



Web Server

Capacity Test Design of Experiment

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Objectives

1. Experimental Setup
2. Capacity Test and Performance Analysis
3. Workload Characterization
4. Hypothesis Tests in MATLAB
- 5. Experimental Design and Analysis**

4. Experimental Design and Analysis

Example: $2^2 3$

- Consider a design of experiment with 2 factors, 2 levels and 3 repetitions
- Evaluate the **importance** of each factor
 - e.g., Importance factor $A = \frac{SSA}{SST}$
- Evaluate the **significance** of each factor
 - verify the normality of residuals
 - verify the homoscedasticity
 - choose the proper test

F	Memoria	Cache	Y
1	4Mb	1Kb	15
2	4Mb	1Kb	18
3	4Mb	1Kb	12
4	4Mb	2Kb	25
5	4Mb	2Kb	28
6	4Mb	2Kb	19
7	16Mb	1Kb	45
8	16Mb	1Kb	48
9	16Mb	1Kb	51
10	16Mb	2Kb	75
11	16Mb	2Kb	75
12	16Mb	2Kb	81

Example: Importance of Factors

Analisi della varianza

Origine	DF	Somma dei quadrati	Media quadratica	Rapporto F
Modello	3	6930,0000	2310,00	181,1765
Errore	8	102,0000	12,75	Prob > F
C. totale	11	7032,0000		<,0001*

Stime dei parametri

Test degli effetti

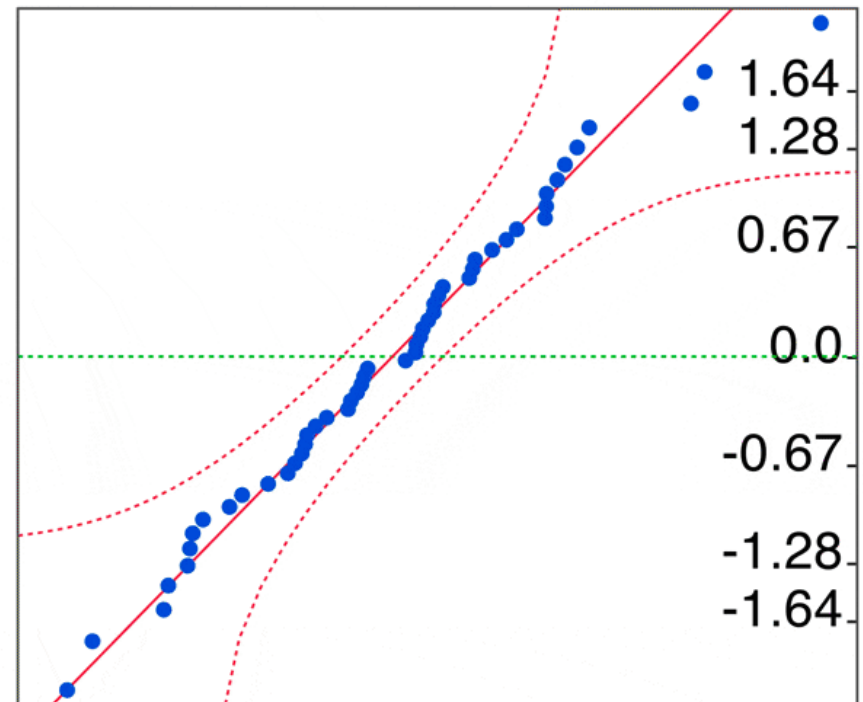
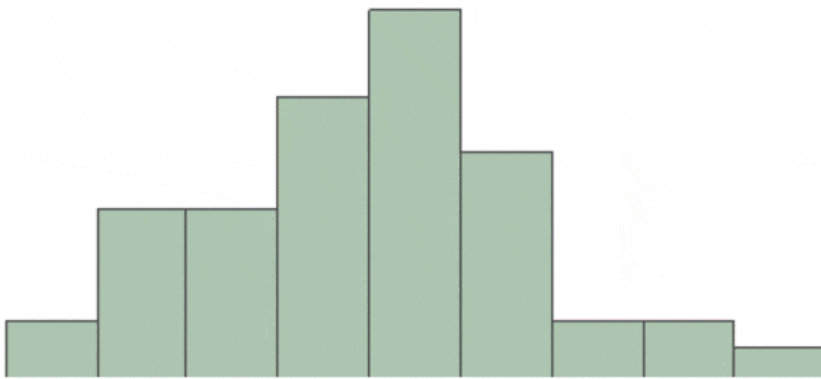
Origine	Nparm	DF	Somma dei quadrati	Rapporto F	Prob > F
Memoria	1	1	5547,0000	435,0588	<,0001*
Cache	1	1	1083,0000	84,9412	<,0001*
Memoria*Cache	1	1	300,0000	23,5294	0,0013*

