Engineering Statistics
工程统计学

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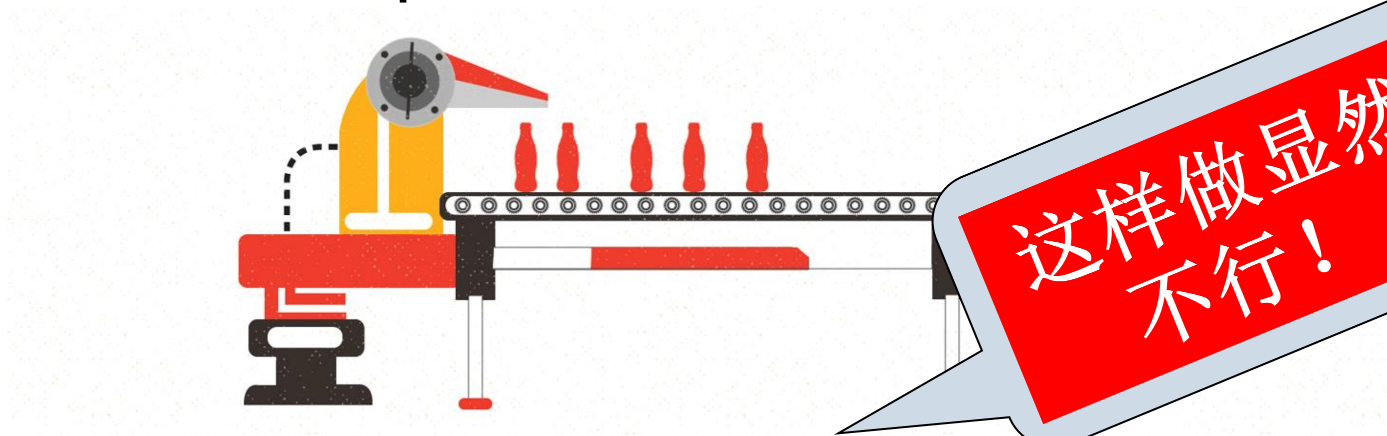
Example 1— Net Volume of Coca-Cola

- The standard net volume of canned Coca-Cola should be between (ml: milliliter)

- Hypothesis test 假设检验
- Statistical process control 统计过程控制

Example 1— Net Volume of Coca-Cola

- Canned cola on the production line is continuously filled and then packaged for shipment.
- How do you know if the capacity of this batch of canned Coke is qualified?

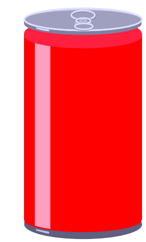


这样做显然不行！

✓ Open each can and pour it into a measuring cup to see whether the capacity conforms to the standard?

Example 1— Net Volume of Coca-Cola

Sampling 抽样检查



- For example, randomly check 5 cans every hour, and get 5 net volume values $X_1,\ldots,X_5$
- How can we make use of these values to obtain the desired conclusion?

Example 2— Statistics and the Ontario Lottery Retailer Scandal

统计数据与安大略省彩票零售商丑闻

“小概率”引发的加拿大彩票历史上的“大事件”

- **In 2006, Jeffrey S. Rosenthal, a professor of statistics at the University of Toronto, was invited by CBC (the Canadian Broadcasting Corporation’s) The Fifth Estate news program to investigate a case of lottery fraud, which opened the long-running Canadian lottery scandal.**

- **Bob Edmonds, a mild-mannered elderly gentleman from the small town of Coboconk, Ontario, Canada. He always played the same lottery numbers, but (like many players) he left it to the store clerk to check if he had won anything. On July 27, 2001, he brought two tickets to his local convenience store.**
- **One of the ticket won him $250,000, but the clerk kept to herself.**

Example 2— Statistics and the Ontario Lottery Retailer Scandal

- When Mr. Edmonds heard about the clerk's win, he realized what had happened. He then spent the next 3.5 years struggling to convince the Ontario Lottery and Gaming Corporation (OLG), the Ontario Provincial Police, and ultimately a court judge of the merits of his case.
- He finally prevailed in March 2005, when the OLG agreed to pay him $200,000 of his winnings, but only on the condition that he promise to keep his case confidential.
- The CBC ascertained (through a Freedom of Information request) that in the period 1999–2006, there were a total of 5,713 major (i.e., $50,000 or more) lottery wins in the province of Ontario.
- Of these 5,713 major wins, about 200 (3.5%) were recorded as being won by lottery retailers, i.e. by people who worked in stores that sold lottery tickets.

The question then became, is 200 wins too many? How many of the 5,713 major prizes should we have expected these sellers to win?

Example 2— Statistics and the Ontario Lottery Retailer Scandal

- The fraction of lottery prizes that we would expect retailers to win should be equal to the fraction of all Ontario lottery tickets that they buy, or (even simpler) the fraction of lottery ticket sales dollars that were spent by retailers.
- 【如果没有欺诈，人们正常期望零售商赢得彩票奖金的所占比，应该大致等于他们付出的金额占所有购买者金额的所占比。】
- Used the upper limit of 60,000 sellers (from the OLG's court testimony), together with the spending factor of 1.5 (from the Fifth Estate survey), then since there were a total of about 8,900,000 adults in Ontario during the time period under review, it followed that we would expect lottery sellers to win approximately
- 在调查进行期间，安大略省总共有大约890万名成年人。如果采用60000名卖家人数的上限和1.5倍的彩票购买系数，预计彩票卖家将赢得大约5713 × 1.5 × 60000/8900000 = 57个奖项，远远低于零售商实际赢得的200个主要奖项

Example 2— Statistics and the Ontario Lottery Retailer Scandal

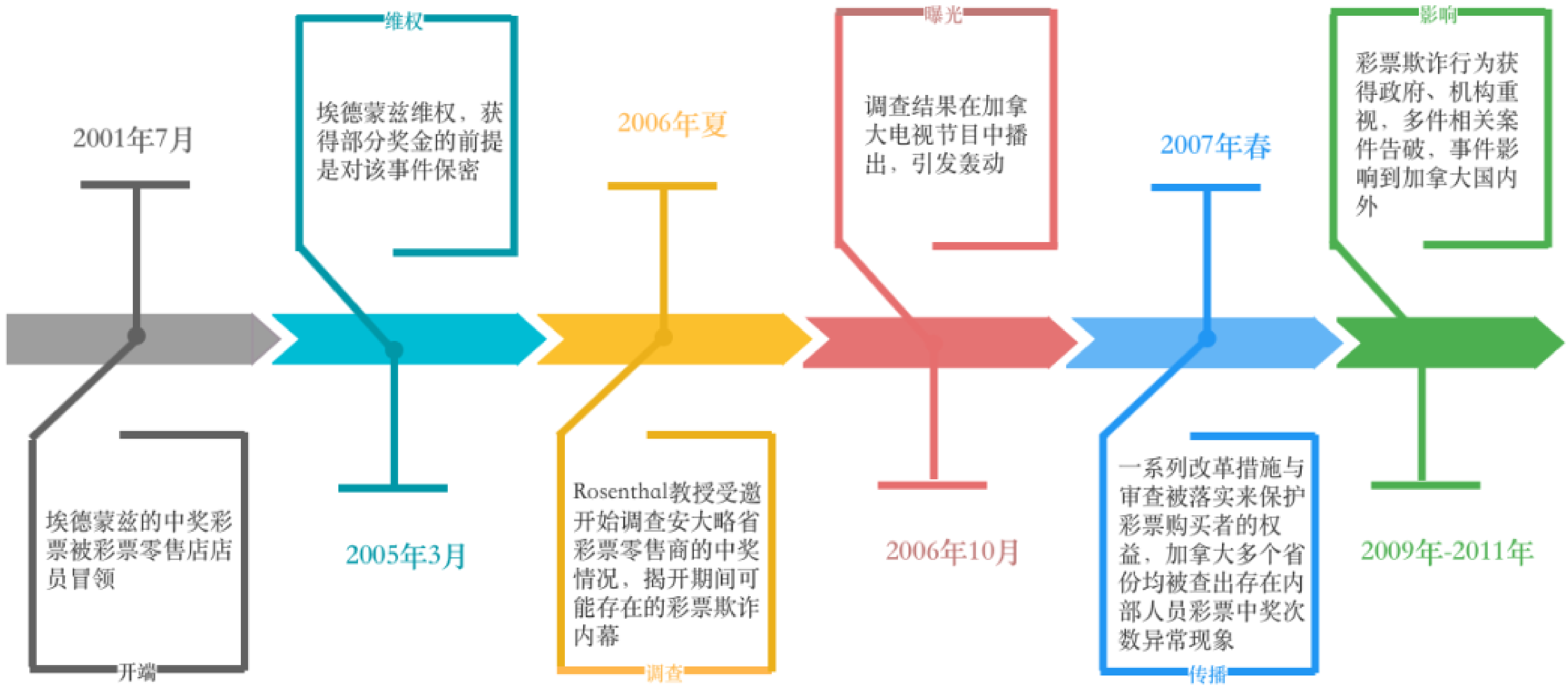
- **Since the number of retailer wins is the result of lots of different tickets, each having a very small probability of winning, this probability distribution should be well approximated by the famous Poisson distribution.**

【由于零售商获奖的彩票来自于**大量**不同种类的彩票，而**每张票的获胜概率都很小**，所以**完全凭借运气赢得彩票大奖的概率分布可以由著名的泊松分布近似**。】

$$P(X=k)=\frac{\lambda^k}{k!}e^{-\lambda}, k=0,1\ldots$$

$$P(X\geqslant 200)=\sum_{n=200}^{\infty}\frac{57^n}{n!}e^{-57}<10^{-48}$$

Example 2— Statistics and the Ontario Lottery Retailer Scandal

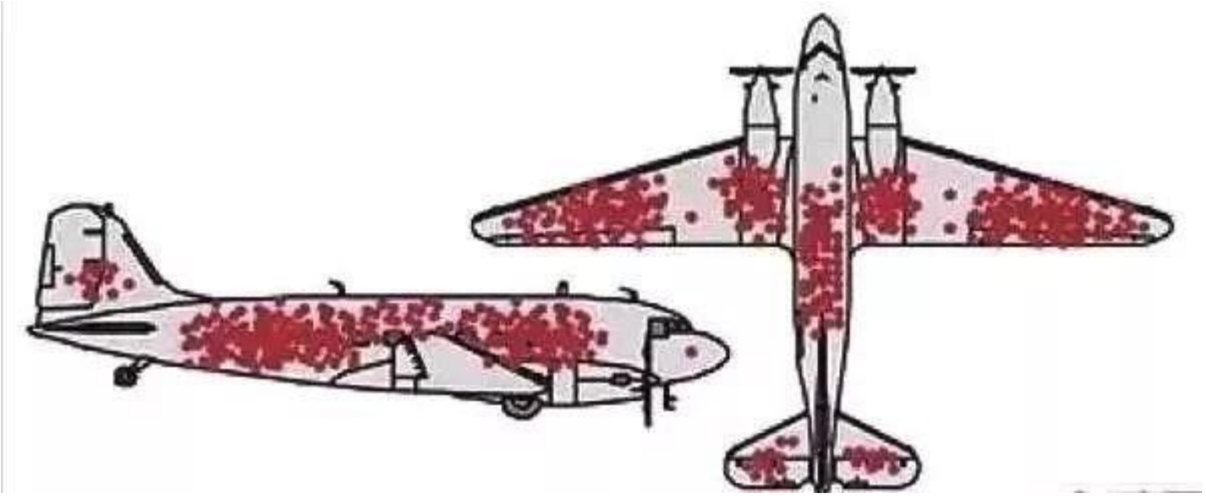


- http://probability.ca/jeff/ftpdir/lotteryart.pdf

Example 3— Survivorship bias

- Around 1940, in the British-German air battle, both sides lost a lot of bombers and pilots. Therefore, a major research topic of the British military department at that time was: which part of the aircraft to thicken the armor can improve the defense capability of the aircraft and reduce losses. 1940年前后，英德空战中，双方损失了大量轰炸机和飞行员。 因此，当时英国军事部门的一个主要研究课题是：飞机的哪个部位加厚装甲，可以提高飞机的防御能力，减少损失。
- The technology was not very mature at that time. If the armor of one part is thickened, it will inevitably reduce the armor of other parts, otherwise it will affect the stability of flight. Therefore, researchers need to make choices to add armor to the most vulnerable areas of the aircraft. 当时的技术还不是很成熟。 如果加厚某一部位的装甲，势必会降低其他部位的装甲，否则会影响飞行的稳定性。 因此，研究人员需要做出选择，为飞机最脆弱的区域增加装甲。

Example 3— Survivorship bias



- The British military at the time studied bombers returning from air battles in continental Europe. As shown in the picture above, the bullet holes on the plane are mainly concentrated in the center of the fuselage and the wings. Therefore, the researchers proposed to add armor to these parts to improve the defense capabilities of the aircraft.
- 当时的英国军方研究了从欧洲大陆的空战中返回的轰炸机。如上图所示，飞机上的弹孔主要集中在机身中央和机翼。因此研究人员提出，在这些部位添加装甲，以提高飞机的防御能力。

Example 3— Survivorship bias

- But statistician Ward proposed that the damage to the wing can be calculated according to the returning aircraft, which shows that the damage to the wing is not fatal to the flight of the aircraft. Most of the crashed bombers should have suffered serious damage to the cockpit and tail. To reduce the crash rate, the cockpit and fuel tank armor must be thickened. So statistician Ward believes that the cockpit and fuel tank should be thickened, and the wing armor should be weakened.而统计学家沃德认为，应当加厚座舱和油舱，减弱机翼装甲。他提出，能够根据返航的飞机统计出机翼的损伤，这正说明机翼的受损对飞机的飞行并不致命。而大部分坠毁的轰炸机应当是座舱和油舱受到了严重损伤。想要减少坠毁率，必须加厚座舱和机尾的装甲。
- Due to the urgency of the battle, the Secretary of the Air Force decided to accept Ward's suggestion and immediately thicken the armor of the cockpit and fuel tank. Soon after, the crash rate of British bombers dropped significantly.

