# Probability Methods in Engineering

CSE-209

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Lecture 1

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# Resource Material

- Course Book
  - A. Leon-Garcia, "Probability and Random Processes for Electrical Engineering", 3rd Edition, Pearson Prentice Hall, 2008
- Reference Books
  - D. Bertsekas and J. N. Tsitsiklis, "Introduction to Probability", 2nd Edition, Athena Scientific, 2008
  - Hossein Pishro-Nik, "Introduction to Probability, Statistics, and Random Processes", Kappa Research, 2014

# Online Resources

- Joining the group is important
  - *https://groups.google.com/g/2021_PME_spring*
- Online group benefits
  - Slides
  - Assignments
  - Announcements
  - Course outline
  - Discussions
  - CLOs and PLOs (OBE)
- Group email
  - *2021_PME_spring@googlegroups.com*
- Teaching method
  - Combination of slides and white board
  - Interaction about concepts encouraged
  - Interruption to ask questions during lectures allowed

# Tentative Grading Criteria

- Exams
  - Final exam: **60%**
  - Mid-term exam: **20%**
- Sessional
  - Attendance: **10%**
  - Assignments: **5%**
  - Quizzes: **5%**
- All lectures interrelated
  - Each lecture provides base for next lecture
  - Missing any lecture would result in problems in understanding subsequent lectures

- No mobile phone usage during class

# Course Outline

- Introduction to Probability
  - Axioms
  - Probabilities using Counting methods
  - Conditional Probability
  - Law on Total Probability
  - Bayes' Rule
  - …
- Random Variables (RVs)
  - Cumulative Distribution Function (CDF)
  - Probability Density Function (PDF)
  - Mean and variance
  - …
- Modern Tools
  - MATLAB
  - Python
  - …

# Course Significance

- Basis for numerous advanced technologies
  - Wave propagation
  - Wireless communication
  - Communication theory
  - Information theory
  - Pattern recognition
  - Radar and sonar signal processing
  - Network design and optimization
  - Artificial intelligence
  - Machine learning
  - Deep learning

# Future Job Market

| ↗ Increasing demand | | ↘ Decreasing demand | |
|---|---|---|---|
| 1 | Data Analysts and Scientists | 1 | Data Entry Clerks |
| 2 | AI and Machine Learning Specialists | 2 | Administrative and Executive Secretaries |
| 3 | Big Data Specialists | 3 | Accounting, Bookkeeping and Payroll Clerks |
| 4 | Digital Marketing and Strategy Specialists | 4 | Accountants and Auditors |
| 5 | Process Automation Specialists | 5 | Assembly and Factory Workers |
| 6 | Business Development Professionals | 6 | Business Services and Administration Managers |
| 7 | Digital Transformation Specialists | 7 | Client Information and Customer Service Workers |
| 8 | Information Security Analysts | 8 | General and Operations Managers |
| 9 | Software and Applications Developers | 9 | Mechanics and Machinery Repairers |
| 10 | Internet of Things Specialists | 10 | Material-Recording and Stock-Keeping Clerks |
| 11 | Project Managers | 11 | Financial Analysts |
| 12 | Business Services and Administration Managers | 12 | Postal Service Clerks |
| 13 | Database and Network Professionals | 13 | Sales Rep., Wholesale and Manuf., Tech. and Sci.Products |
| 14 | Robotics Engineers | 14 | Relationship Managers |
| 15 | Strategic Advisors | 15 | Bank Tellers and Related Clerks |
| 16 | Management and Organization Analysts | 16 | Door-To-Door Sales, News and Street Vendors |
| 17 | FinTech Engineers | 17 | Electronics and Telecoms Installers and Repairers |
| 18 | Mechanics and Machinery Repairers | 18 | Human Resources Specialists |
| 19 | Organizational Development Specialists | 19 | Training and Development Specialists |
| 20 | Risk Management Specialists | 20 | Construction Laborers |

Source

Future of Jobs Survey 2020, World Economic Forum.

# Course Significance (cont.)

- Disadvantages of weak probability concepts
  - No scope in research fields
  - Poor analytical skills
  - Fear of interview questions
  - Inability to conceptualize techniques
  - No major role possible in engineering problem solving
  - Minimum contribution towards nation building
  - Incapability to carry out feasibility studies for mega projects

# Assessment Test

- A fair die is rolled thrice. What is the probability of getting
  - A six in the first attempt
  - Sixes in first two attempts
  - Sixes in all three attempts
  - All odd outcomes
  - All outcomes greater than 4
- What is the number of all possible outcomes?

