1 Introduction

First we start with a road map for the course. The subject of **engineering statistics** is defined, its importance is described and basic terminology is introduced.

1.1 What is statistics?

Statistics is the science of collecting, presenting, analyzing, and making decisions from data. Often, as an engineer, it is necessary to **collect and interpret data** that will help in understanding how a new system or product works.

Statistics has applications to engineering through quality control, process control, reliability, risk management, system identification, design of experiments, etc.

Definition 1.1. *Engineering statistics* is the study of how best to

1. collect engineering data,
2. summarize or describe engineering data, and
3. draw formal inference and practical conclusions on the basis of engineering data,

all while recognizing the reality of variation.

We can break down this study into three main tasks:

1. **Summary:** describe, summarize and display data
2. **Inference:** draw conclusions from data
3. **Interpretation:** explain those conclusions in layman's terms (i.e. to people outside of statistics)

Example 1.1 (Heat treating gears, pg. 2). A process engineer is faced with the question, "How should gears be loaded into a continuous carburizing furnace in order to minimize distortion during heat treating?" The engineer conducts a well-thought-out study and obtains the runout values for 38 gears laid and 39 gears hung.

hung	laid
7, 8, 8, 10, 10,	5, 8, 8, 9, 9, 9,
10, 10, 11, 11,	9, 10, 10, 10,
11, 12, 13, 13,	11, 11, 11, 11,
13, 15, 17, 17,	11, 11, 11, 12,
17, 17, 18, 19,	12, 12, 12, 13,
19, 20, 21, 21,	13, 13, 13, 14,
21, 22, 22, 22,	14, 14, 15, 15,
23, 23, 23, 23,	15, 15, 16, 17,
24, 27, 27, 28,	17, 18, 19, 27
31, 36	

Table 1: Thrust face runouts (.0001 in.)

This data, as is, is hard to get insights from. Should the gears be hung or laid? We still cannot tell by looking at the table.

Numerical summaries:

mean laid runout is 12.6 (.0001 in)

mean hung runout is 17.9 (.0001 in)

Variation: within a loading method

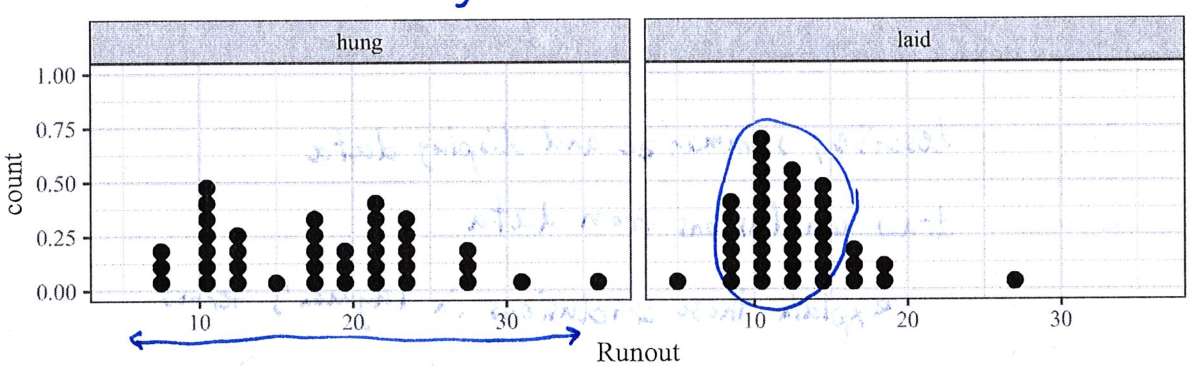


Figure 1: Dot diagrams of runouts.

hung gears more variable than laid gears.

Inference: Runout values are variable, is there any assurance that the difference seen in the present data would reappear in further testing?

Points to need for methods of formal statistical inference from data and translation into practical conclusions. We can use statistical inference to say

1. We are roughly 90% sure that the difference in long-run mean runout produced under conditions like those in the study is in the range 3.2 to 7.4.