由于战况紧急，空军部长决定接受沃德的建议，立即加厚座舱和油舱的装甲。不久之后，英国轰炸机的坠毁率显著下降。

Example 3— Survivorship bias

- 如果仅仅根据返航的飞机上的弹孔分布，来研究该加强飞机的哪部分时，就忽略掉了“飞机被击落”这个筛选的过程。

- 能返航的飞机都是躲过防空炮火筛选的、没有受过致命伤的。他们多中弹于翼部和尾部，而油箱和驾驶员仓位完好；但凡油箱和驾驶员仓位受伤的飞机，基本没有活着回来的。

- 因此油箱和驾驶员仓位才是真正致命的地方，这些部位受伤的飞机却因为被击落而被筛出研究样本，从而变成了“不会说话的死人”，或“silent data 沉默的数据”。

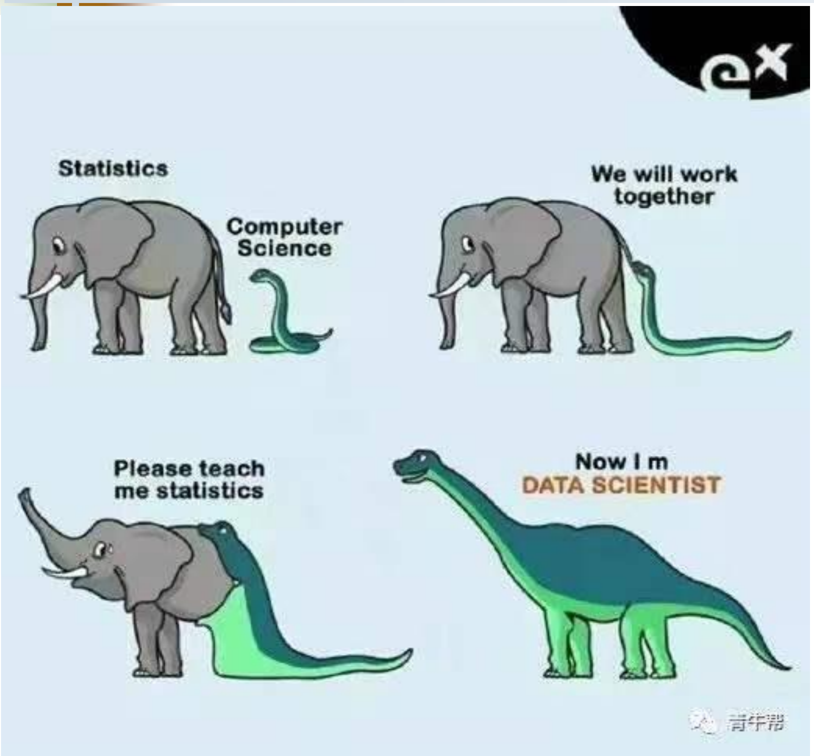
- **——幸存者偏倚（Survivorship bias）是一种常见的逻辑谬误，即只能看到经过某种筛选而产生的结果，而没有意识到筛选的过程，因此忽略了被筛选掉的关键信息。**

再思考：信息茧房、购物推荐机制、…

LEARNING CONTENT

- CHAPTER 1 The Role of Statistics in Engineering
- CHAPTER 2 Data Summary and Presentation
- CHAPTER 3 Random Variables and Probability Distributions
- CHAPTER 4 Decision Making for a Single Sample
- CHAPTER 5 Decision Making for Two Samples
- CHAPTER 6 Building Empirical Models
- CHAPTER 7 Design of Engineering Experiments
- CHAPTER 8 Statistical Process Control

Some extra bonus…



1. Once upon a time, there was a statistician who drowned while crossing a river with an average water level of less than 1 meter deep.

2. There was once a student of statistics who always accelerated at intersections, and then slowed down while driving. One day, he was accompanied by a passenger who was frightened by his driving style and asked why he was driving like that.
The student replied: It's like this, from a statistical perspective, crossroads are accident prone areas, so I want to spend as little time as possible.

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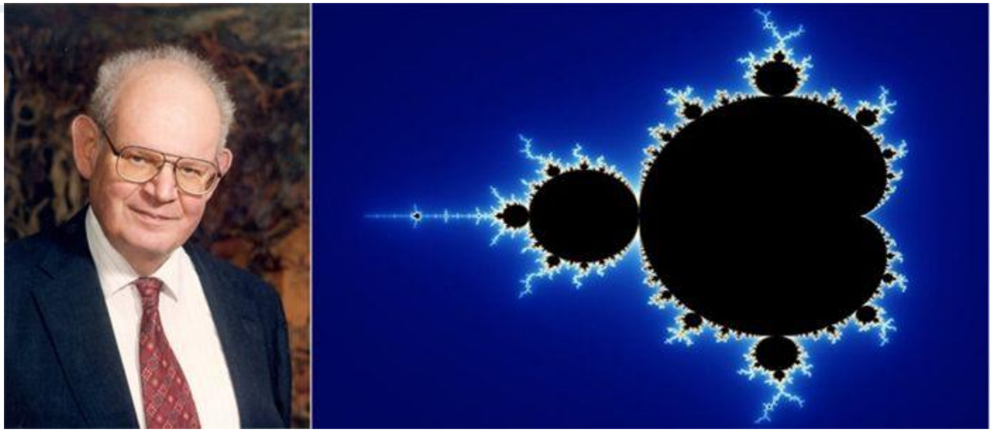
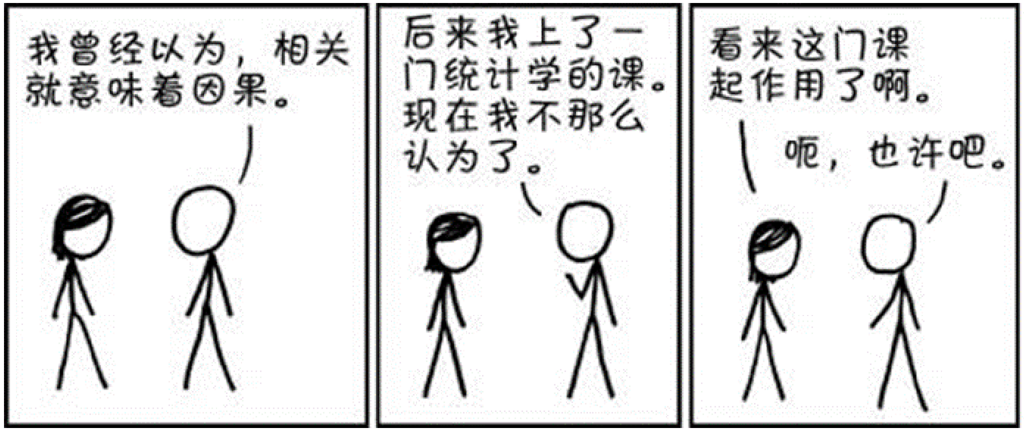
Some extra bonus…

（三）曼德勃罗有一次说，他出生在波兰，但在法国上的学，所以平均而言他是个德国人。

（所以，我出生在广东，但在东北上过学，所以平均而言我是个湖北人……）



分形（ Fractal ）之父(Mandelbrot)
曼德勃罗先生(1924-2010)



1 The Role of Statistics in Engineering

LEARNING OBJECTIVES—Chapter 1

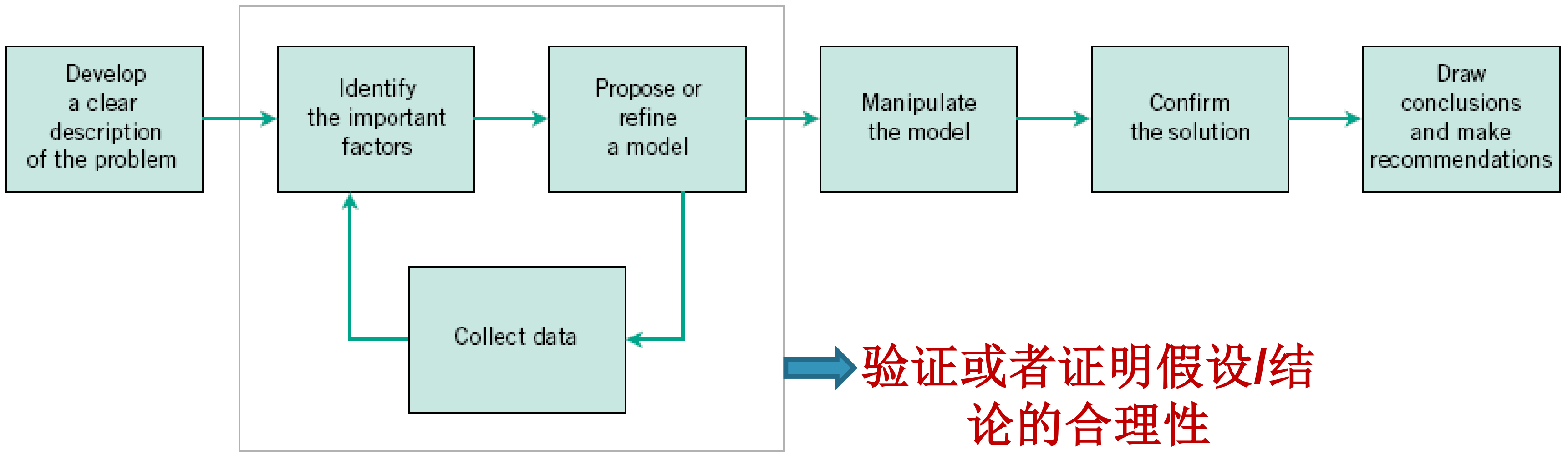
After careful study of this chapter, you should be able to do the following:

1. **Identify the role that statistics can play in the engineering problem-solving process.**
2. **Discuss how variability(变异性) affects data collected and used in making decisions.**
3. **Discuss the methods that engineers use to collect data.**
4. **Explain the importance of random samples(随机样本).**
5. **Identify the advantages of designed experiments(实验设计) in data collection.**
6. **Explain the difference between mechanistic and empirical models(机理模型和经验模型).**
7. **Explain the difference between enumerative and analytic studies(计数性研究和分析型研究).**

Α α **Alpha** 阿尔法	Β β **Beta** 贝塔	Γ γ **Gamma** 伽玛	Δ δ **Delta** 德尔塔	Ε ε **Epsilon** 艾普西龙	Ζ ζ **Zeta** 捷塔
Η η **Eta** 依塔	Θ θ **Theta** 西塔	Ι ι **Iota** 艾欧塔	Κ κ **Kappa** 喀帕	Λ λ **Lambda** 拉姆达	Μ μ **Mu** 缪
Ν ν **Nu** 拗	Ξ ξ **Xi** 克西	Ο ο **Omicron** 欧麦克轮	Π π **Pi** 派	Ρ ρ **Rho** 柔	Σ σ **Sigma** 西格玛
Τ τ **Tau** 套	Υ υ **Upsilon** 宇普西龙	Φ φ **Phi** 服艾	Χ χ **Chi** 器	Ψ ψ **Psi** 普赛	Ω ω **Omega** 欧米伽

1-1 The Engineering Method and Statistical Thinking

- Engineers solve problems of interest to society by the efficient application of **scientific principles**
- The **engineering** or **scientific method** is the approach to formulating and solving these problems.



验证或者证明假设/结论的合理性

Figure 1-1 The engineering problem-solving method.

1-1 The Engineering Method and Statistical Thinking

The Field of Probability

- Used to quantify likelihood or chance
- Used to represent risk or uncertainty in engineering applications
- Can be interpreted as our degree of belief or relative frequency

1-1 The Engineering Method and Statistical Thinking

The field of statistics deals with the collection, presentation, analysis, and use of data to

- Make decisions
- Solve problems
- Design products and processes

统计学这一领域涉及数据收集、数据描述、数据分析和利用数据来做出决策和解决问题。

1-1 The Engineering Method and Statistical Thinking

- Statistical techniques are useful for describing and understanding variability(变异性).
- By variability, we mean successive observations of a system or phenomenon do *not* produce exactly the same result.（连续观察一个系统或现象并不能得到完全相同的结果）
- Statistics gives us a framework for describing this variability and for learning about potential sources of variability（变异性来源）.

1-1 The Engineering Method and Statistical Thinking

Engineering Example

- Suppose that an engineer is developing a rubber compound(橡胶复合物) for use in O-rings(闭合环). The O-rings are to be employed as seals(密封条) in plasma etching(乳胶蚀刻) tools used in the semiconductor industry, so their resistance to acids and other corrosive substances(抗酸性和其它防腐蚀性) is an important characteristic.
- The engineer uses the standard rubber compound to produce eight O-rings in a development laboratory and measures the tensile strength(抗张强度) of each specimen after immersion(浸泡) in a nitric acid solution(硝酸溶液) at 30° C for 25 minutes.
- The tensile strengths (in psi千帕) of the eight O-rings are 1030, 1035, 1020, 1049, 1028, 1026, 1019, and 1010.