JMP: Importanza e Residui

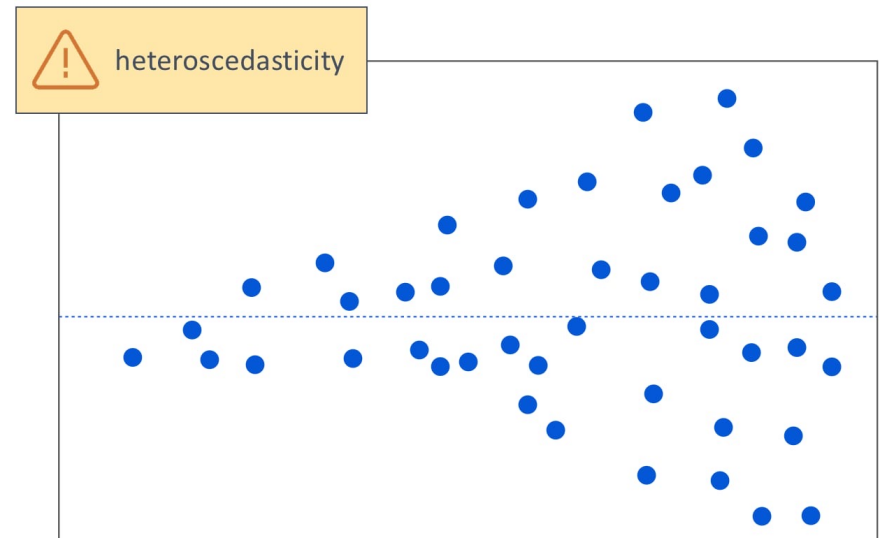
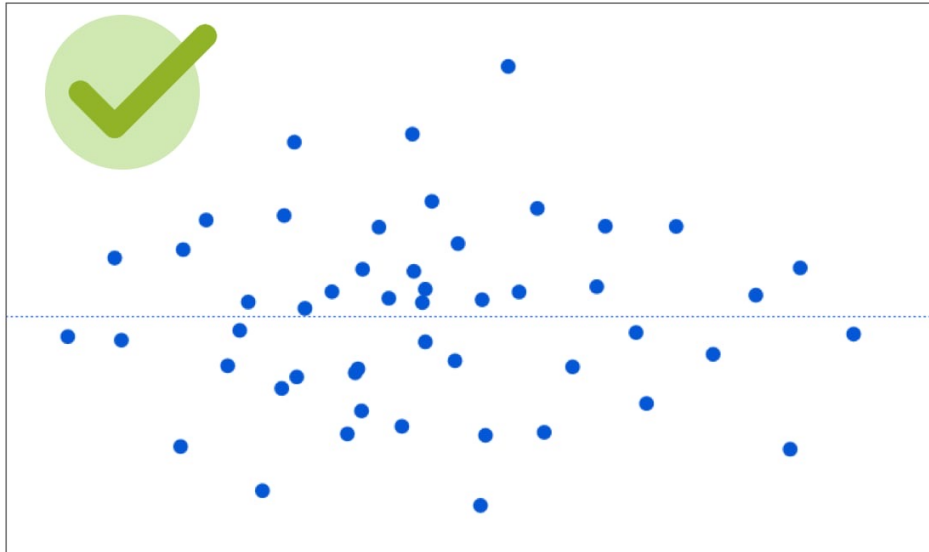
- Analizza → Stima Modello → Incrocia I fattori per calcolare l'interazione → Enfasi su leverage degli effetti
- Risposta Y → Salva Colonne → Residui (per verificare la normalità)

