Lecture 3: Aug 25

Last time

- Set theory (1.1)

Today

- Set theory (1.1)
- Axiomatic Foundations (1.2)

Theorem For any three events, A, B, and C, defined on a sample space S,

1. Commutativity
$$A \cup B = B \cup A,$$
$$A \cap B = B \cap A;$$

2. Associativity
$$A \cup (B \cup C) = (A \cup B) \cup C,$$
$$A \cap (B \cap C) = (A \cap B) \cap C;$$

3. Distributive Laws
$$A \cap (B \cup C) = (A \cap B) \cup (A \cap C),$$
$$A \cup (B \cap C) = (A \cup B) \cap (A \cup C);$$

4. DeMorgan's Laws
$$(A \cup B)^c = A^c \cap B^c,$$
$$(A \cap B)^c = A^c \cup B^c;$$

We show the proof of $A \cap (B \cup C) = (A \cap B) \cup (A \cap C)$ in the distributive laws. Caution: Venn diagrams are helpful in visualization, but they do not constitute a formal proof. To prove that two sets are equal, we need to show that each set contains the other.
proof:

- $A \cap (B \cup C) \subset (A \cap B) \cup (A \cap C)$:
Let $x \in (A \cap (B \cup C))$. By definition of intersection, $x \in (B \cup C)$ that is, either $x \in B$ or $x \in C$. Since x also must be in A, we have that either $x \in (A \cap B)$ or $x \in (A \cap C)$; therefore, $x \in ((A \cap B) \cup (A \cap C))$.

- $(A \cap B) \cup (A \cap C) \subset A \cap (B \cup C)$:
Let $x \in ((A \cap B) \cup (A \cap C))$. This implies that $x \in (A \cap B)$ or $x \in (A \cap C)$. If $x \in (A \cap B)$, then x is in both A and B. Since $x \in B$, then $x \in (B \cup C)$and thus $x \in (A \cap (B \cup C))$. It follows the same argument when $x \in (A \cap C)$, we still have $x \in (A \cap (B \cup C))$.

Definition Two events A and B are *disjoint* (or *mutually exclusive*) if $A \cap B = \varnothing$. The events $A_1, A_2, \ldots$ are *pairwise disjoint* (or *mutually exclusive*) if $A_i \cap A_j = \varnothing$ for all $i \neq j$.

Definition If $A_1, A_2, \ldots$ are pairwise disjoint and $\cup_{i=1}^{\infty} A_i = A_1 \cup A_2 \cup \cdots = S$, then the collection of $A_1, A_2, \ldots$ forms a *partition* of S.

Example The sets $A_i = [i, i+1), i = 0, 1, 2, \ldots$ form a partition of $[0, \infty)$.

Basics of Probability Theory

When an experiment is performed, the realization of the experiment is an outcome in the sample space. If the experiment is performed a number of times, then

- different outcomes may occur each time
- some outcomes may repeat
- the "frequency of occurrence" of an outcome can be thought of as a probability

However, we **do not** define probabilities in terms of frequencies but instead take the mathematically simpler axiomatic approach. The axiomatic approach is not concerned with the interpretations of probabilities, but is concerned only that the probabilities are defined by a function satisfying the axioms. Interpretations of the probabilities are quite another matter:

- The "frequency of occurrence" of an event is one example of a particular interpretation of probability.
- Another possible interpretation is a subjective one, where we can think of the probability as a belief in the chance of an event occurring.