1-1 The Engineering Method and Statistical Thinking

Engineering Example

- The dot diagram is a very useful plot for displaying a small body of data（少量数据）- say up to about 20 observations（最多20个）.
- This plot allows us to see easily two features of the data; the location（中心位置）, or the middle（中位数）, and the scatter（分散程度） or variability（变异性）.

Figure 1-2 Dot diagram of the O-ring tensile strength data for the original rubber compound.

1-1 The Engineering Method and Statistical Thinking

Engineering Example

- The **dot diagram** is also very useful for comparing sets of data.

改进配方

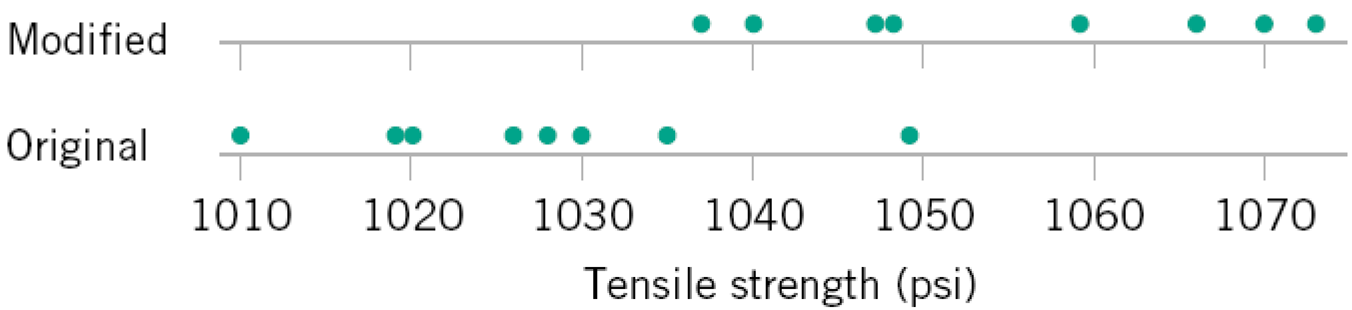


Figure 1-3 Dot diagram of O-ring tensile strength data for the original and modified rubber compounds.

新的问题：1.另一组样品是否会给出不同的结果？2. 8个样本的结果可信吗？3. 究竟是随机性还是改进的配方影响了实验结果？

1-1 The Engineering Method and Statistical Thinking

Engineering Example

- Since tensile strength varies or exhibits variability（变异性）, it is a random variable（随机变量）.
- A random variable, X, can be model by

$$X = \mu + \varepsilon$$

where μ is a constant and ε a random disturbance（随机扰动或者噪声）.

注：如果不存在扰动，则**ε=0**，**X**的值总是等于μ，但工程实践中不可能实现。

→描述变异性、量化变异和最终减少变异。

1-1 The Engineering Method and Statistical Thinking

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从一般定理到实际例子的推理 ☑

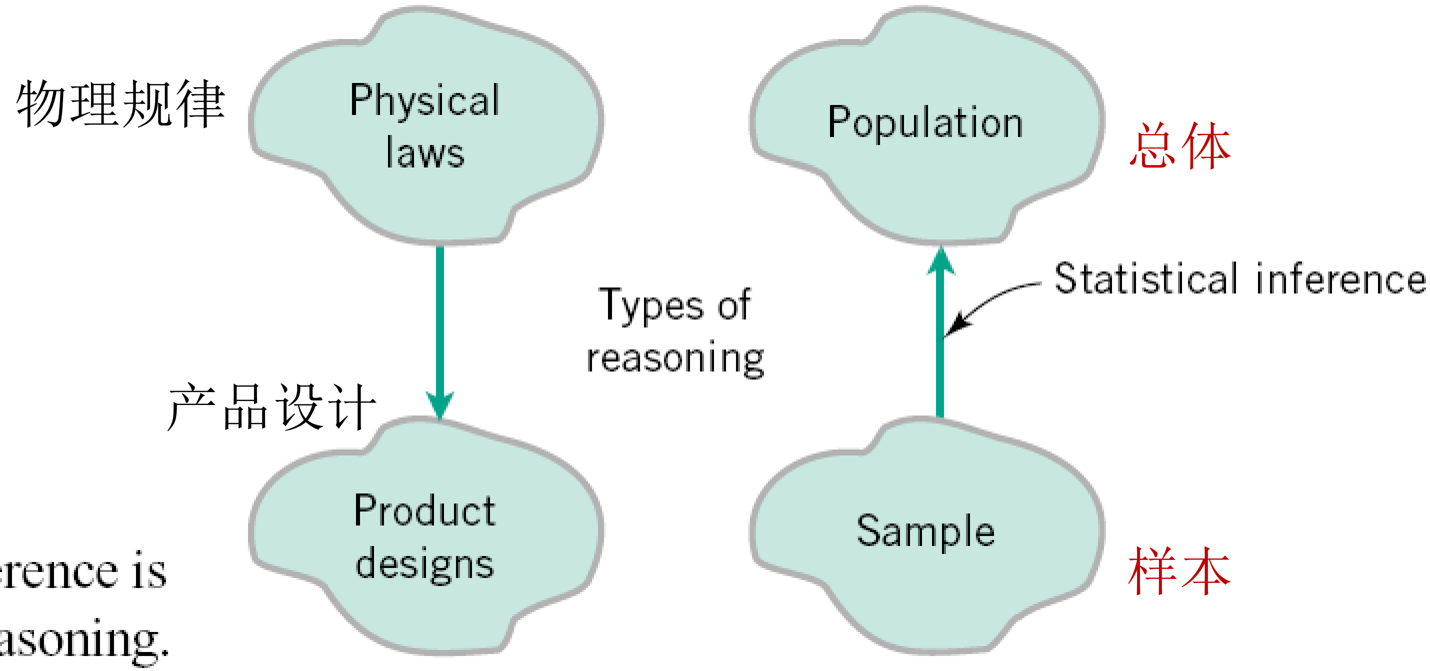

Figure 1-4
Statistical inference is one type of reasoning.

从样本到总体→统计推断☑

1-1 The Engineering Method and Statistical Thinking

Three basic methods for collecting data:

- A **retrospective（回顾性）** study using historical data（历史数据）
- An **observational** study（观察研究）
- A **designed experiment** （设计实验）

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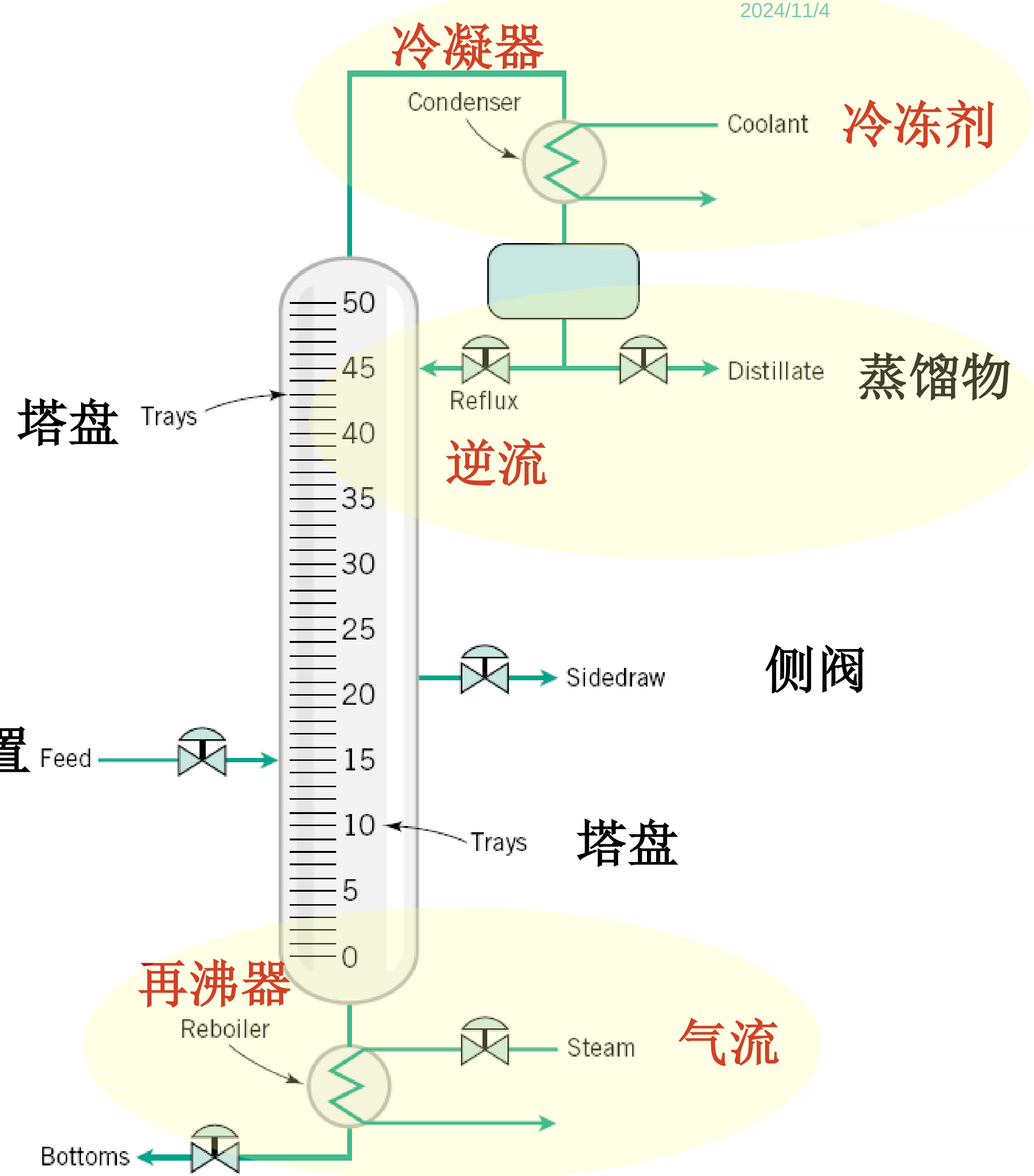


Figure 1-5 Acetone-butyl alcohol distillation column.

丙酮丁醇分裂蒸馏塔

1-2 Collecting Engineering Data

1-2.1 Retrospective Study

- A retrospective study uses either all or a sample of the historical process data from some period of time. （一段时间内所有历史数据或者从中抽取的样本数据）
- The objective of this study might be to determine the relationships among the two temperatures and the reflux rate on the acetone concentration in the output product stream. （两种温度和逆流速度与输出的液流中丙酮浓度之间的关系）
- In most such studies, the engineer is interested in using the data to **construct a model** relating the variables of interest.
- For example, in this case the model might relate acetone concentration (the dependent variable因变量) to the three independent variables（自变量）, reboil temperature（再沸温度）, condenser temperature（冷凝温度）, and reflux rate（逆流速度）.
- These types of models are called **empirical models**（经验模型）, and they are illustrated in more detail in Section 1-3.

1-2 Collecting Engineering Data

1-2.1 Retrospective Study

- Retrospective studies, although often the quickest and easiest way to collect engineering process data, often provide limited useful **information** for controlling and analyzing a process. 搜集数据过程最快最简单，但对控制和分析过程提供的有用信息很有限。
- Using historical data always involves **the risk** that, for whatever reason, some of the important data were not collected or were lost or were **inaccurately transcribed or recorded**. Consequently, historical data often suffer from problems with **data quality**. These errors also make historical data **prone to outliers**. 一些重要的数据没有搜集到，或被不正确地转录或记录
- Just because data are convenient to collect **does not mean** that these data are useful. Often, data that are not considered essential for routine process monitoring and that are not convenient to collect have a significant impact on the process。搜集数据方便并不意味这些数据是有用的；往往有重要影响的数据在常规监测中很难或者未被收集到。

1-2 Collecting Engineering Data

1-2.2 Observational Study

An observational study simply observes the process of population during a period of routine operation. （简单地观察一段常规操作中地过程或总体）

Drawbacks:

1. 不能直接用来建模、不能用来验证
2. 有可能涉及巨大的数据集

1-2 Collecting Engineering Data

1-2.3 Designed Experiments

- In a designed experiment, the engineer makes deliberate or purposeful changes **in controllable variables** (called **factors因子**) of the system, observes the resulting system output, and then **makes a decision or an inference** about which variables are **responsible for** the changes that he or she observes in the output performance. 特意或有目的地改变系统中的控制变量，观察系统输出结果，对哪些变量引起了观测结果中的变异而做出结论或者推断。

- Statistical techniques called **hypothesis testing（假设检验）** and **confidence intervals（置信区间）** can be used to make this comparison.