Normality Residuals

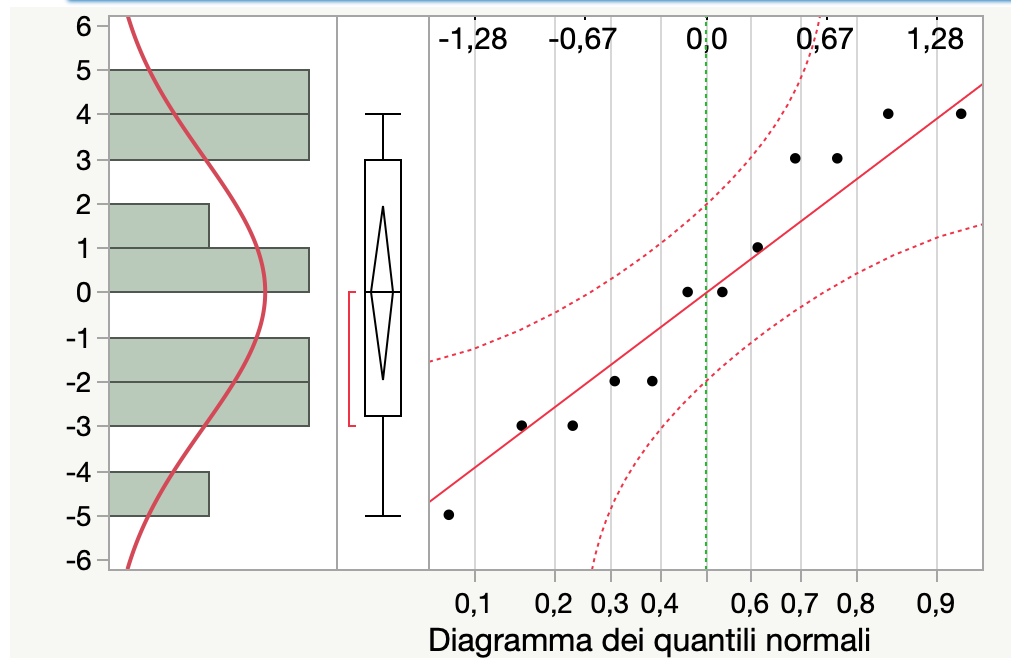
✓ approximately
normally
distributed



Homoscedasticity vs Heteroscedasticity



Example: Verify Normality of Residuals



Visual
Test

▼ Test della bontà di adattamento

Test W di Shapiro-Wilk

W	Prob<W
0,928878	0,3684

Nota: Ho = i dati provengono dalla distribuzione Normale. I p-value bassi rifiutano Ho.

Shapiro
Wilk
Test

Null hypothesis is
NOT rejected →
Normality verified

JMP: Normalità Residui

- Test Visivo
 - Analizza distribuzione → Y residuals → diagramma dei quantili normali
- Shapiro Wilk:
 - Y residuals → Stima continua → Attiva stimatori legacy
 - Stimatori Legacy → stima continua → stima normale
 - Stima normale → bonta di adattamento

Example: Verify Homoscedasticity (for each factor)

Test	Rapporto F	Num DF	Den DF	p-value
O'Brien[.5]	0,3556	1	10	0,5642
Brown-Forsythe	0,0976	1	10	0,7612
Levene	0,1250	1	10	0,7310
Bartlett	0,1438	1	.	0,7045
Test F bilaterale	1,4286	5	5	0,7051

