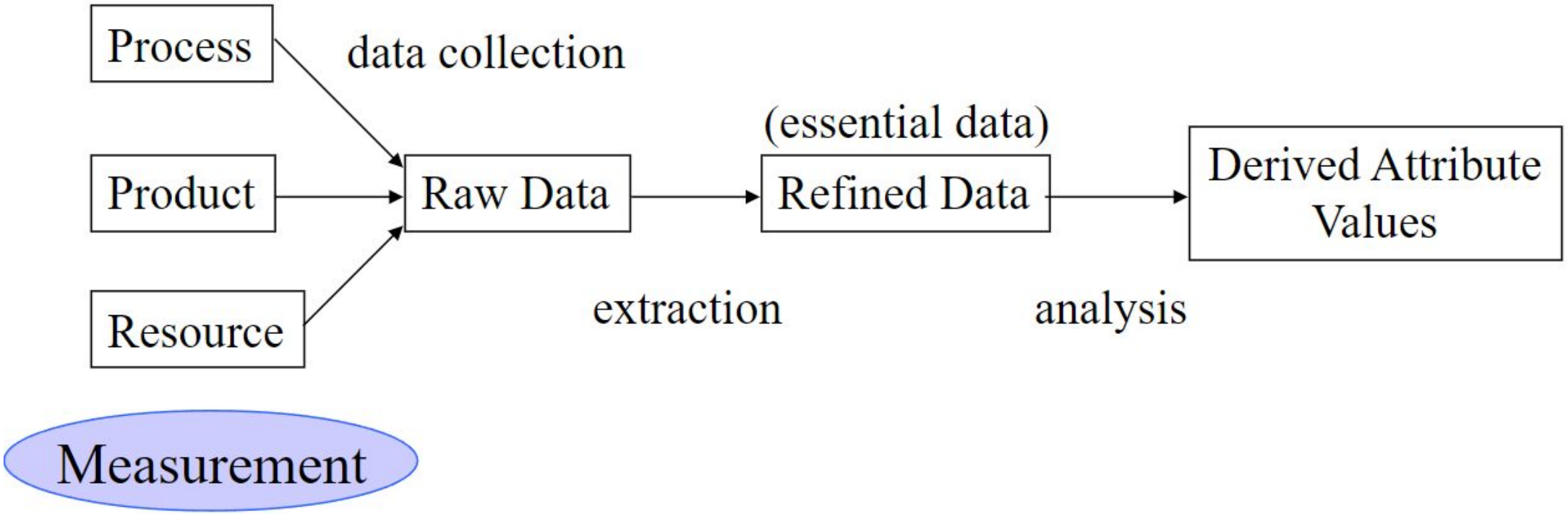
Data Collection Techniques and ANOVA test

Software Metrics Data Collection



What is Good Data?

- Are they correct?
- Are they accurate?
- Are they appropriately precise?
- Are they consistent?
- Are they associated with a particular activity or time period?
- Can they be replicated?

How to Define the Data

Deciding what to measure - GQM (Goal-Question-Metric)

List the major goals of the development
or maintenance project

Derive from each goal the questions that must
be answered to determine if the goals are being met

Decide what must be measured in order to be able to
answer the questions adequately

How to Define the Data

Goal: Evaluate effectiveness of coding standard

Questions: who is using standard?
what is coder's productivity?
What is code quality?

Metrics: Proportion of coders
Experience of coders
Code size (function point, line of codes)
Errors

Data Collection Techniques for Software Field Studies

- Interviews and questionnaires are the most straightforward instruments, but the data they produce typically present an incomplete picture.
- For example, assume your goal is to assess which programming language features are most error-prone. A developer can give you general opinions and anecdotal evidence about this; however, you would obtain far more accurate information by recording and analyzing the developer's *work practices* - their efforts at repeatedly editing and compiling code
- To learn about different aspects of a phenomenon, it is often best to use multiple data collection methods

A Taxonomy of Data Collection

Table 1. Data collection techniques suitable for field studies of software engineering.