1-2 Collecting Engineering Data

1-2.3 Designed Experiments

- Factorial experiment（析因实验）

The distillation column problem. Three factors: the two temperatures and the reflux rate. The experimental design must ensure that we can **separate out the effects of these three factors on the response variable**, the concentration of acetone in the output product stream. （实验设计必须能分离出三个因子对响应变量的影响）

1-2 Collecting Engineering Data

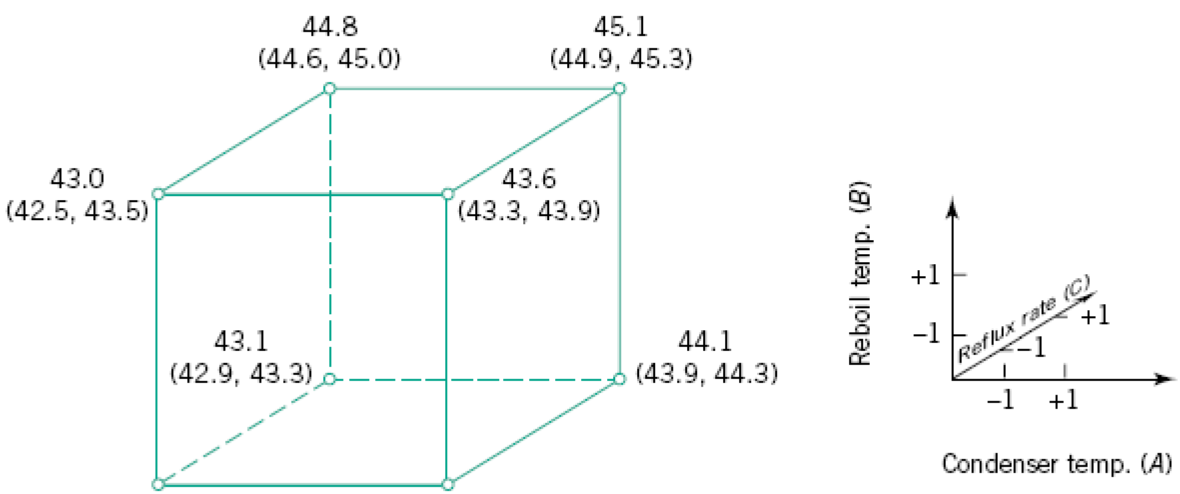
1-2.3 Designed Experiments

- Factorial experiment（析因实验）

In a designed experiment, often only two or three levels of each factor are employed. Suppose that two levels of the temperatures and the reflux rate are used and that each level is coded to +1，-1 (or low, high) level.

The best experimental strategy to use when there are several factors of interest is to conduct a **factorial experiment**.

1-2 Collecting Engineering Data



(a) Geometric view

	Factors		
Run	A	B	C
1	−	−	−
2	+	−	−
3	−	+	−
4	+	+	−
5	−	−	+
6	+	−	+
7	−	+	+
8	+	+	+

(b) Design or test matrix

Figure 1-6 A factorial design for the distillation column.

Replicates （反复/重复）：每种2次，共16次

1-2 Collecting Engineering Data

Rate	Temp.	Avg. Conc.
–1	–1	43.25
–1	+1	43.30
+1	–1	43.60
+1	+1	44.95

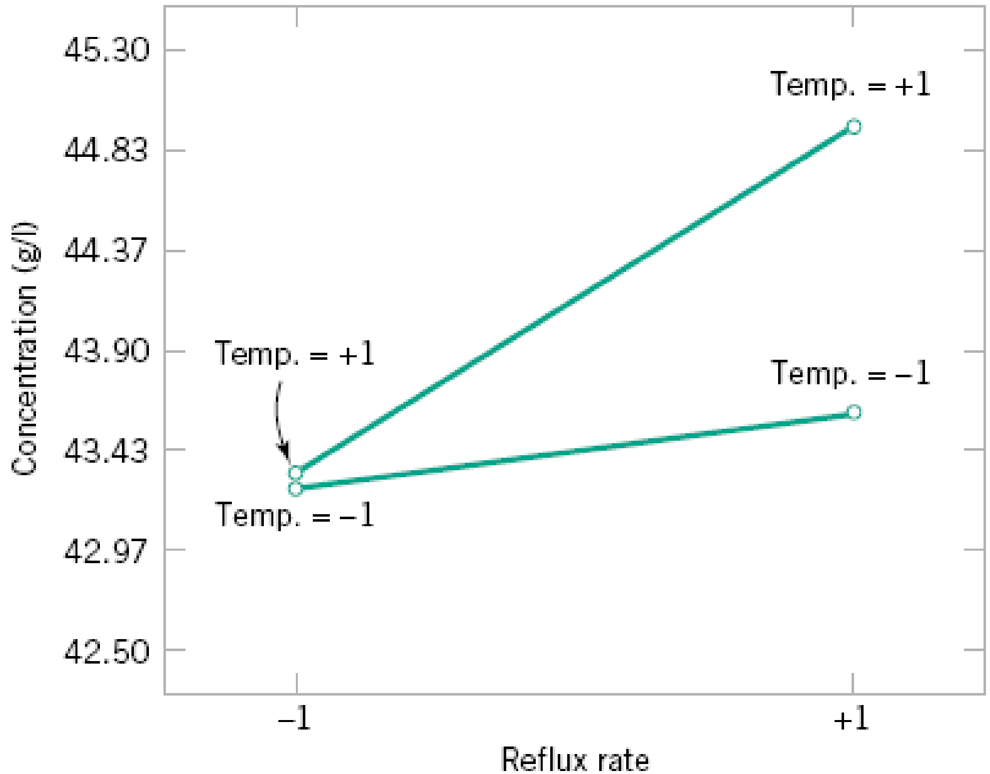


Figure 1-7 The two-factor interaction between reflux rate and reboil temperature.

Interaction（交互作用）：因子间存在交互作用，需被注意

1-2 Collecting Engineering Data

1-2.3 Designed Experiments

- Factorial experiment（析因实验）
- Replicates （反复/重复）
- Interaction（交互作用）
- Fractional factorial experiment （部分析因实验）
- One-half fraction（二分之一部分）

1-2 Collecting Engineering Data

1-2.4 Random Samples

A **simple random sample** of size n is a sample that has been selected from a population in such a way that each possible sample of size n has an equally likely chance of being selected.

【定义】样本量为n的简单随机样本就是从总体中按如下规则选择样本：每一个样本量为n的样本都有相等的机会被选择。

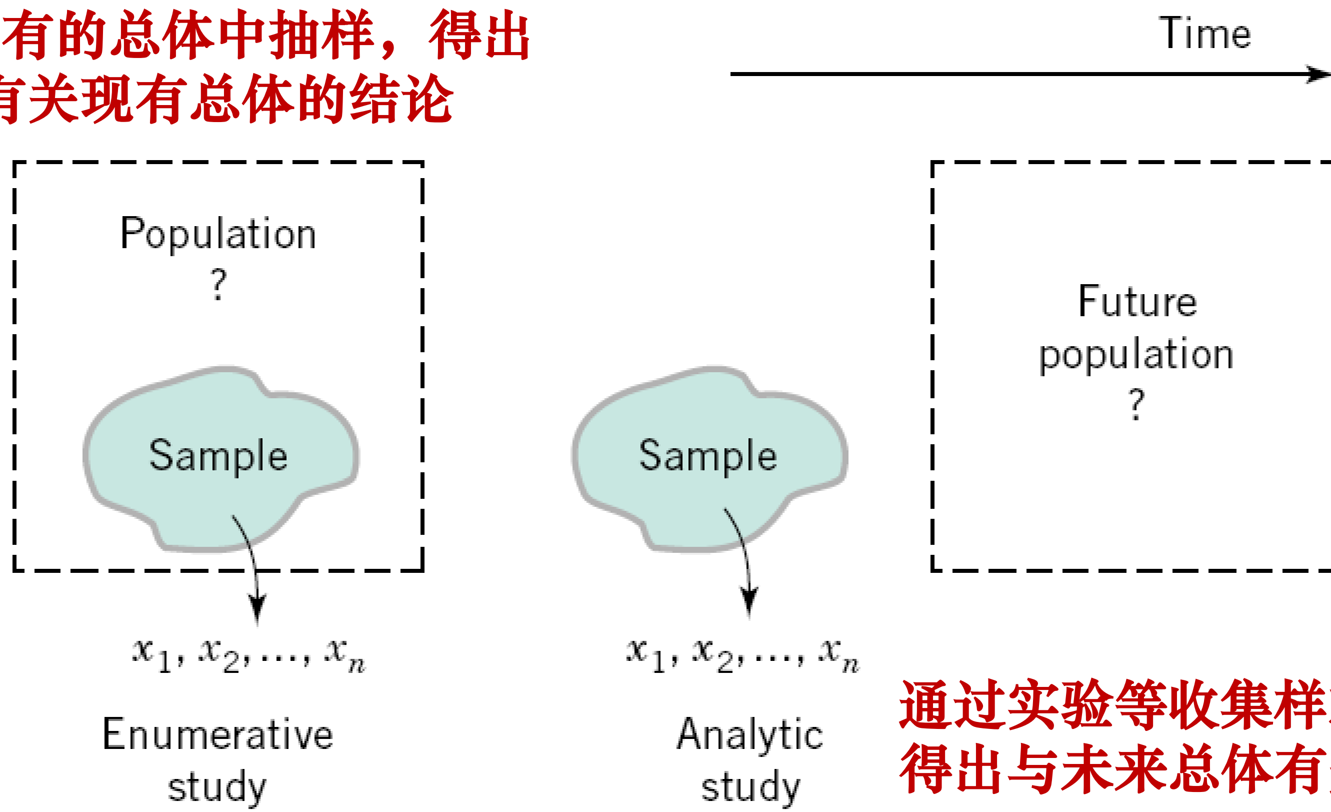
1-2 Collecting Engineering Data

1-2.4 Random Samples

从现有的总体中抽样，得出有关现有总体的结论

计数型研究

分析型研究



通过实验等收集样本数据，得出与未来总体有关的结论

Figure 1-10 Enumerative versus analytic study.

1-3 Mechanistic and Empirical Models

A **mechanistic model** is built from our underlying knowledge of the basic physical mechanism that relates several variables.（基于已有的与这些变量相关的基本物理原理而构造）

Example: Ohm's Law

Current = voltage/resistance

电流 = 电压/电阻

$$I = E/R$$

$$I = E/R + \varepsilon$$

1-3 Mechanistic and Empirical Models

Sometimes engineers work with problems for which there is no simple or well-understood mechanistic model that explains the phenomenon.（当没有简单的现成的机理模型能够解释现象时)

An **empirical model** is built from our engineering and scientific knowledge of the phenomenon, but is not directly developed from our theoretical or first-principles understanding of the underlying mechanism.（用到了现象的工程学与科学知识，但这并不是从我们的理论或者对潜在的机理模型的第一理解而直接得到）

1-3 Mechanistic and Empirical Models

Example of an Empirical Model

Suppose we are interested in the number average molecular weight (M_n) of a polymer（聚合物的平均分子质量）. Now we know that M_n is related to the viscosity（黏性） of the material (V), and it also depends on the amount of catalyst (C，催化剂) and the temperature (T) in the polymerization reactor（聚合反应）when the material is manufactured. The relationship between M_n and these variables is $M_n = f(V,C,T)$

say, where the *form* of the function f is unknown.

$$M_n = \beta_0 + \beta_1 V + \beta_2 C + \beta_3 T + \epsilon$$

where the β's are unknown parameters.

1-3 Mechanistic and Empirical Models

线状结合体

Table 1-1 Wire Bond Data

Observation Number	Pull Strength, y	Wire Length, x_1	Die Height, x_2	Observation Number	Pull Strength, y	Wire Length, x_1	Die Height, x_2
1	9.95	2	50	14	11.66	2	360
2	24.45	8	110	15	21.65	4	205
3	31.75	11	120	16	17.89	4	400
4	35.00	10	550	17	69.00	20	600
5	25.02	8	295	18	10.30	1	585
6	16.86	4	200	19	34.93	10	540
7	14.38	2	375	20	46.59	15	250
8	9.60	2	52	21	44.88	15	290
9	24.35	9	100	22	54.12	16	510
10	27.50	8	300	23	56.63	17	590
11	17.08	4	412	24	22.13	6	100
12	37.00	11	400	25	21.15	5	400
13	41.95	12	500				
	拉拔强度	金属丝长度	模子高度		拉拔强度	金属丝长度	模子高度

1-3 Mechanistic and Empirical Models

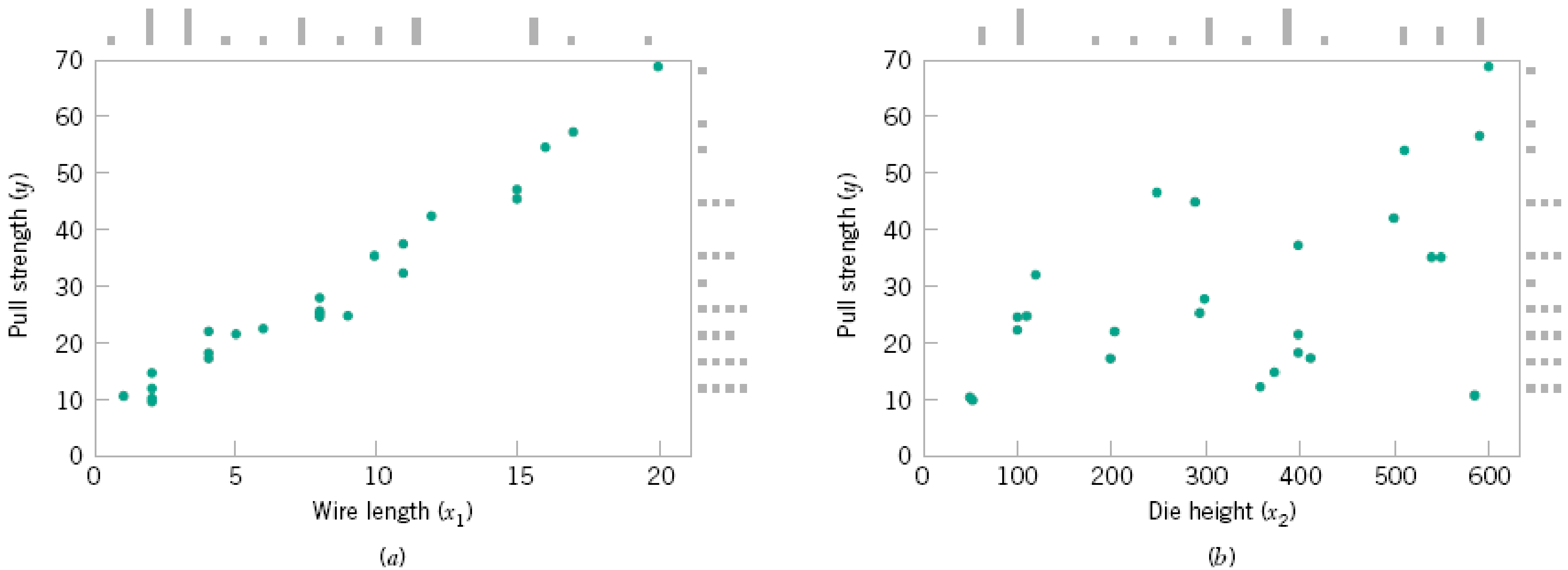


Figure 1-11 Scatter plots of the wire bond pull strength data in Table 1-1.