# Randomness

- What is Randomness?
  - Chaos
  - Uncertainty
  - Doubt

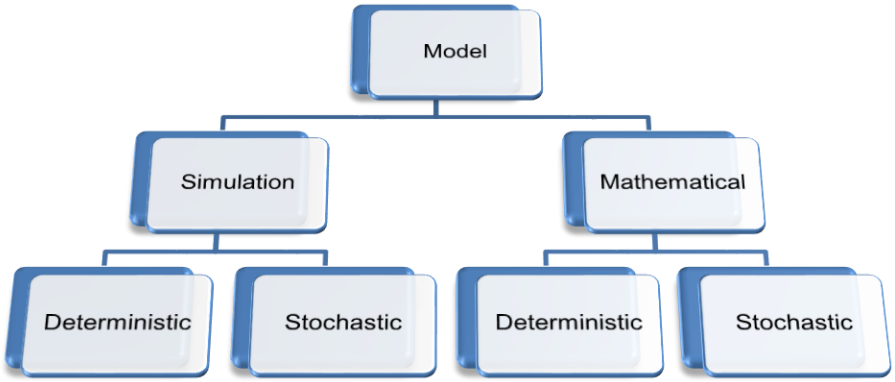
- Humans desire some level of 'certainty'
- Examples
  - Solar system
  - Weather forecast at Chitral Airport
  - Traffic situation on University road

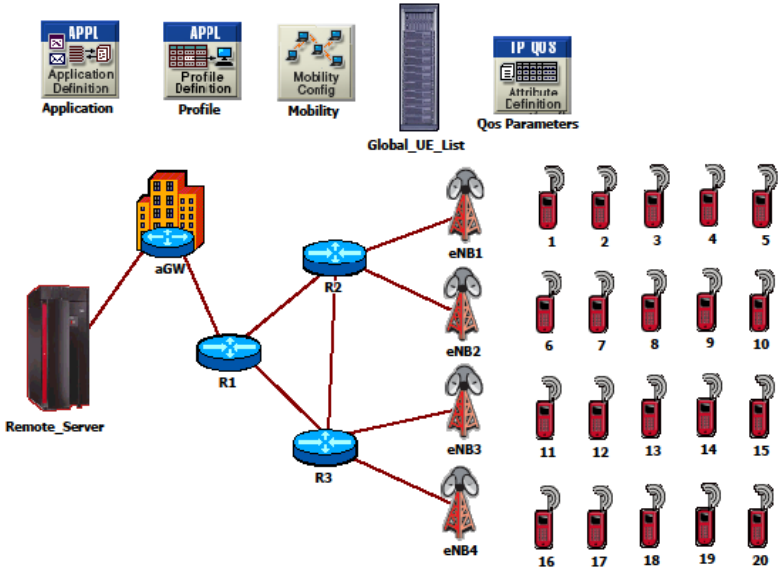
- Engineers **quantify** 'certainty'

**Source**: Computer Vision Research Group, *CIIT Lahore*, Pakistan

# Model of a Physical System

- **Model**: Approximate representation of physical situation
  - **Mathematical model**: Set of assumptions about how system works
    - **Deterministic model**: Offers repeatability of results, (e.g. Ohm's Laws)
    - **Stochastic model**: Characterizes randomness and uncertainty
  - **Simulation model**: Imitation of real system
    - **Deterministic model**: No random component involved, (e.g. chemical reaction)
    - **Stochastic model**: Must have random input component



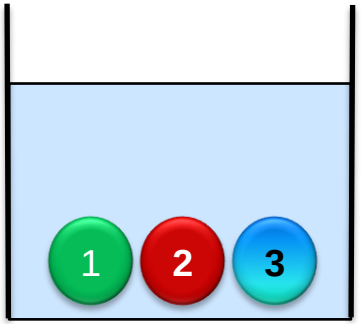

**Source**: S. N. K. Marwat, PhD Thesis, *University of Bremen, Germany*

# Random Experiment

- **Random Experiment**: The result varies in random manner
- **Sample Space**: Set of all possible experiment results
- **Outcome**: A single element of sample space
- **Event**: A subset of sample space

- Example: An urn containing three balls, one is drawn
  - How probable it is that a ball withdrawn at random is labeled '1'?
  - Can you quantify this 'chance'?
  - Everyone of you should be able to write the sample space for this experiment!