Category	Technique
First Degree (direct involvement of software engineers)	Inquisitive techniques • Brainstorming and Focus Groups • Interviews • Questionnaires • Conceptual Modeling Observational techniques • Work Diaries • Think-aloud Protocols • Shadowing and Observation Synchronized Shadowing • Participant Observation (Joining the Team)
Second Degree (indirect involvement of software engineers)	• Instrumenting Systems • Fly on the Wall (Participants Taping Their Work)
Third Degree (study of work artifacts only)	• Analysis of Electronic Databases of Work Performed • Analysis of Tool Use Logs • Documentation Analysis • Static and Dynamic Analysis of a System

Data Collection Techniques

- *First degree:* Evaluators or researchers directly interact with developers. They may interview developers, observe them working, or otherwise interact directly with developers in their daily activities.
- *Second degree:* Evaluators or researchers indirectly interact with developers. They may instrument software development tools to collect information or may record meetings or other development activities.
- *Third degree:* Evaluators have no interactions with developers. Rather, they study artifacts such as revision control system records, fault reports and responses, testing records, etc. Third-degree studies can be performed retrospectively.

Some Definitions

- A **work diary protocol** for a study involves providing participants with guidelines and instructions for maintaining a journal or diary where they document their daily work activities, tasks, thoughts, and reflections. The collected data from these diaries is then analyzed to gain insights into participants' work processes, decision-making, challenges, and experiences
- A **think-aloud study** is a research method in which participants verbalize their thoughts, reactions, and decision-making processes while performing a specific task or solving a problem.
- **Shadowing and observation** is a research method where a researcher closely follows and observes a participant as they go about their daily activities or tasks. Researchers use this method to collect data by directly observing participants without direct involvement.

Definitions

- **Fly-on-the-wall** research is an observational technique that allows a researcher to collect data by seeing and listening. Usually, researchers employ this method to gain insight into people, environment, interactions and objects in a space. It is the primary responsibility of the researcher to stay completely unnoticed during the observation so as to not bias the participants in any way.

- ***The selection of a data collection method should be done in the context of a research goal or question.***

Table 2. Questions asked by software engineering researchers (column 2) that can be answered by field study techniques.

Technique	Used by researchers when their goal is to understand:	Volume of data	Also used by software engineers for:
First Order Techniques			
Brainstorming and Focus Groups	Ideas and general background about the process and product, general opinions (also useful to enhance participant rapport)	Small	Requirements gathering, project planning
Surveys	General information (including opinions) about process, product, personal knowledge etc.	Small to Large	Requirements and evaluation
Conceptual modeling	Mental models of product or process	Small	Requirements
Work Diaries	Time spent or frequency of certain tasks (rough approximation, over days or weeks)	Medium	
Think-aloud sessions	Mental models, goals, rationale and patterns of activities	Medium to large	UI evaluation
Shadowing and Observation	Time spent or frequency of tasks (intermittent over relatively short periods), patterns of activities, some goals and rationale	Small	Advanced approaches to use case or task analysis
Participant observation (joining the team)	Deep understanding, goals and rationale for actions, time spent or frequency over a long period	Medium	
Second Order Techniques			
Instrumenting systems	Software usage over a long period, for many participants	Large	Software usage analysis
Fly in the wall	Time spent intermittently in one location, patterns of activities (particularly collaboration)	Medium	
Third Order Techniques			
Analysis of work databases	Long-term patterns relating to software evolution, faults etc.	Large	Metrics gathering
Analysis of tool use logs	Details of tool usage	Large	
Documentation analysis	Design and documentation practices, general understanding	Medium	Reverse engineering
Static and dynamic analysis	Design and programming practices, general understanding	Large	Program comprehension, metrics, testing, etc.

- One way ANOVA Test

One-Way ANOVA

- One-way analysis of variance (ANOVA) is a statistical method for testing for differences in the means of **three or more groups**.
- One-way ANOVA is typically used when you have a single independent variable or factor. The independent variable divides cases into two or more mutually exclusive levels, categories, or groups. Your goal is to investigate if variations or different levels of that factor have a measurable effect on a dependent variable.
- One-way ANOVA can only be used when investigating a single factor and a single dependent variable. When comparing the means of three or more groups**, it can tell us if at least one pair of means is significantly different**, **but it can't tell us which pair**.

