ENGINEERING 1N

THE NATURE OF ENGINEERING

MEASUREMENT, ESTIMATION, APPROXIMATION

- Engineering and Quantification
- Instrument(s) and Protocol (Procedure, Technique)
- Characterizing Measurements
  - Direct vs. indirect (calculated)
  - Intrusive vs. non-intrusive
  - Destructive vs. non-destructive
  - Support: point, local, global, sampling
  - Discrete vs. continuous
Evaluating Measurements

- Measurement “Error”
  Uncertainty

- Accuracy (Bias)
  Applicable to a single measurement or to a set of measurements
  Bias = True value - [average] measured value
  “True” values, standards, relative accuracy
  Systematic errors

- Precision
  Reproducibility/repeatability
  Applicable to a set of measurements, whether or not we actually make them
  Random errors

- Sensitivity
  Instrument responsiveness to changes in the quantity being measured
Measurement Histograms

\[ N = 100 \]
\[ \text{True Value} = 1.700 \text{ sec} \]

**UNCERTAINTY**

- **Sources**
  - Instrument design
  - Operator differences
  - Environmental differences (external variables)
  - Problems of definition
    - Variability and sampling

- **Representation**
  - Best estimate ± uncertainty (error) index \( \hat{u} \pm \mu \)
  - Significant figures (digits)

- **Quantification**
  - Bounds
    - Maximum/minimum values, instrument scale divisions
  - Statistical measures
    - Standard deviation, \( \sigma \) or \( s \)
DESCRIPTIVE STATISTICS

- **Central Tendency**
  - Mean (Average)
  - Median
  - Mode

- **Spread**
  - Standard Deviation
  - Coefficient of Variation

- **Asymmetry**
  - (Coefficient of) Skew

**Formulas**

\[
\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]

\[
\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2}
\]

\[
CV = \frac{\sigma}{\bar{x}}
\]

\[
g = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^3}{(n-1)(n-2)\sigma^3}
\]

**Graph**

- Bin Upper Limit (sec)
- Number of Observations

- Max = 2.728 sec
- Min = 0.793 sec
- Mean = 1.692 sec
- Median = 1.707 sec
- Standard Deviation = 0.330 sec
- Coefficient of Variation = 0.19
- Skew = 0.03

- True Value = 1.700