S = {  }



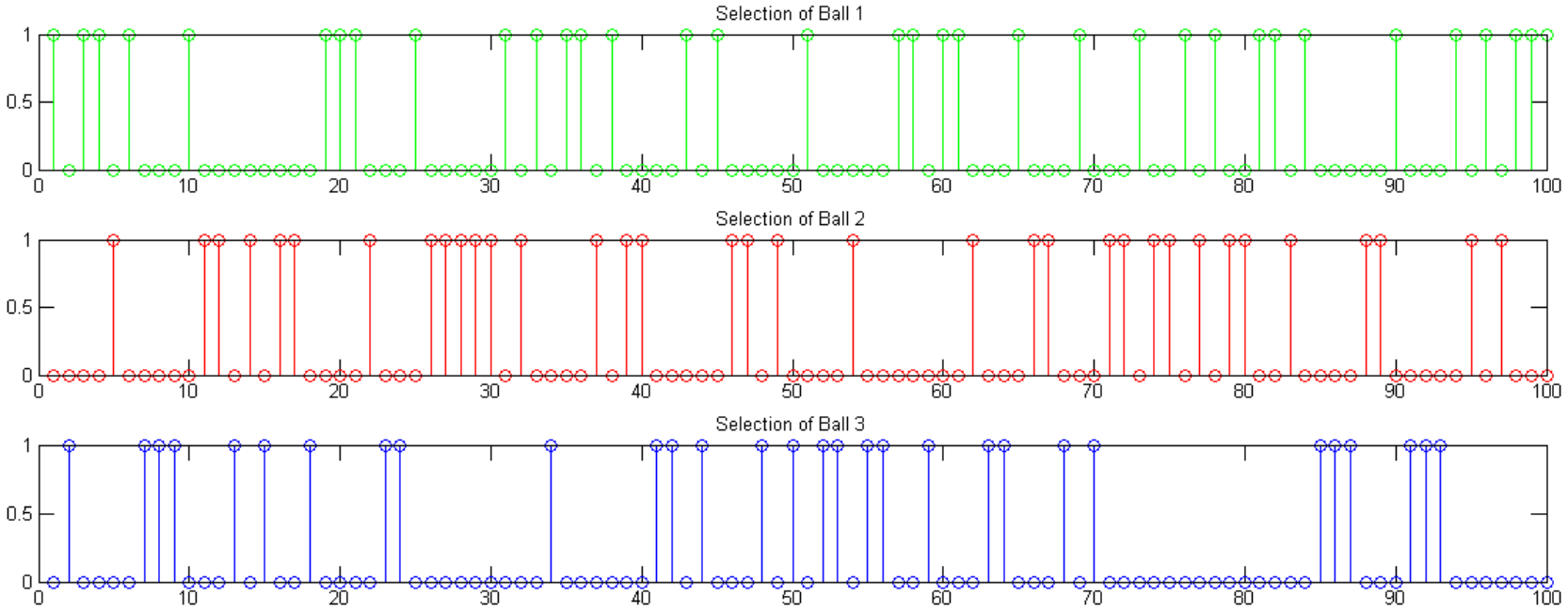
# Random Experiment (cont.)

- Some more questions to answer
  - Is withdrawing all the three balls equi-probable (or is any ball more likely to be drawn)?
  - If '1' means 'sure occurrence' and '0' means 'no chance of occurrence', what number can be given to the chance of getting 'ball 1'?
  - What is the chance of withdrawing an odd-numbered (or even-numbered) ball?