散点图：二维点图

1-3 Mechanistic and Empirical Models

$$\text{Pull strength} = \beta_0 + \beta_1(\text{wire length}) + \beta_2(\text{die height}) + \epsilon$$

In general, this type of empirical model is called a **regression model（回归模型）.**

The **estimated** regression line is given by

$$\widehat{\text{Pull strength}} = 2.26 + 2.74(\text{wire length}) + 0.0125(\text{die height})$$

∧：该符号表示估计量

- **"Please give me a copper coin", a beggar stopped a statistical expert from the Ministry of Finance in Parliament Square and said," I haven't eaten anything for three days".**
- **"Ah", the statistical expert asked kindly," how does it compare to the same period last year"?**

- A statistician met a mathematician and joked with him, saying:

----Didn't you say that if X=Y and Y=Z, then X=Z! So surely if you like a girl, then you will also like the boy that girl likes!? "

- The mathematician thought for a moment and asked,
- ----“So you can put your left hand in a pot of boiling water that is one hundred degrees and your right hand in a pot of ice water that is at zero degrees.

----It‘s probably okay! Because their average temperature is only fifty degree”

1-3 Mechanistic and Empirical Models

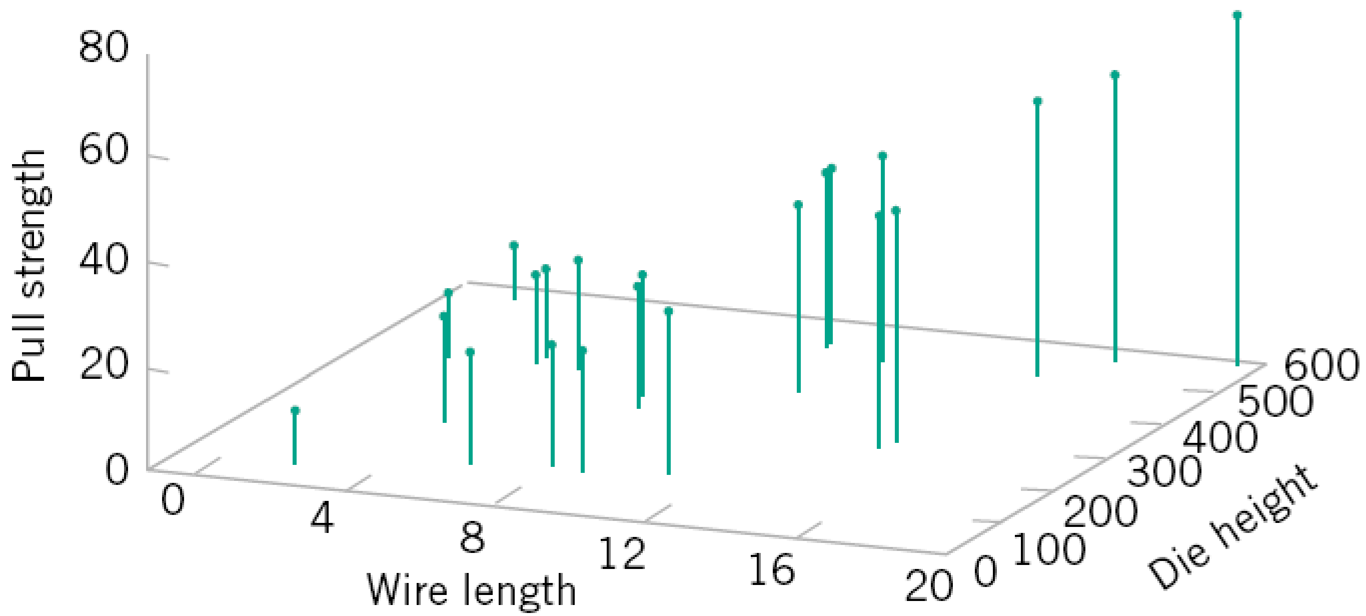


Figure 1-12 Three-dimensional scatter diagram of the wire and pull strength data.

1-3 Mechanistic and Empirical Models

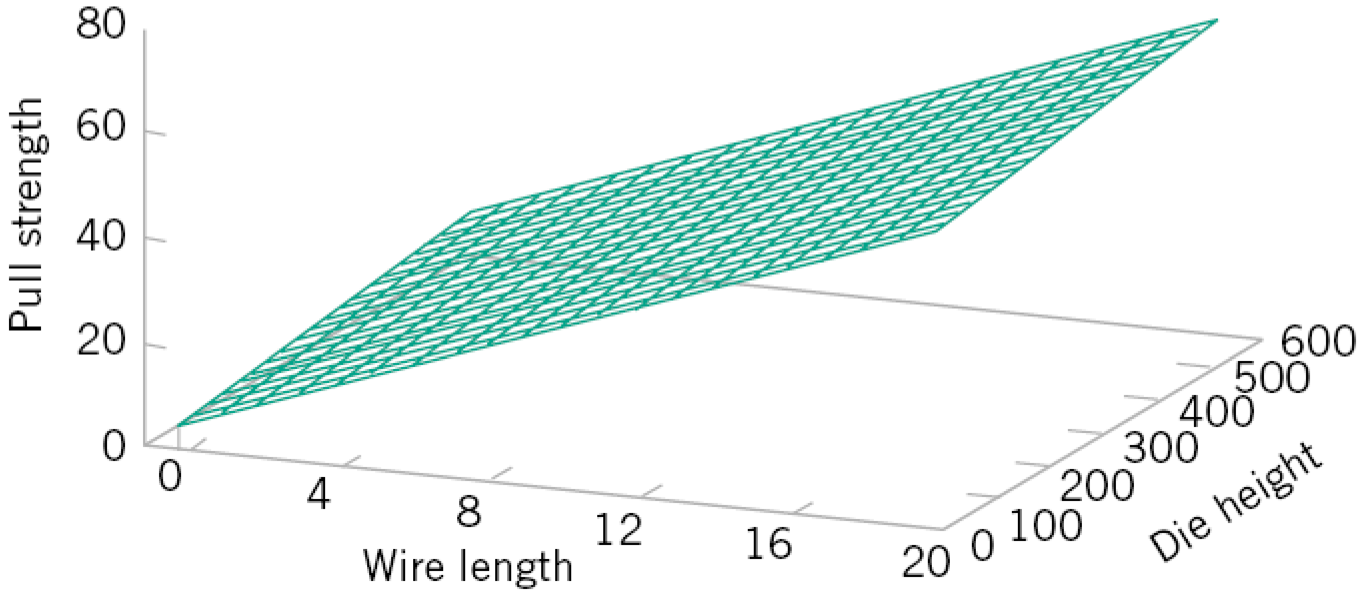


Figure 1-13 Plot of estimated values of pull strength from the empirical model in equation 1-6.

1-4 Observing Processes Over Time 按时间顺序观察过程

Whenever data are collected over time it is important to plot the data over time. Phenomena that might affect the system or process often become more visible in a time-oriented plot and the concept of stability can be better judged. 以时间顺序展示出来的数据，使得影响系统或流程的现象变得容易发现，也能更好地调整系统的稳定性。

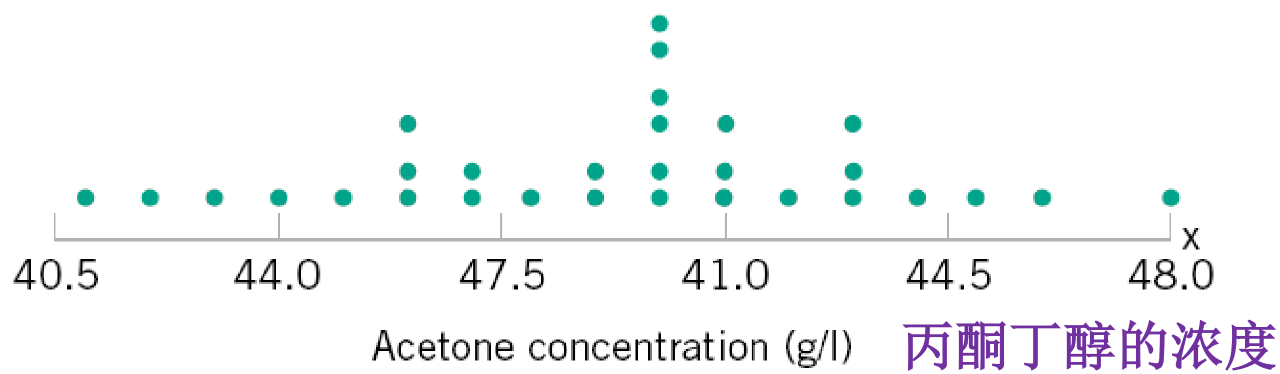


Figure 1-14 A dot diagram illustrates variation but does not identify the problem.

1-4 Observing Processes Over Time

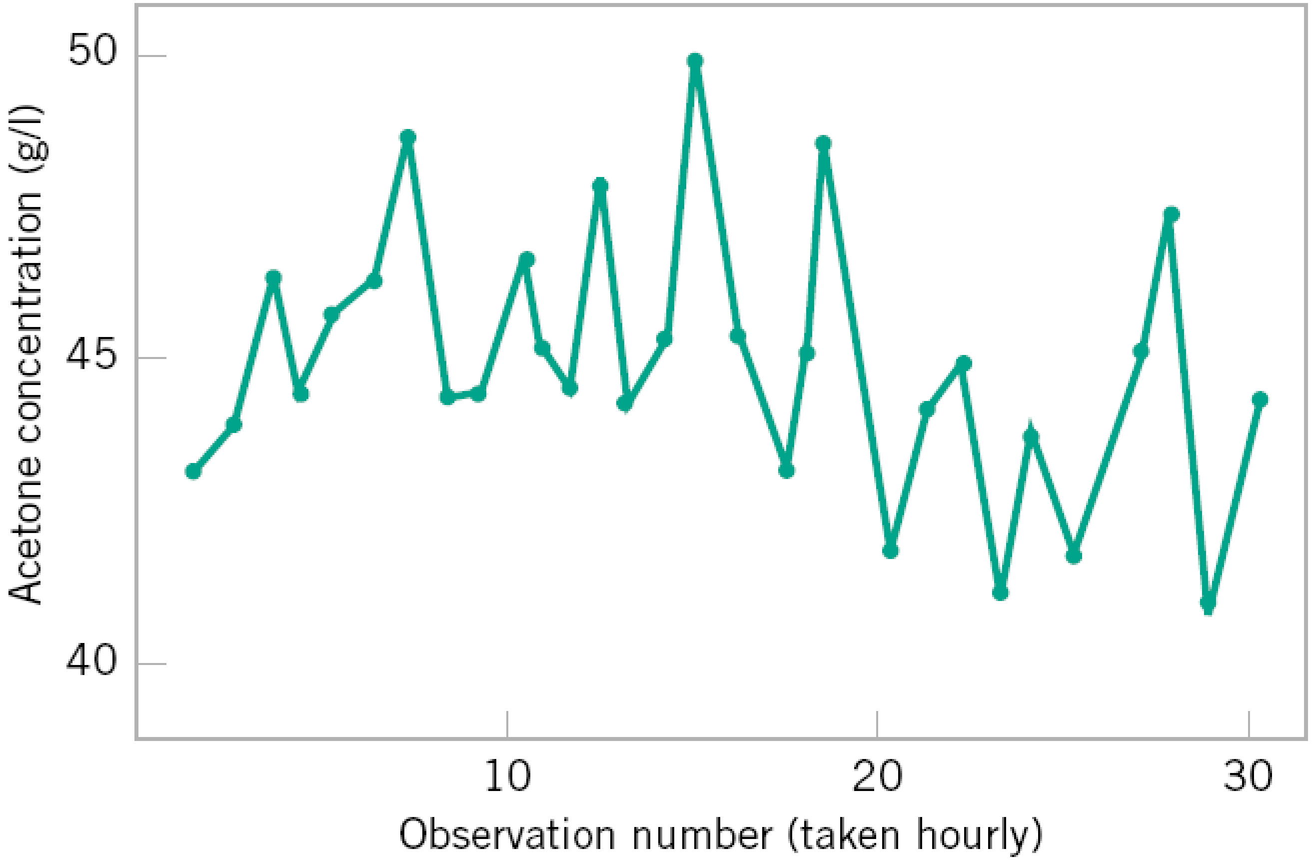


Figure 1-15 A time series plot of acetone concentration provides more information than the dot diagram. 丙酮丁醇