One-Way ANOVA (cont..)

- One-way ANOVA is a test for differences in group means
- One-way ANOVA is a statistical method to test the null hypothesis (H_0) that three or more population means are equal vs. the alternative hypothesis (H_a) that at least one mean is different.

Examples

- 1# Your independent variable is social media use, and you assign groups to low, medium, and high levels of social media use to find out if there is a difference in hours of sleep per night.
- 2# Your independent variable is brand of soda, and you collect data on Coke, Pepsi, Sprite, and Fanta to find out if there is a difference in the price per 100ml.
- 3# You independent variable is type of fertilizer, and you treat crop fields with mixtures 1, 2 and 3 to find out if there is a difference in crop yield.

Example 2

- Imagine you work for a company that manufactures an adhesive gel that is sold in small jars. The viscosity of the gel is important: too thick and it becomes difficult to apply; too thin and its adhesiveness suffers. You've received some feedback from a few unhappy customers lately complaining that the viscosity of your adhesive is not as consistent as it used to be. You've been asked by your boss to investigate.
- You decide that a good first step would be to examine the average viscosity of the five most recent production lots. If you find differences between lots, that would seem to confirm the issue is real. It might also help you begin to form hypotheses about factors that could cause inconsistencies between lots.

You measure viscosity using an instrument that rotates a spindle immersed in the jar of adhesive. This test yields a measurement called torque resistance. You test five jars selected randomly from each of the most recent five lots

