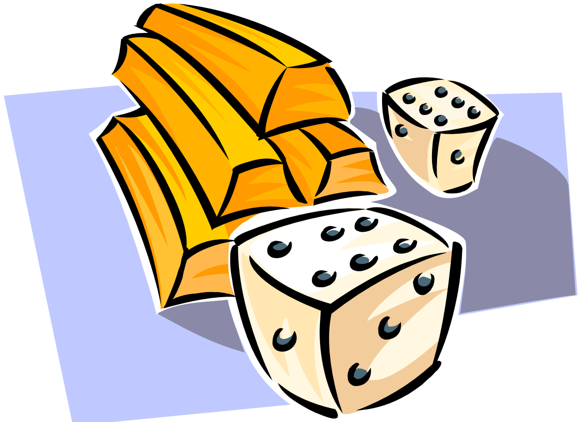
- When analyzing data, the mean alone cannot signal possible mistakes. There are a number of ways to define the dispersion or spread of data.
- You can compute how much each number deviates from the mean, add up all the deviations, and then take their average as shown in the table below.

TABLE 19.4 Deviations from the Mean

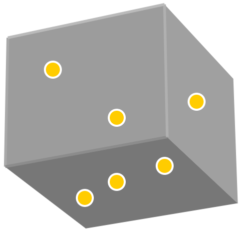
$\rho_{avg} = 1000$ Group A			$\rho_{avg} = 1000$ Group B		
ρ	$(\rho - \rho_{avg})$	$\lvert(\rho - \rho_{avg})\rvert$	ρ	$(\rho - \rho_{avg})$	$\lvert(\rho - \rho_{avg})\rvert$
1020	+20	20	950	−50	50
1015	+15	15	940	−60	60
990	−10	10	890	−110	110
1060	+60	60	1080	+80	80
1030	+30	30	1120	+120	120
950	−50	50	900	−100	100
975	−25	25	1040	+40	40
1020	+20	20	1150	+150	150
980	−20	20	910	−90	90
960	−40	40	1020	+20	20
	$\sum = 0$	$\sum = 290$		$\sum = 0$	$\sum = 820$

Origins of Probability





The study of probabilities originally came from gambling!



Why are Probabilities Important?

- They help you to assess your expected reward for certain actions, e.g.,
  - Economic planning
- They help you to make good decisions, e.g.,
  - Decision theory
- They help you to minimize risk, e.g.,
  - Insurance
- They are used in average-case time complexity analyses of Computer algorithms.
- They are used to model processes in Engineering.

Random Experiments

- The concept behind probabilities is called the ***random experiment***.
- A random experiment is an experiment that can be repeated over and over, giving different results.

Probability as a *Frequency*

- If we have a probability p that an experiment will result in outcome A, then if we repeat this experiment a large number of times we should expect the fraction of times that A will occur is very close to p.

Frequency Definition of Probability

- Consider probability as a measure of the frequency of occurrence.
  - For example, the probability of “heads” in a coin flip is essentially equal to the number of heads observed in *T* trials, divided by *T*, as *T* approaches infinity.

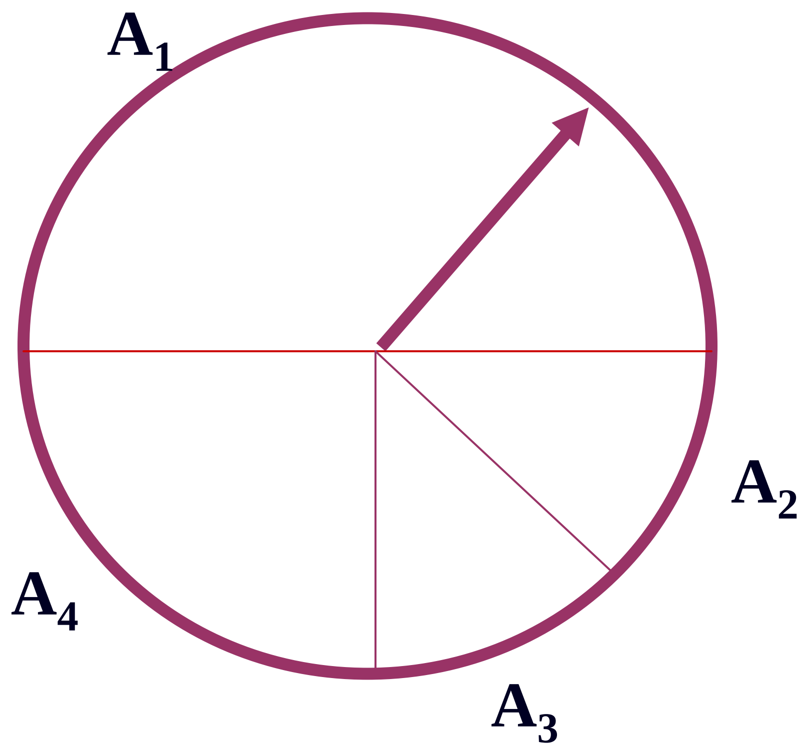
$$\Pr(heads) \approx \lim_{T \to \infty} \frac{\#\text{ of heads}}{T}$$

Probability as a Frequency

- Consider a random experiment with possible outcomes $w_1, w_2, \ldots, w_n$. For example, we roll a die and the possible outcomes are 1,2,3,4,5,6 corresponding to the side that turns up. Or we toss a coin with possible outcomes H (heads) or T (tails).
- We assign a probability $p(w_j)$ to each possible outcome w_j in such a way that:
  - $p(w_1) + p(w_2) + \ldots + p(w_n) = 1$
- For the dice, each outcome has probability 1/6. For the coin, each outcome has probability ½.

Example: Probability as Frequency

Spinner with unit circumference



Arcs $\mathbf{A_1}$ $\mathbf{A_2}$ $\mathbf{A_3}$**, and** $\mathbf{A_4}$ have lengths ½, 1/8, 1/8, and ¼, respectively.

Example Continued

- We spin a pointer. If it stops at arc A_1, we say that outcome w_1 occurs. If it stops at arc A_2, we say that outcome w_2 occurs, etc.
- The probability that the spinner stops in an arc is equal to the length of that arc.
  - In a simulation, the experimental frequency that the spinner will stop in an arc will be very close to the length of the arc -- if the number of spins is high.
  - The more experiments we run, the closer the frequency will be to the true probability. (Tossing a coin 10,000 times will give a proportion of H close to 0.5 and a proportion of T close to 0.5.)

Computer Simulation of Probabilities