1-4 Observing Processes Over Time

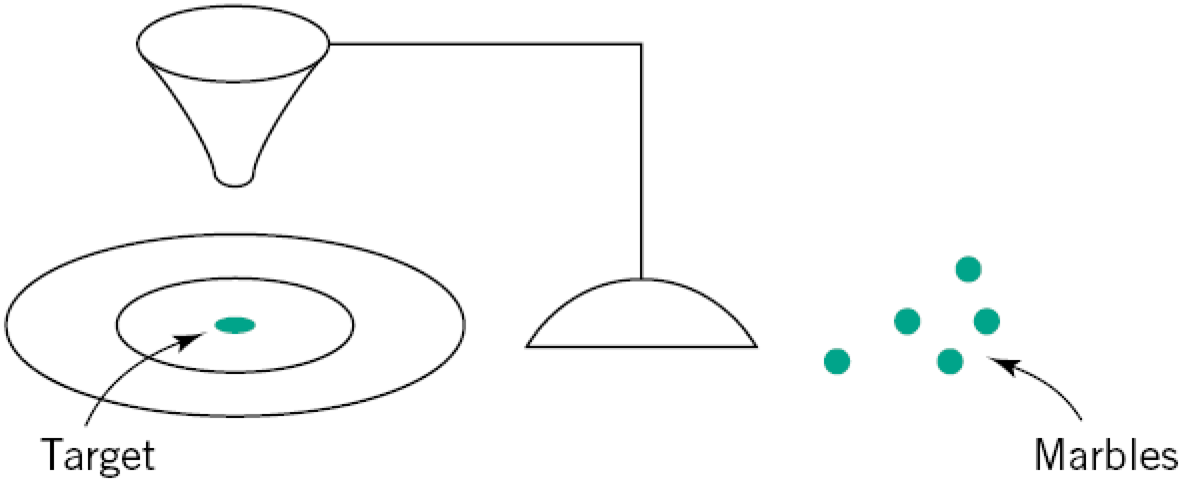


Figure 1-16
Deming's funnel experiment.

The famous quality authority W. Edwards Deming

1-4 Observing Processes Over Time

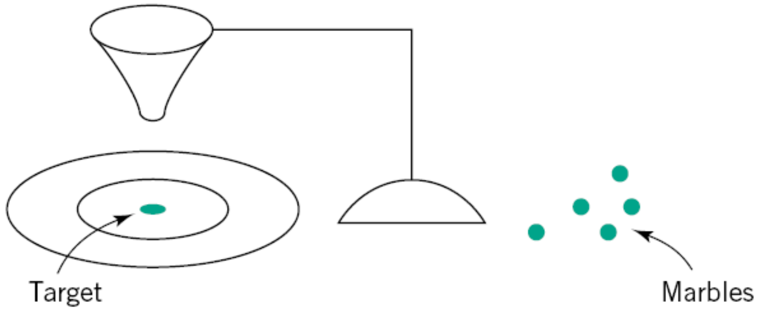


Figure 1-16
Deming's funnel experiment.

The famous quality authority W. Edwards Deming stressed that it is important to understand the nature of variation in processes over time. He conducted an experiment in which he attempted to drop marbles as close as possible to a target on a table. He used a funnel mounted on a ring stand and the marbles were dropped into the funnel. See Fig. 1-16. The funnel was aligned as closely as possible with the center of the target. Deming then used two different strategies to operate the process. (1) He never moved the funnel. He simply dropped one marble after another and recorded the distance from the target. (2) He dropped the first marble and recorded its location relative to the target. He then moved the funnel an equal and opposite distance in an attempt to compensate for the error. He continued to make this type of adjustment after each marble was dropped.

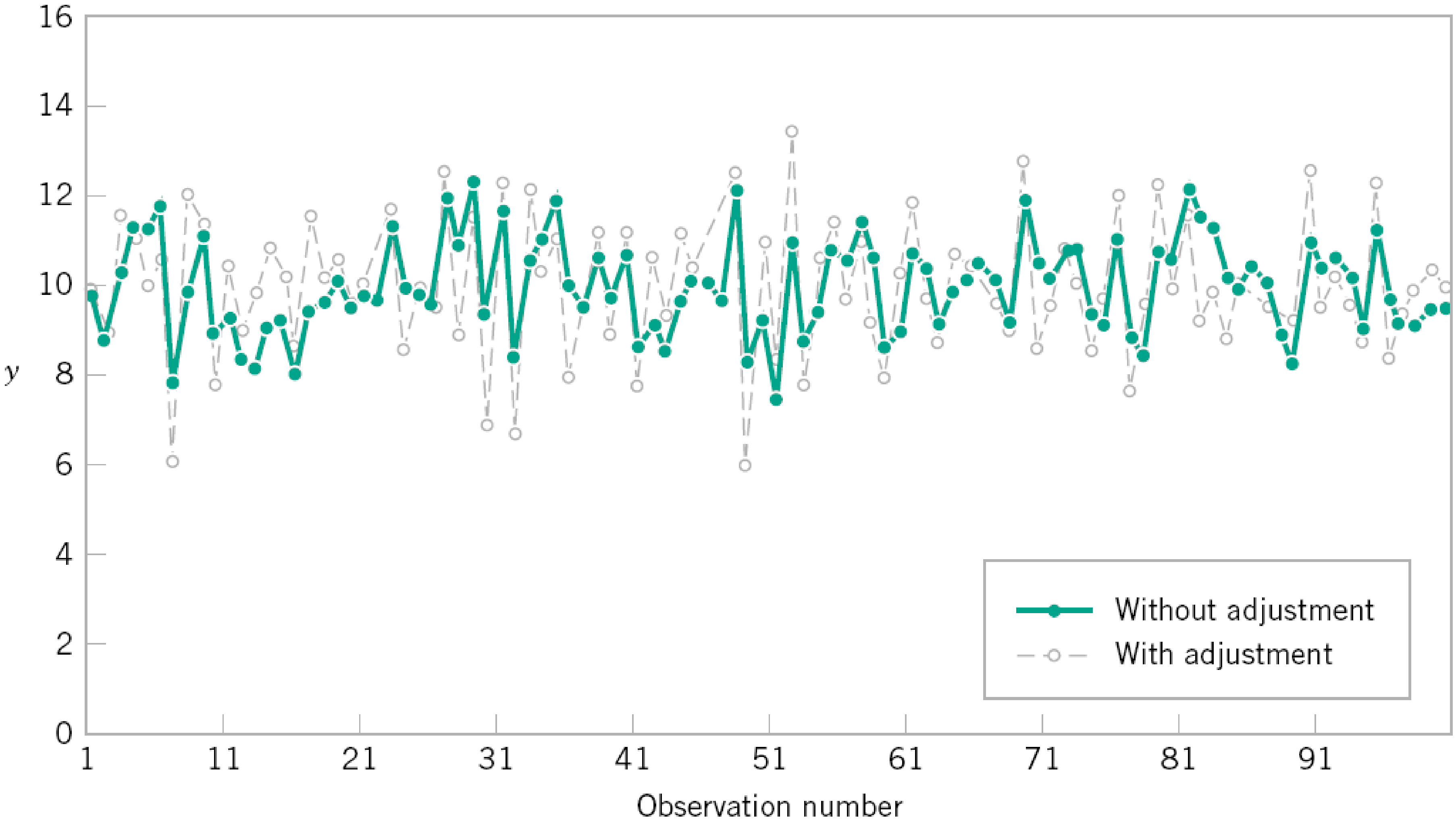
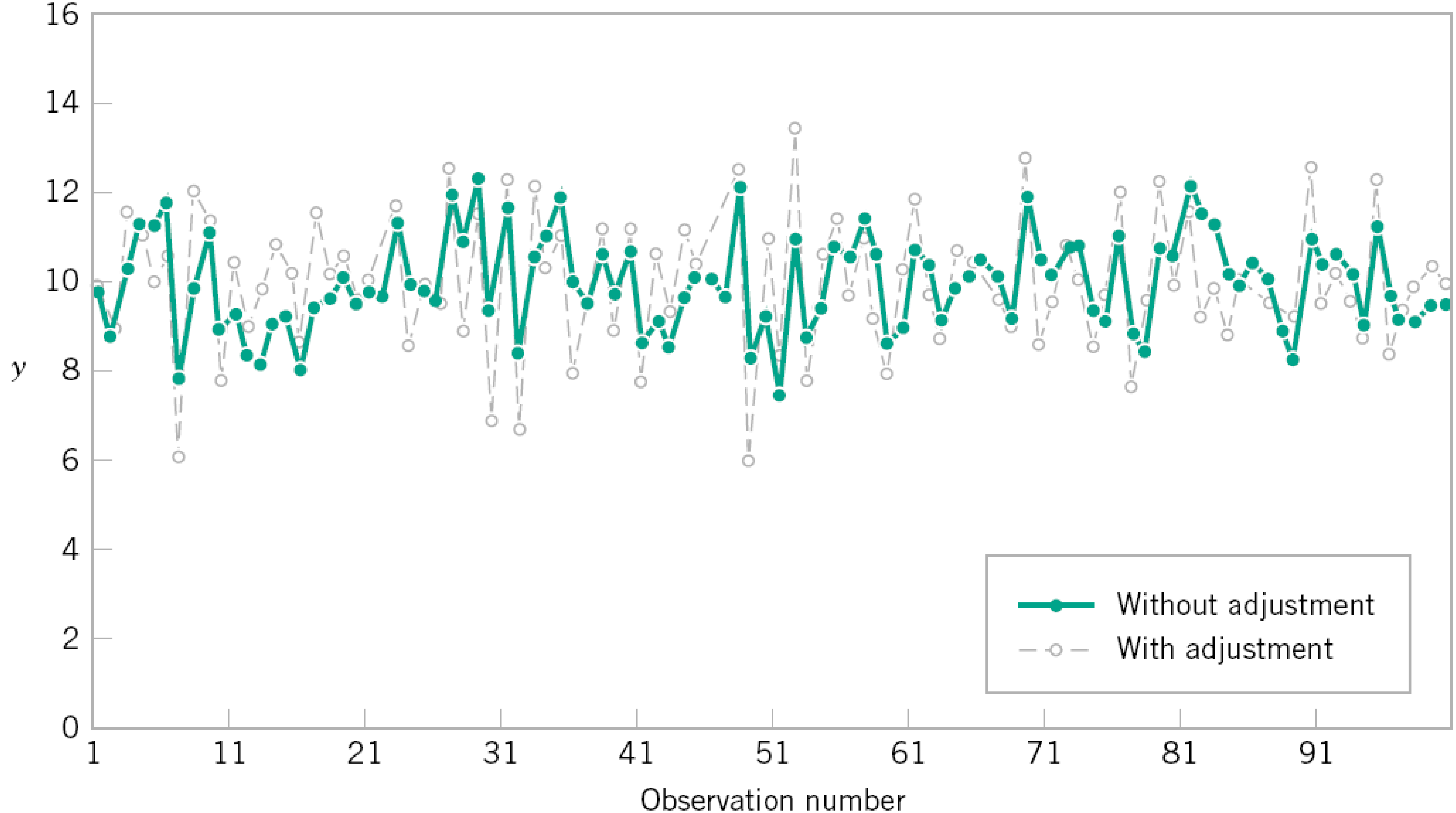


Figure 1-17 Adjustments applied to random disturbances overcontrol the process and increase the deviations from the target.

After both strategies were completed, Deming noticed that the variability in the distance from the target for strategy 2 was approximately twice as large as for strategy 1. The adjustments to the funnel increased the deviations from the target. The explanation is that the error



(the deviation of the marble's position from the target) for one marble provides no information about the error that will occur for the next marble. Consequently, adjustments to the funnel do not decrease future errors. Instead, they tend to move the funnel farther from the target.

