UC Berkeley
Mechanical Engineering Department

ME103:: Experimentation and Measurements

Lecture #6

ME103:: Experimentation and Measurements

Engineering Ethics & Measurements

Many of these have come up without the ethics-label

- Falsifying Data
- Ignoring Outliers without justification
- Copying Data
- Ignoring Safety during Experiments

Final Design of Experiment

- Wind Tunnel
  - Boeing
  - 70 Hesse
- Instron
- GRADE
- CAM
- Metal 3d Print
- Thermal Rocket
- Thermal Camera
- Inverted Pendulum
- Vibrating Beam

ME103:: Experimentation and Measurements

Why perform experiments ?

- To prove/disprove a hypothesis
  - Will this configuration work? Testing a system
  - Does a physical system behave in a certain way?
  - Is there something new to discover?

- How you set up an experiment is just as important as the sensors and instrumentation you use
  - Focus on the outcome desired
  - What settings to use, what sequence of experiments, how unwanted variation is limited…

What is Design of Experiment (DOE)?

- NIST (National Institute of Standards and Technology)
  - Part of the Department of Commerce
  - To promote U.S. innovation and industrial competiveness by advancing measurement science, standards and technology

- Design of experiments (DOE) is a systematic, rigorous approach to engineering problem-solving that applies principles and techniques at the data collection stage so as to ensure the generation of valid, defensible, and supportable engineering conclusions. In addition, all of this is carried out under the constraint of a minimal expenditure of engineering runs, time, and money.

Three Principles of Design of Experiment (DOE)?

- *Replication*: enough replicates of each experiment to bring standard error of the mean low enough that clear conclusions can be drawn
- *Randomization*: carry out runs in a random sequence to prevent drift effects from becoming conflated with systematic effects we are trying to study
- *Blocking*: grouping experimental units that are **similar to each other** and running the experiment **within those groups**

Successful experimentation is often iterative

This does not mean, however, that the whole experimental process should be by trial-and-error

- Start with a coarse screening, to identify parameters and ranges to focus on
- Do methodical design of experiments in the region of interest
- Don’t do all your experiments in one go – plan perhaps 20% of your time budget to get preliminary results, analyze, then revise next steps of plan based on what you’ve learned

Propagation of Error

Our goal here is to determine the total error of something that is a function of a number of independent variables

$$y\,(x_1 \pm u_1,\ x_2 \pm u_2,\ x_3 \pm u_3,\ \ldots)$$

u_n = uncertainty or error for x_n

$$\text{total error} = u_y = \sqrt{\left(\frac{\partial y}{\partial x_1} u_1\right)^2 + \left(\frac{\partial y}{\partial x_2} u_2\right)^2 + \cdots}$$

Intuitively, where does this come from?

$$\text{total error} = u_y = \sqrt{\left(\frac{\partial y}{\partial x_1} u_1\right)^2 + \left(\frac{\partial y}{\partial x_2} u_2\right)^2 + \cdots}$$

- Partial derivative is a "weighting factor" that gives us the importance of that particular term

- Each variable and corresponding error is an independent vector➔adding vectors to get magnitude

A Few More Comments

- We have focused on random errors, which leads to data being a Gaussian distribution→**Precision**
- You can also have systematic errors (**Biased**)?
- What if you have **both precision and biased errors**?

$$u_y = \sqrt{P_y^2 + B_y^2}$$