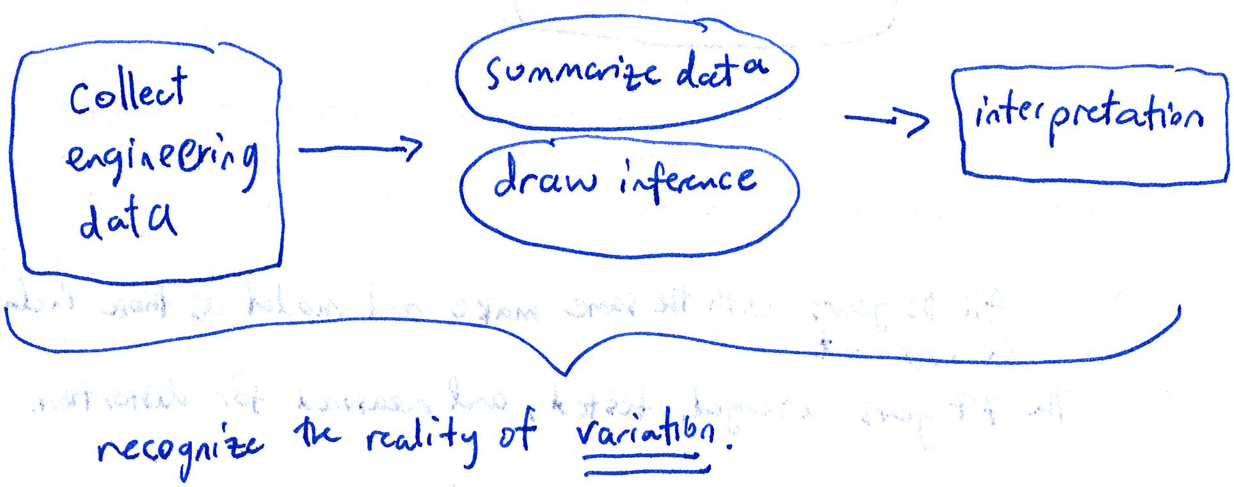
2. We are roughly 95% sure that the difference in long-run mean runout produced under conditions like those in the study is in the range 3.0 to 22.2.

Interpretation: Explains those answers in layman's terms without all the probability theory, symbols and equations.

Combine with other information, such as the consequences of a given amount of runout and the cost for hanging and laying gears

$\Longrightarrow$ apply sound engineering judgement

Overview/schematic:



1.2 Basic terminology

It's important we speak the same language. This section introduces common terminology related to statistical studies, types of data, and types of data structures.

1.2.1 Population vs. sample

Definition 1.2. A *population* is the entire group of objects about which one wishes to gather information in a statistical study.

Definition 1.3. A *sample* is the group of objects on which one actually gathers data.

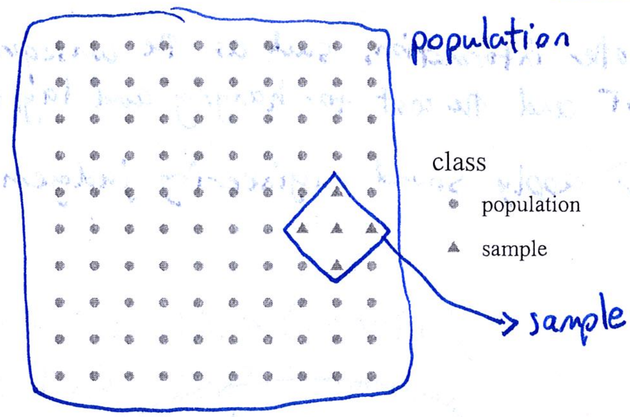


Figure 2: The relationship between a population and a sample. In this example, we have 100 parts and 5 are examined in order to verify acceptibility. Notice we say "one sample", not "five samples".

Example 1.2 (Heat treating gears, cont'd).

Population: All the gears with the same make and model as those included in the experiment.

Sample: The 77 gears arranged, tested, and measured for distortion.

Example 1.3 (Fiscal cliff). On Dec. 1-2, 2012, Gallup conducted a study to find out what proportion of Americans prefer a compromise on the Fiscal Cliff issue. 1000 adults were randomly selected for telephone interviews. The adults were aged 18 and older and living in any of the 50 U.S. states or the District of Columbia.

Population: All Americans in the 50 states or DC aged 18 and older

Sample: 1000 adults who were called.

Example 1.4. Esbit manufactures fuel pellets out of compressed hexamine powder. Suppose a new shipment of 100 pelletizing machines arrives, and the goal of a new study is to determine the quality of this particular new shipment.

5 machines out of the 100 are randomly selected for comprehensive testing in which each produces 200 pellets, and each pellet's mass, volume, flash point, and rate of combustion are measured.

Population: 100 new pelletizing machines in the shipment.

Sample: 5 machines selected for testing

1.2.2 Types of studies

When an engineer **collects data**, (s)he must decide how active to be. Should the engineer manipulate the process or let things happen and record the results?

Definition 1.4. An *experimental study* (or, more simply, an experiment) is one in which the investigator's role is active. Process variables are manipulated, and the study environment is regulated.

Definition 1.5. In a *randomized experiment*, investigators control the assignment of treatments to experimental units using a chance mechanism (like the flip of a coin or a computer's random number generator).