This interesting experiment points out that adjustments to a process based on random disturbances can actually *increase* the variation of the process. This is referred to as **overcontrol**

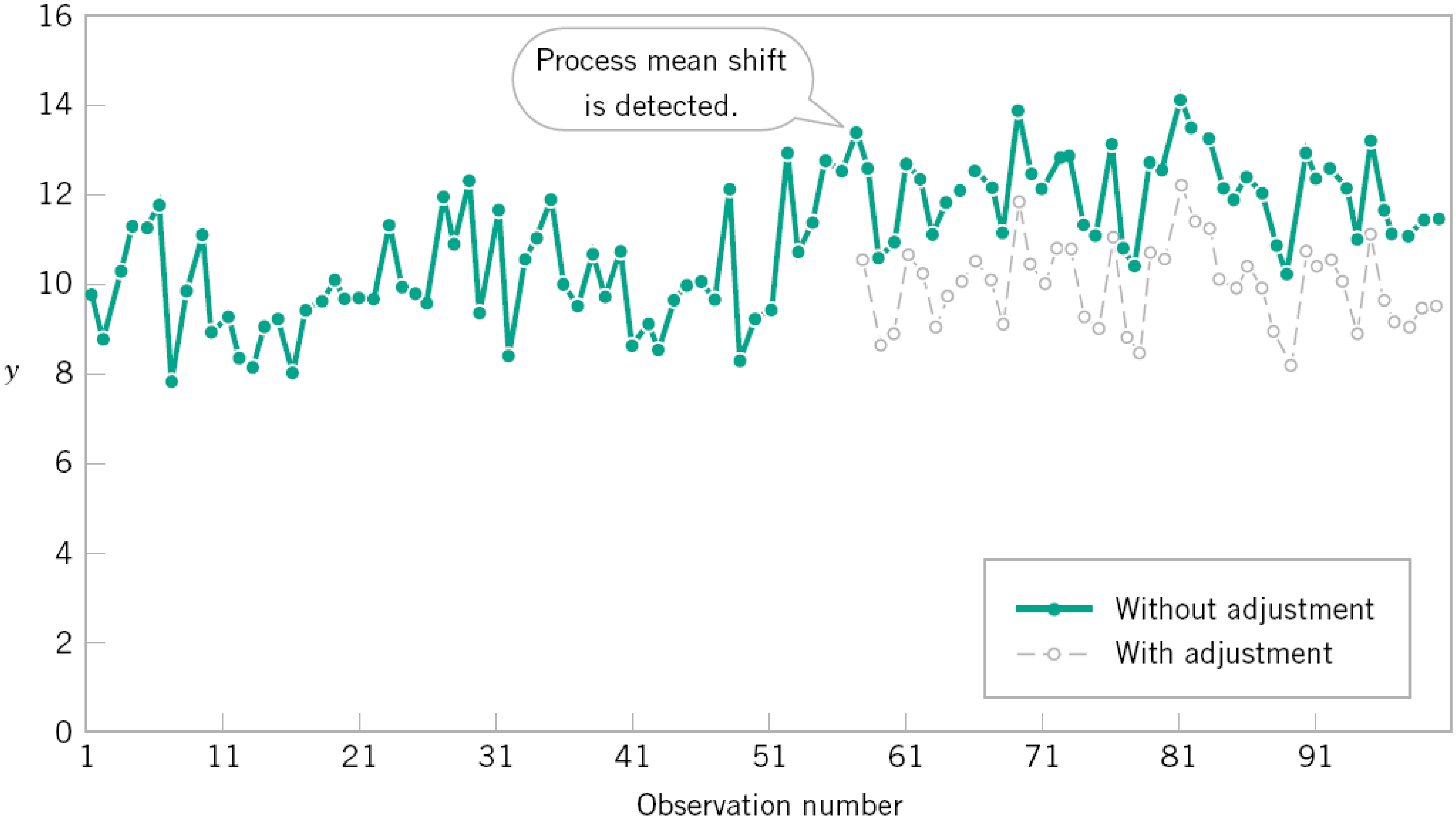


Figure 1-18 Process mean shift is detected at observation number 57, and one adjustment (a decrease of two units) reduces the deviations from the target.

Adjustments should be applied only to compensate for a nonrandom shift in the process—then they can help

1-4 Observing Processes Over Time

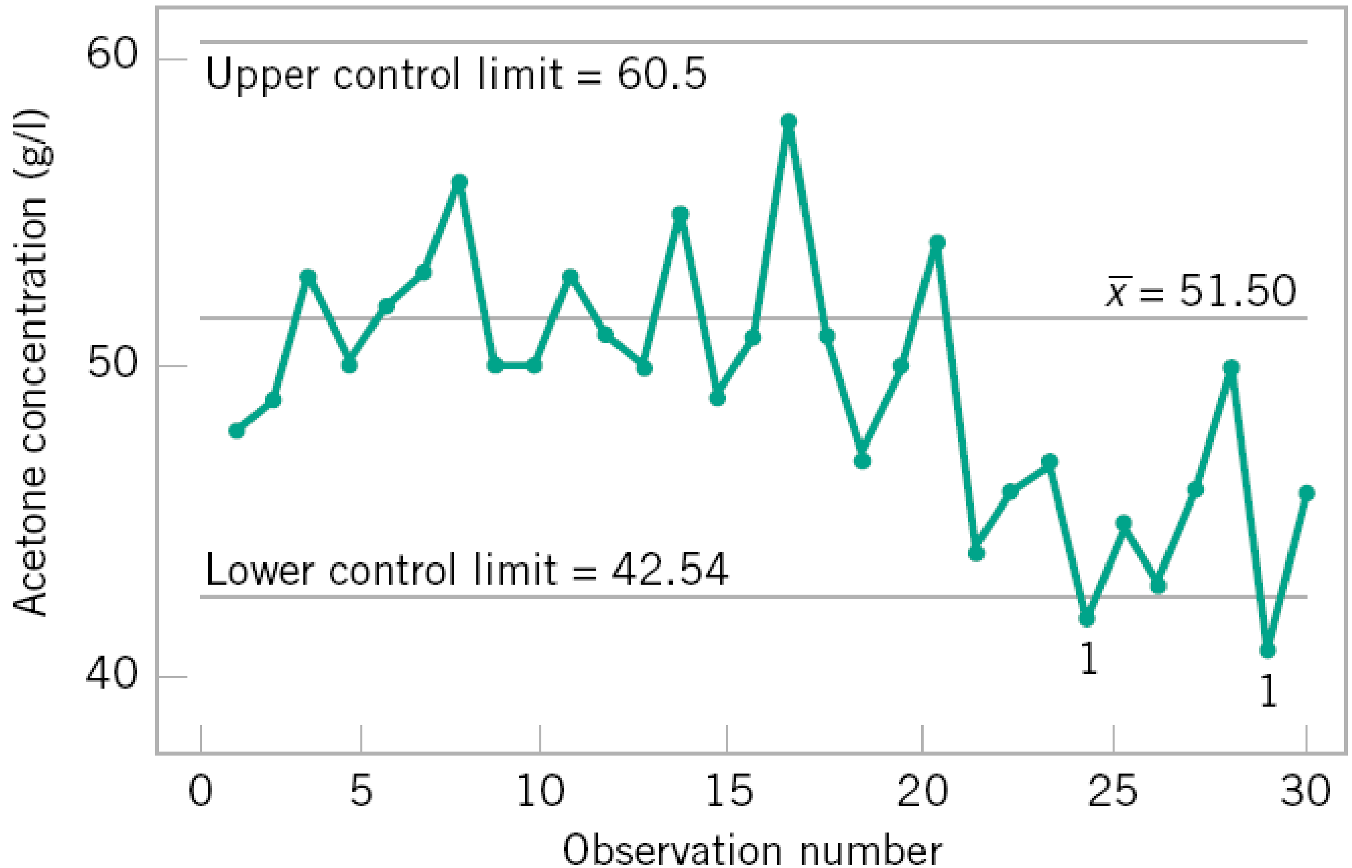


Figure 1-19 A control chart for the chemical process concentration data.

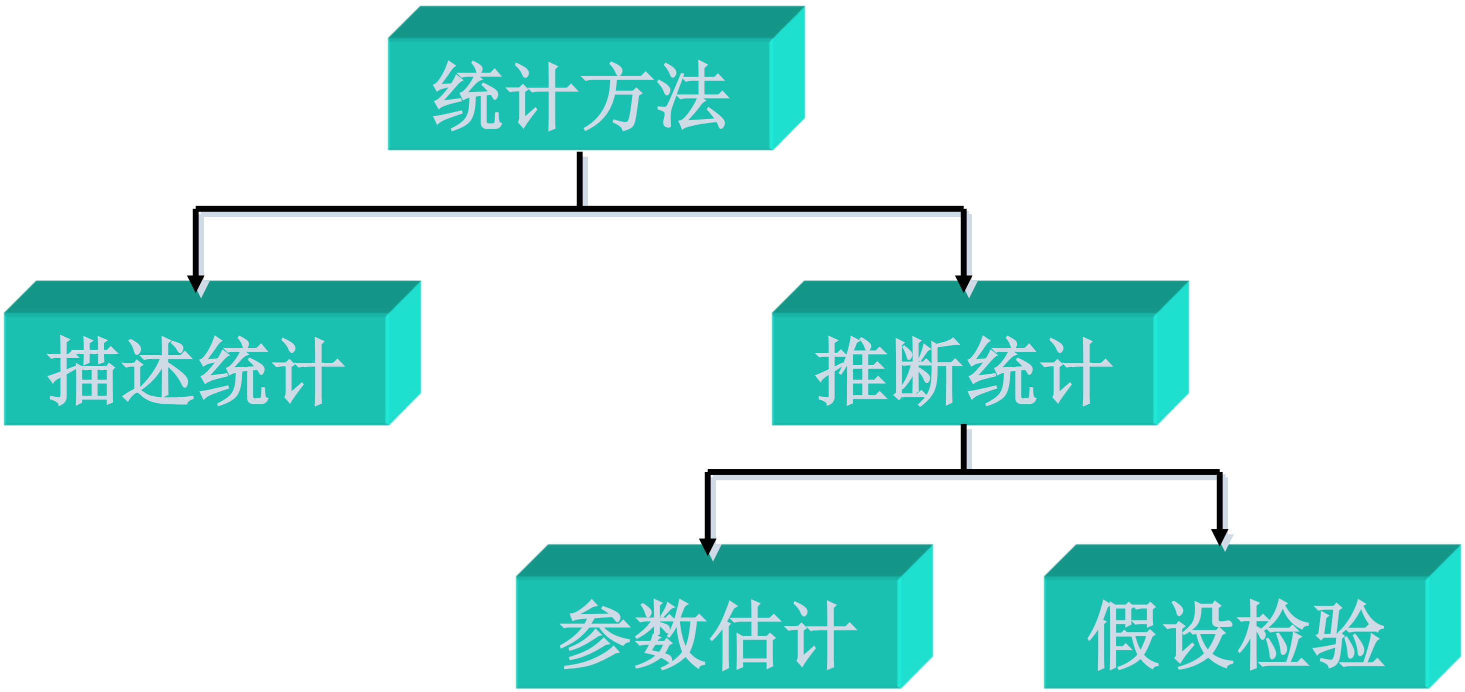
IMPORTANT TERMS AND CONCEPTS FOR THIS CHAPTER

Analytic study	Empirical model	Factorial experiment	Scatter diagram
Control chart	Engineering or scientific method	Mechanistic model	Sources of variability
Designed experiment	Enumerative study	Observational study	Statistical thinking
Dot diagram		Retrospective study	Variability

IMPORTANT TERMS AND CONCEPTS DISCUSSED FURTHER IN SUBSEQUENT CHAPTERS

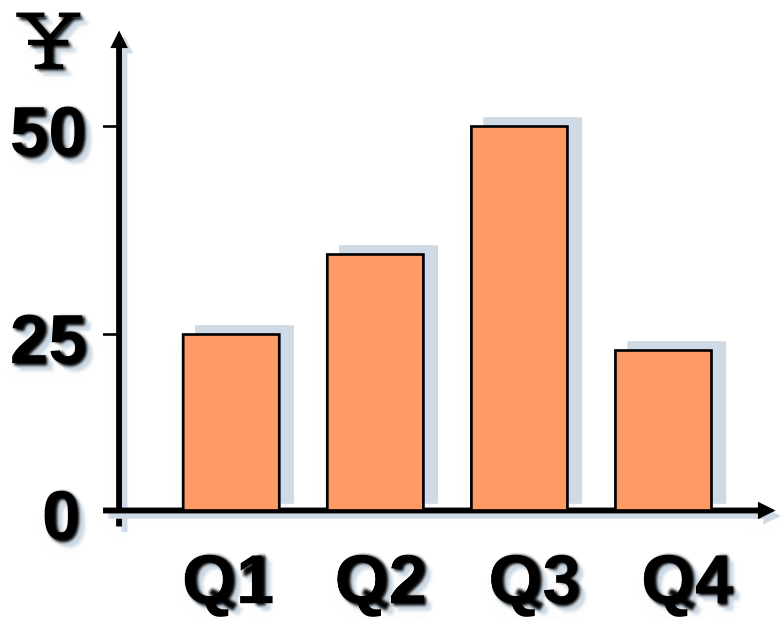
Confidence interval	Fractional factorial experiment	Mechanistic model	Response variable
Control chart	Hypothesis testing	Model	Sample
Designed experiment	Interaction	Random variable	Scatter diagram
Empirical model		Replication	Variability
Factorial experiment			

统计方法



描述统计(descriptive statistics)