Let the nature answer this

# Random Experiment (cont.)

- Take a ball from the urn
- Record the outcome
- Put it back in the urn
- Do the experiment '$n$' times



# Random Experiment (cont.)

- Number of times $k^{th}$ outcome occurred (or **frequency** of $k$) in a total of $n$ trails

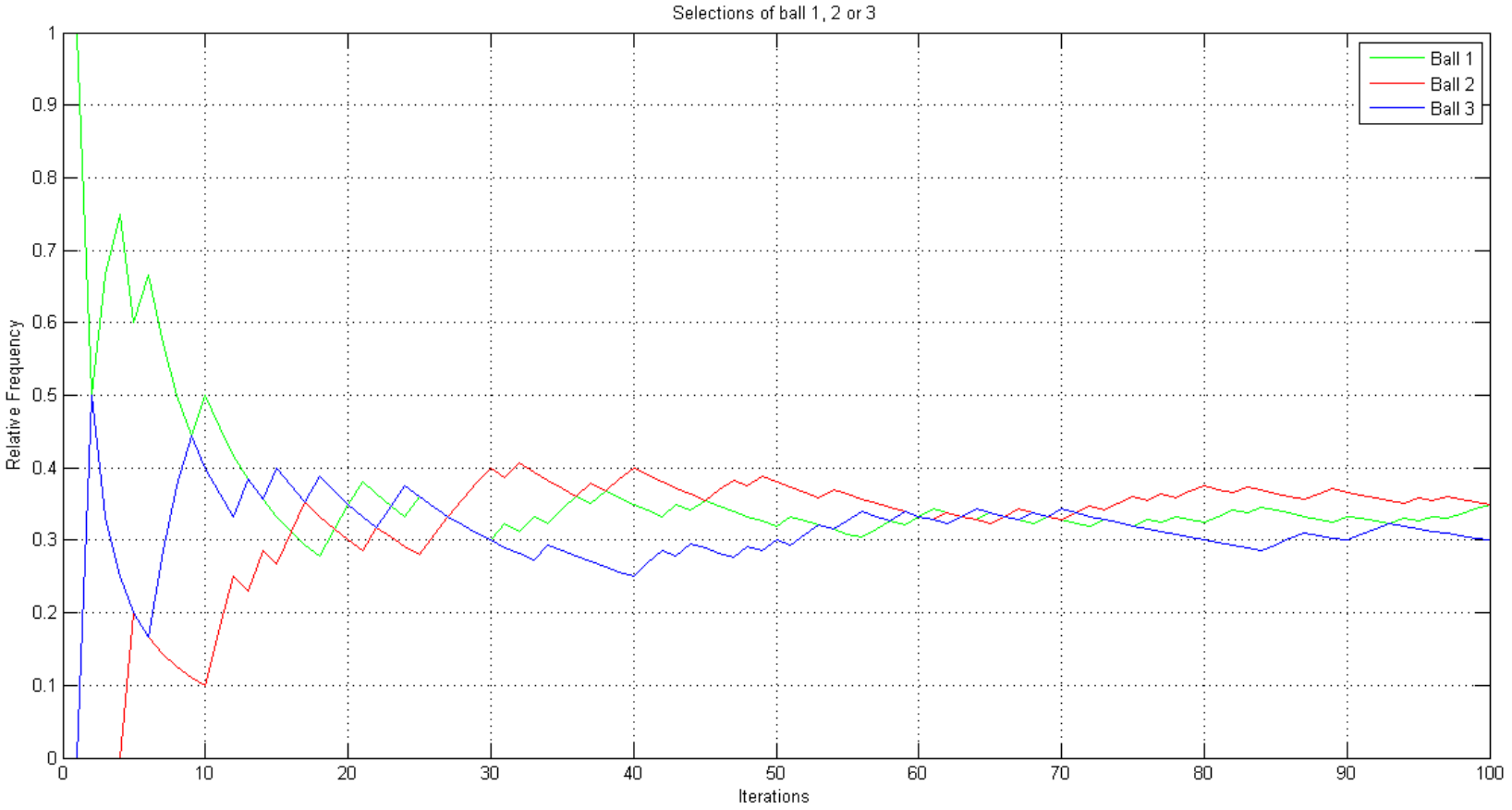
$$N_k(n)$$

- The **relative frequency** of $k^{th}$ outcome

$$f_k(n) = \frac{N_k(n)}{n}$$

# Random Experiment (cont.)

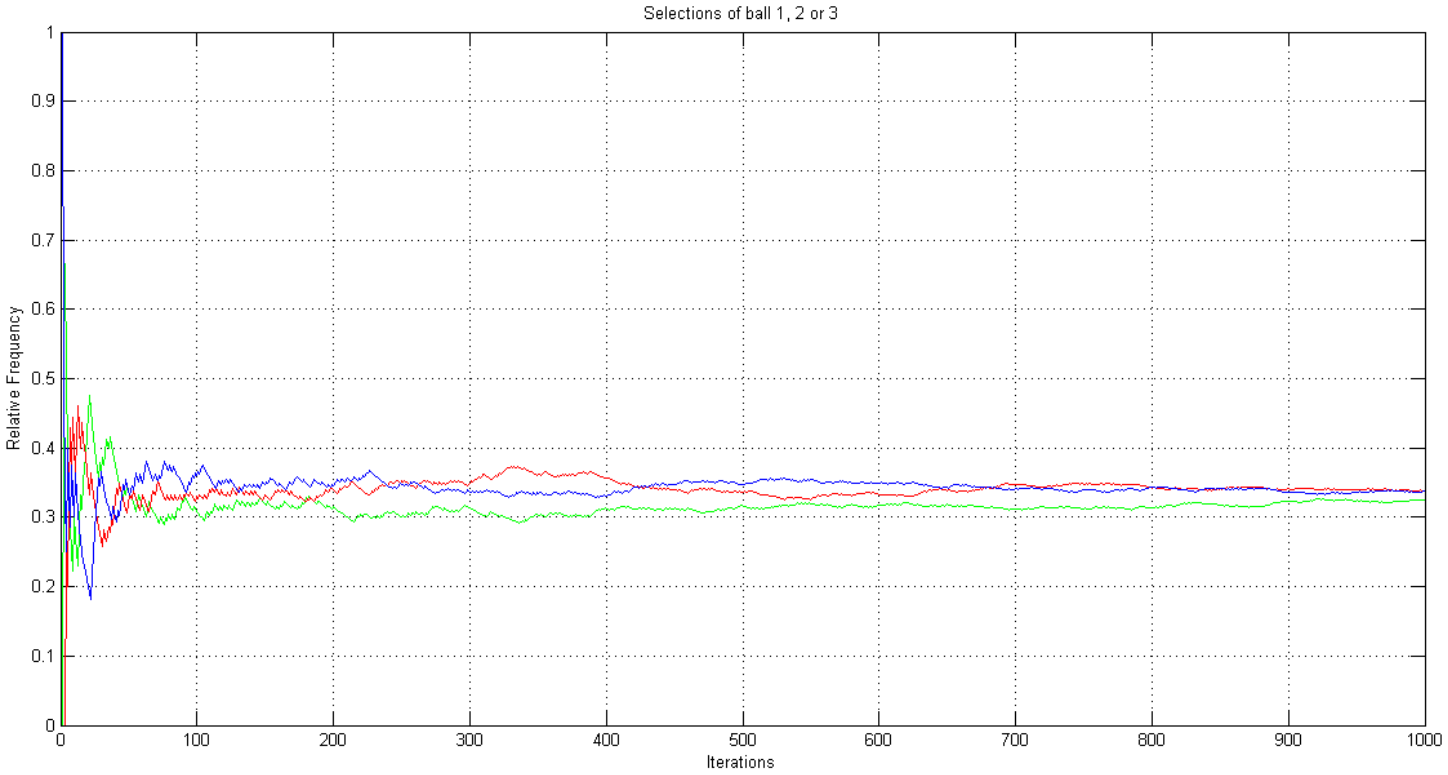
- **Statistical Regularity**
  - Averages obtained in long sequences yield same value



# Random Experiment (cont.)

- **Probability** defined by *von Mises* as 'limiting case of relative frequency'

$$\lim_{n\to\infty} f_k(n) = \lim_{n\to\infty} \frac{N_k(n)}{n} = p_k$$



# Properties of Relative Frequency

- Number of occurrences of an outcome in $n$ trials
  - A number between zero and $n$

$$0 \leq N_k(n) \leq n$$

- Relative frequencies are
  - A number between zero and one
  - Divide the above equation by $n$ to get

$$0 \leq f_k(n) \leq 1$$

# Properties of Relative Frequency (cont.)

- Sum of number of occurrences of all possible outcomes
  - Must be $n$

$$\sum_{k=1}^{K} N_k(n) = n$$

- Sum of all relative frequencies
  - Must be 1

$$\sum_{k=1}^{K} f_k(n) = 1$$