Aleatory and Epistemic Uncertainties

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Uncertainty in Engineering

- The presence of uncertainty in engineering is unavoidable.
  - Incomplete or insufficient data
- Design must rely on predictions or estimations based on idealized models with unknown degrees of imperfection relative to reality.
- In practice, we might identify two broad types of uncertainty: namely,
  - Uncertainty associated with the randomness of the underlying phenomenon that is exhibited as variability in the observed information, and
  - Uncertainty associated with imperfect models of the real world because of insufficient or imperfect knowledge of reality.
- These two types of uncertainty may be called, respectively,
  - the *aleatory uncertainty* and
  - the *epistemic uncertainty.*
- The two types of uncertainty may be combined and analyzed as a total uncertainty, or treated separately. In either case, the principles of probability and statistics apply equally.

Aleatory Uncertainty

- From *Alea* Latin for “dice”

- This means that it represents inherent RANDOMNESS

Aleatory Uncertainty

- The aleatory (databased) uncertainty is associated with the inherent variability of basic information, which is part of the real world (within our ability to observe and describe).
- Much of the aleatory uncertainty that civil engineers must deal with are inherent in nature and, therefore, **may not be reduced** or modified.
- On the other hand, epistemic (or knowledge-based) uncertainty is associated with imperfect knowledge of the real world, and **may be reduced** through application of better prediction models and/or improved experiments.
- The respective consequences of these two types of uncertainty may also be different
  - the effect of the aleatory randomness leads to a calculated probability or risk,
  - whereas the effect of the epistemic type expresses an uncertainty in the estimated probability or risk

Epistemic Uncertainty

- This is referred to as EPISTEMIC uncertainty because it reflects our lack of knowledge.

From *epistêmê* Greek for "knowledge")

Celsus Library, Ephesus

Uncertainty in Engineering

- Finally, there should be no problem in delineating between the two types of uncertainty
  - the aleatory type is essentially databased,
  - whereas the epistemic type is knowledge based.
- For practical purposes, the epistemic uncertainty may be limited to the estimation of the mean or median values, even though in theory it includes inaccuracies in the prescribed form of probability distributions and in all the parameters.

Aleatory Uncertainty

- Many phenomena or processes of concern to engineers, or that engineers must contend with, contain randomness; that is, the expected outcomes are unpredictable (to some degree). Such phenomena are characterized by field or experimental data that contain significant ***variability*** that represents the natural randomness of an underlying phenomenon;
    - i.e., the observed measurements are different from one experiment (or one observation) to another, even if conducted or measured under apparently identical conditions.
- In other words, there is a range of measured or observed values of the experimental results; moreover, within this range certain values may occur more frequently than others. The variability inherent in such data or information is statistical in nature, and the realization of a specific value (or range of values) involves probability.

Probability

- Probability
  - Likelihood of occurrence of an event relative to other events
  - A numerical measure of the likelihood of occurrence of an event within an exhaustive set of all possible alternative events.

Definitions

- Random Experiment
  - Outcome is not known until experiment is complete
    - For example flipping a coin – outcome is either a head or a tail, but cannot be predicated with certainty
- Sample Space
  - Collection of all possible outcomes S={H,T}
- Frequency of the Event
  - Repeat experiment n times, and then count the number of time, f, that outcome occurred A={H}
- Relative Frequency
  - f/n
- See Table 2.1-1 of text (Page 88), P(A) = Probability of A = ½, A={H}

Deterministic Vs. Probabilistic