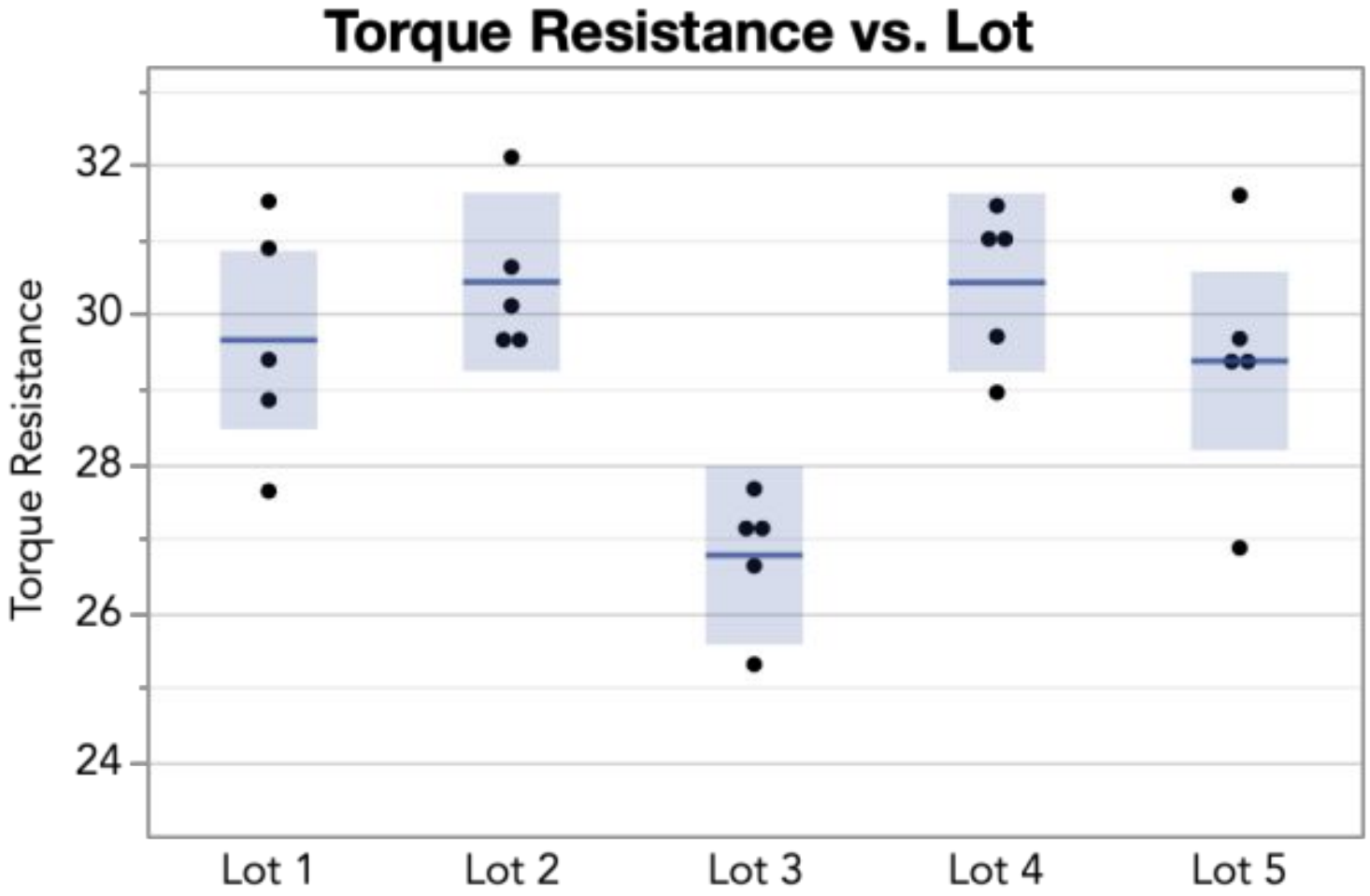


Table 1: Mean torque measurements from tests of five lots of adhesive

Lot #	N	Mean
1	5	29.65
2	5	30.43
3	5	26.77
4	5	30.42
5	5	29.37

Table 2: ANOVA table with results from our torque measurements

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob-> F
Lot	4	45.25	11.31	6.90	0.0012
Error	20	32.80	1.64		
Total	24	78.05			

- One key element in this table to focus on for now is the p-value. The p-value is used to evaluate the validity of the null hypothesis that all the means are the same. In our example, the p-value (Prob-> F) is 0.0012. This small p-value can be taken as evidence that the means are not all the same
- Remember, an ANOVA test will not tell you which mean or means differs from the others, and (unlike our example) this isn't always obvious from a plot of the data

- ***Hypothesis****: the viscosity of the adhesive is not consistent among different lots*
- ***Null Hypothesis:*** *the viscosity of the adhesive is consistent in all lots*

One-way ANOVA calculation

Table 3: Torque measurements by Lot

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Jar 1	29.39	30.63	27.16	31.03	29.67
Jar 2	31.51	32.10	26.63	30.98	29.32
Jar 3	30.88	30.11	25.31	28.95	26.87
Jar 4	27.63	29.63	27.66	31.45	31.59
Jar 5	28.85	29.68	27.10	29.70	29.41
Mean	**29.65**	**30.43**	**26.77**	**30.42**	**29.37**

n_i = Number of observations for treatment i (in our example, Lot i)

N = Total number of observations

Y_{ij} = The j^{th} observation on the i^{th} treatment

$\overline{Y}_i$ = The sample mean for the i^{th} treatment

$\overline{\overline{Y}}$ = The mean of all observations (grand mean)

Sum of Squares

- The sum of squares gives us a way to quantify variability in a data set by focusing on the difference between each data point and the mean of all data points in that data set. The formula below partitions the overall variability into **two parts**: the variability due to the model or the factor levels, and the variability due to random error.