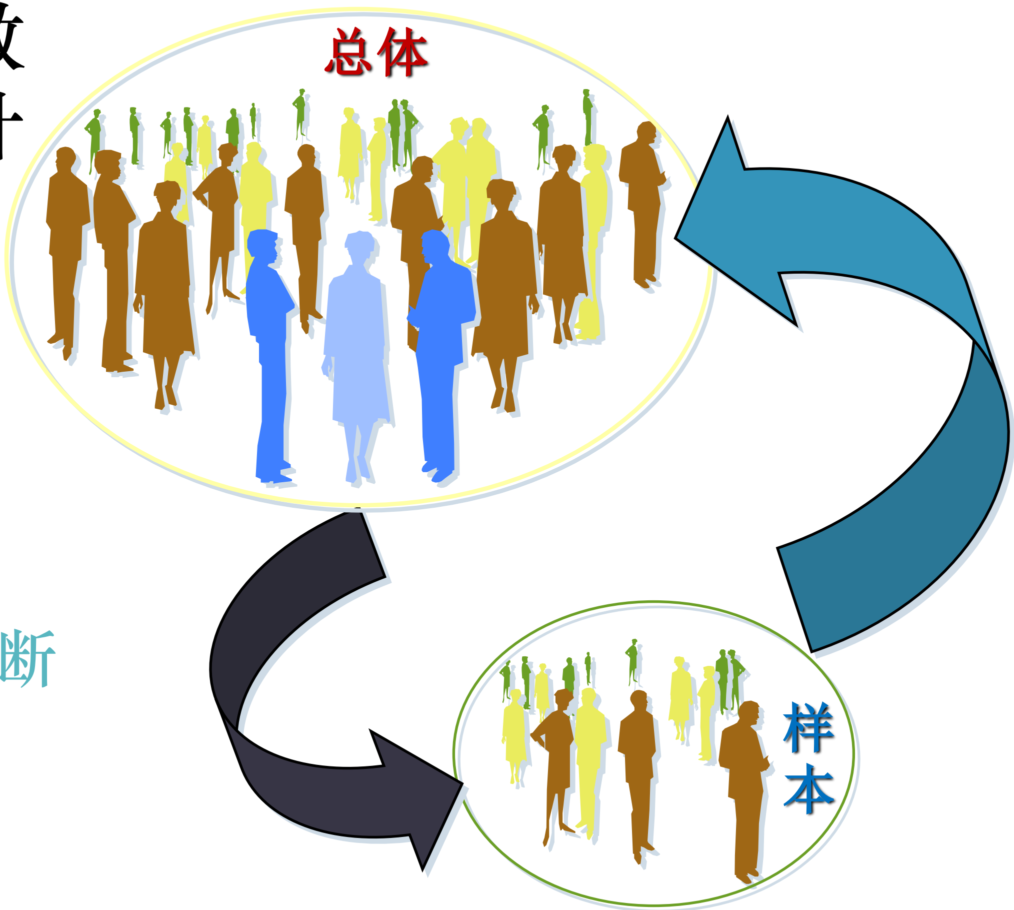
1. 研究数据收集、整理和描述的统计学分支
    - 搜集数据
    - 整理数据
    - 展示数据
    - 描述性分析
2. 目的
    - 描述数据特征
    - 找出数据的基本规律



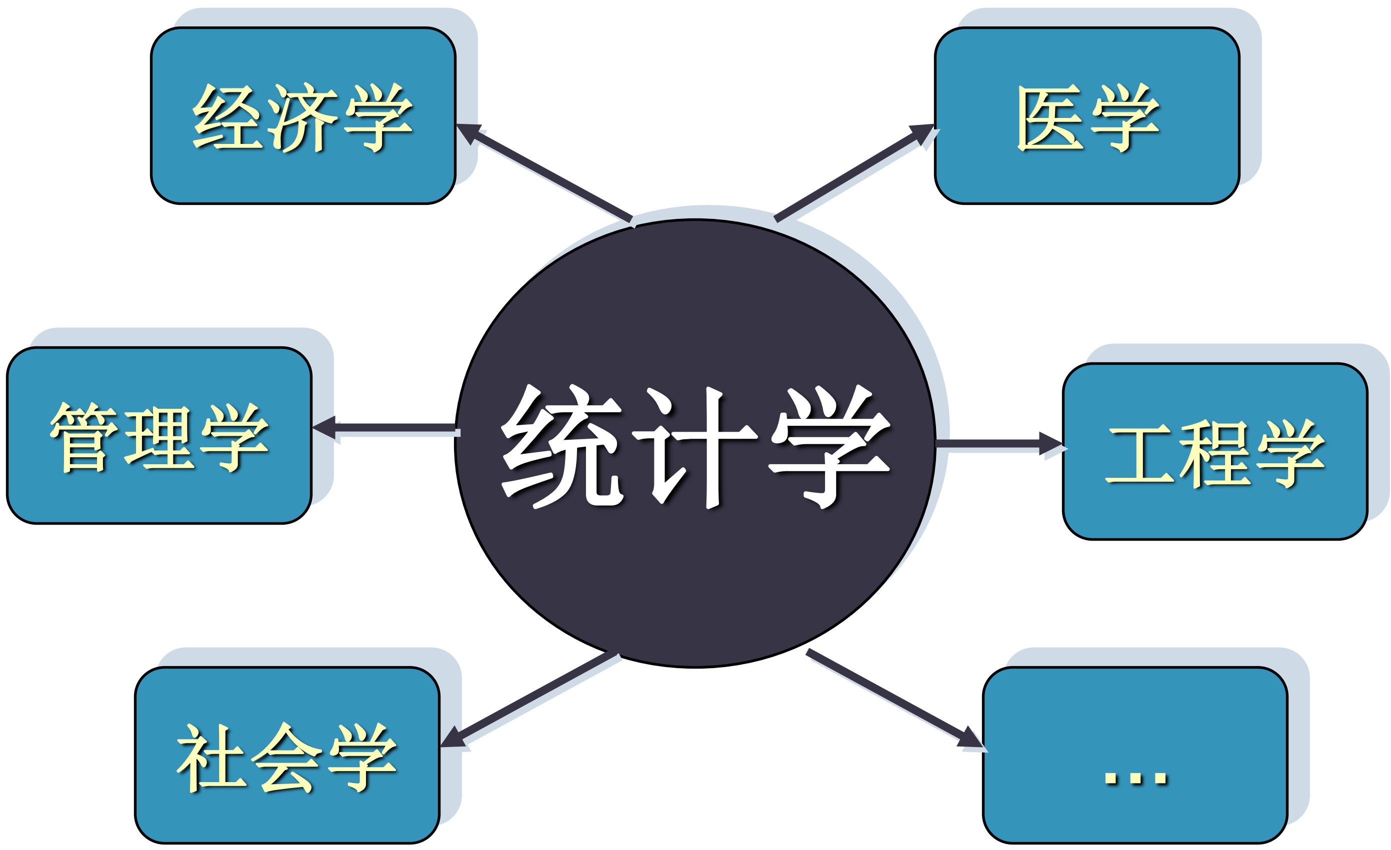
$\bar{x} = 30 \quad s^2 = 105$

推断统计(inferential statistics)

1. 研究如何利用样本数据推断总体特征统计学分支
   - 参数估计
   - 假设检验
2. 目的
   - 对总体特征作出推断



统计的应用领域



统计的应用领域

actuarial work (精算)
agriculture (农业)
animal science (动物学)
anthropology (人类学)
archaeology (考古学)
auditing (审计学)
crystallography (晶体学)
demography (人口统计学)
dentistry (牙医学)
ecology (生态学)
econometrics (经济计量学)
education (教育学)
election forecasting and projection (选举预测和策划)
engineering (工程)
epidemiology (流行病学)
finance (金融)
fisheries research (水产渔业研究)
gambling (赌博)
genetics (遗传学)
geography (地理学)
geology (地质学)
historical research (历史研究)
human genetics (人类遗传学)

统计的应用领域

hydrology (水文学)
Industry (工业)
linguistics (语言学)
literature (文学)
manpower planning (劳动力计划)
management science (管理科学)
marketing (市场营销学)
medical diagnosis (医学诊断)
meteorology (气象学)
military science (军事科学)
nuclear material safeguards (核材料安全管理)
ophthalmology (眼科学)
pharmaceutics (制药学)
physics (物理学)
political science (政治学)
psychology (心理学)
psychophysics (心理物理学)
quality control (质量控制)
religious studies (宗教研究)
sociology (社会学)
survey sampling (调查抽样)
taxonomy (分类学)
weather modification (气象改善)

统计数据及其类型

一. 分类数据、顺序数据、数值型数据

二. 观测数据和实验数据

三. 截面数据和时间序列数据

什么是统计数据? (data)

1. 对现象进行计量的结果
2. 不是指单个的数字，而是由多个数据构成的数据集
3. 不仅仅是指数字，它可以是数字的，也可以是文字的

统计数据的分类

- **统计数据的分类**
  - 按计量层次
    - 分类的数据
    - 顺序的数据
    - 数值型数据
  - 按收集方法
    - 观察的数据
    - 试验的数据
  - 按时间状况
    - 截面的数据
    - 时序的数据

统计数据的分类(按计量尺度分)

1. **分类数据(categorical data)**
   - 对事物进行分类的结果
   - 数据表现为类别，用文字来表述
   - 例如，人口按性别分为男、女两类
2. **顺序数据(rank data)**
   - 对事物类别顺序的测度
   - 数据表现为类别，用文字来表述
   - 例如，产品分为一等品、二等品、三等品、次品等
3. **数值型数据(metric data)**
   - 对事物的精确测度
   - 结果表现为具体的数值
   - 例如：身高为175cm、168cm、183cm

统计数据的分类(按收集方法分)

1. **观测的数据(observational data)**
   - 通过调查或观测而收集到的数据
   - 在没有对事物人为控制的条件下而得到的
   - 有关社会经济现象的统计数据几乎都是观测数据
2. **试验的数据(experimental data)**
   - 在试验中控制试验对象而收集到的数据
   - 比如，对一种新药疗效的试验，对一种新的农作物品种的试验等
   - 自然科学领域的数据大多数都为试验数据

统计数据的分类(按时间状况分)

1. **截面数据(cross-sectional data)**
   - 在相同或近似相同的时间点上收集的数据
   - 描述现象在某一时刻的变化情况
   - 比如，2002年我国各地区的国内生产总值数据
2. **时间序列数据(time series data)**
   - 在不同时间上收集到的数据
   - 描述现象随时间变化的情况
   - 比如，1996年至2002年国内生产总值数据

统计中的几个基本概念

一. 总体和样本

二. 参数和统计量

三. 变量

总体和样本

1. **总体(population)**
   - 所研究的全部元素的集合，其中的每一个元素称为个体
   - 分为有限总体和无限总体
     - 有限总体的范围能够明确确定，且元素的数目是有限的
     - 无限总体所包括的元素是无限的，不可数的
2. **样本 (sample)**
   - 从总体中抽取的一部分元素的集合
   - 构成样本的元素的数目称为样本容量

参数和统计量

1. 参数(parameter)
   - 研究者想要了解的总体的某种特征值
   - 所关心的参数主要有总体均值（μ）、标准差（σ）、总体比例（Π）等
   - 总体参数通常用希腊字母表示
2. 统计量(statistic)
   - 根据样本数据计算出来的一个量
   - 所关心的样本统计量有样本均值($\bar{x}$)、样本标准差(s)、样本比例(p)等
   - 样本统计量通常用小写英文字母来表示

变　量 (Variable)

1. 说明现象某种特征的概念
   - 如商品销售额、受教育程度、产品的质量等级等
   - 变量的具体表现称为变量值，即数据

2. 变量可以分为
   - 分类变量(categorical variable)：说明事物类别的一个名称
   - 顺序变量(rank variable)：说明事物有序类别的一个名称
   - 数值型变量(metric variable)：说明事物数字特征的一个名称
     - 离散变量：取有限个值
     - 连续变量：可以取无穷多个值

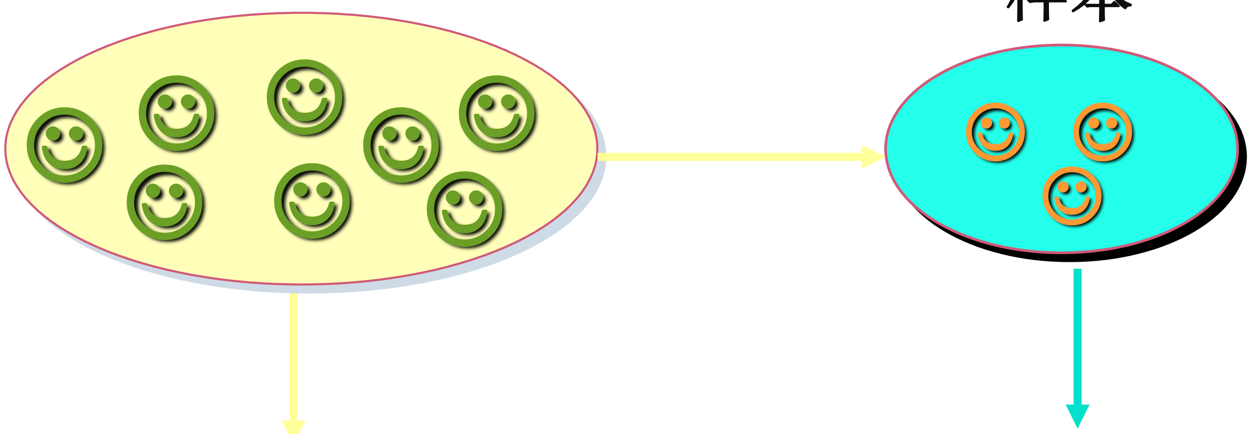
- 观测数据＝真值＋偏差值＋随机误差

- 偏差值——由系统误差引起的，偏差项存在与否及偏差的大小是衡量统计数据质量的一个重要方面；
- 随机误差——难以消除的，影响统计推断的精度

统计中的几个基本概念

总体

样本



参数		统计量
μ	平均数	$\bar{x}$
σ	标准差	s
Π	比例	p

几种常用的统计软件(Software)

- ☞典型的统计软件
  - SAS
  - SPSS
  - MINITAB
  - STATISTICA
  - Excel
  - Python