$$\sum_{i=1}^{a}\sum_{j=1}^{n_i}(Y_{ij}-\overline{\overline{Y}})^2 = \sum_{i=1}^{a} n_i(\overline{Y}_i-\overline{\overline{Y}})^2 + \sum_{i=1}^{a}\sum_{j=1}^{n_i}(Y_{ij}-\overline{Y}_i)^2$$

$$SS(Total) = SS(Factor) + SS(Error)$$

Lot	Y_{ij}	$\overline{Y}_i$	$\overline{\overline{Y}}$	$\overline{Y}_i - \overline{\overline{Y}}$	$Y_{ij} - \overline{\overline{Y}}$	$Y_{ij} - \overline{Y}_i$	$(\overline{Y}_i - \overline{\overline{Y}})^2$	$(Y_{ij} - \overline{Y}_i)^2$	$(Y_{ij} - \overline{\overline{Y}})^2$
1	29.39	29.65	29.33	0.32	0.06	-0.26	0.10	0.07	0.00
1	31.51	29.65	29.33	0.32	2.18	1.86	0.10	3.46	4.75
1	30.88	29.65	29.33	0.32	1.55	1.23	0.10	1.51	2.40
1	27.63	29.65	29.33	0.32	-1.70	-2.02	0.10	4.08	2.89
1	28.85	29.65	29.33	0.32	-0.48	-0.80	0.10	0.64	0.23
2	30.63	30.43	29.33	1.10	1.30	0.20	1.21	0.04	1.69
2	32.10	30.43	29.33	1.10	2.77	1.67	1.21	2.79	7.68
2	30.11	30.43	29.33	1.10	0.78	-0.32	1.21	0.10	0.61

4	31.45	30.42	29.33	1.09	2.12	1.03	1.19	1.06	4.49
4	29.70	30.42	29.33	1.09	0.37	-0.72	1.19	0.52	0.14
5	29.67	29.37	29.33	0.04	0.34	0.30	0.00	0.09	0.12
5	29.32	29.37	29.33	0.04	-0.01	-0.05	0.00	0.00	0.00
5	26.87	29.37	29.33	0.04	-2.46	-2.50	0.00	6.26	6.05
5	31.59	29.37	29.33	0.04	2.26	2.22	0.00	4.93	5.11
5	29.41	29.37	29.33	0.04	0.08	0.04	0.00	0.00	0.01
Sum of Squares							**SS (Factor) = 45.25**	**SS (Error) = 32.80**	**SS (Total) = 78.05**

Degrees of Freedom (DF)

- The number of values that are free to vary in a data set
- The degrees of freedom indicates the number of independent pieces of information used to calculate each sum of squares.
- For a one-factor design with a factor at k levels (five lots in our example) and a total of N observations (five jars per lot for a total of 25), the degrees of freedom are as follows:

	Degrees of Freedom (DF) Formula	Calculated Degrees of Freedom
SS (Factor)	k - 1	5 - 1 = 4
SS (Error)	N - k	25 - 5 = 20
SS (Total)	N - 1	25 - 1 = 24

Mean Squares (MS) and F Ratio

- We divide each sum of squares by the corresponding degrees of freedom to obtain Mean Squares (**MS)**. When the null hypothesis is true (i.e. the means are equal), **MS (Factor) and MS (Error) are both would be about the same size**. **Their ratio, or the F ratio, would be close to one.** When the null hypothesis is not true then the MS (Factor) will be larger than MS (Error) and **their ratio greater than 1**. In our adhesive testing example, the computed F ratio, 6.90, presents significant evidence **against** the null hypothesis that the means are equal.

Table 6: Calculating mean squares and F ratio

	Sum of Squares (SS)	Degrees of Freedom (DF)	Mean Squares	F Ratio
SS (Factor)	45.25	4	45.25/4 = 11.31	11.31/1.64 = 6.90
SS (Error)	32.80	20	32.80/20 = 1.64	

- The ratio of MS(factor) to MS(error)—the F ratio—has an F distribution. The F distribution is the distribution of F values that we'd expect to observe when the null hypothesis is true (i.e. the means are equal). F distributions have different shapes based on two parameters, called the numerator and denominator degrees of freedom. For an ANOVA test, the numerator is the MS(factor), so the degrees of freedom are those associated with the MS(factor). The denominator is the MS(error), so the denominator degrees of freedom are those associated with the MS(error).
- If your computed F ratio exceeds the expected value from the corresponding F distribution, then, assuming a sufficiently small p-value, you would reject the null hypothesis that the means are equal. **The p-value in this case is the probability of observing a value greater than the F ratio from the F distribution when in fact the null hypothesis is true.**