Memory

Test	Rapporto F	Num DF	Den DF	p-value
O'Brien[.5]	1,0735	1	10	0,3246
Brown-Forsythe	1,1765	1	10	0,3035
Levene	1,2500	1	10	0,2897
Bartlett	0,4113	1	.	0,5213
Test F bilaterale	1.8333	5	5	0.5220

Cache

Homoscedasticity accepted for both factors

JMP: Homoscedasticity Tests

- Analizza Y rispetto a X
 - Y risposta (Residui)
 - X fattori
- Analisi ad una via Y Residuo rispetto fattore → Varianze Ineguali

Normality & Homoscedasticity → F Test

Stime dei parametri					
Test degli effetti					
Origine	Nparm	DF	Somma dei quadrati	Rapporto F	Prob > F
Memoria	1	1	5547,0000	435,0588	<,0001*
Cache	1	1	1083,0000	84,9412	<,0001*
Memoria*Cache	1	1	300,0000	23,5294	0,0013*

All factors are significative

Normality and Heteroscedasticity → Welch

▼ Test di Welch

ANOVA di Welch verifica l'uguaglianza delle medie, ammette deviazioni standard non uguali

Rapporto F	Num DF	Den DF	Prob > F
37,3535	1	6,3659	0,0007*

Test t

6,1118

Memory is statistically significant

▼ Test di Welch

ANOVA di Welch verifica l'uguaglianza delle medie, ammette deviazioni standard non uguali

Rapporto F	Num DF	Den DF	Prob > F
1,8205	1	8,3859	0,2126

Test t

1,3492

Cache is NOT statistically significant

JMP: Test di Welch

- Analizza Y rispetto a X
 - Y risposta
 - X fattori
- Analisi ad una via Y rispetto fattore → Varianze Ineguali

What if the normality was not verified?

Use a non-parametric test

▼ Test di Wilcoxon/Kruskal-Wallis (somme dei ranghi)

Livello	Conteggio	Somma degli score	Score atteso	Media degli score	(Media-Media0)/Std0
16Mb	6	57,000	39,000	9,50000	2,807
4Mb	6	21,000	39,000	3,50000	-2,807

▼ Test a due campioni, approssimazione normale

S	Z	Prob> Z
21	-2,80715	0,0050*

▼ Test a una variabile, approssimazione chi-quadrato

Chi-quadrato	DF	Prob>ChiQu
8,3368	1	0,0039*

JMP: Wilcoxon / Kruskal-Wallis Test

- Non-Parametric:
 - Analizza Y rispetto a X → Analisi ad una via Y rispetto fattore
→ Test Non parametrico

Exercise

DESIGN OF EXPERIMENT

Objective

- Design an experiment to study the impact of the factors on the response time
- Use the Design of Experiment technique

Design

- Response Variable
 - Response time
- Factors
 - Intensity (request rate), Page Type

Design

- Since we analyze only two factors, we can choose several options, e.g.:
 - Group together *intensity* in 2 levels, Low and High, and page type in 4 levels (e.g., 4 different pages)
 - Group together *intensity* in 4 levels, Low, Low-Medium, High-Medium, and High, and page types in 2 types (e.g., with high page size, and low page size, or static and dynamic page)
 - etc.

How to choose the factor intensity?

- Intensity levels can be determined in terms of percentage w.r.t. the **usable** capacity
 - 2 levels: 25% and 75% of the usable capacity
 - 3 levels: 25%, 50% and 75% of the usable capacity
 - 4 levels: 20%, 40%, 60% and 80% of the usable capacity
 - ...
- Repeat a treatment N times
 - with $N \geq 5$
 - Assume that each repetition lasts for at least 1 minute, and take the average response time

Analysis

- Allocation of Variation
 - Assess the importance of the factors
- Run ANOVA with repetition
 - Assess which factor (neglecting interactions) is statistically significant, if any
 - Steps:
 - Verify normality of residuals
 - Verify homoscedasticity
 - Choose the type of analysis (parametric vs non-parametric) and thus the corresponding test (F-test, Kruskal-Wallis, Welch)

Example

Create a custom design

- Intensity Factor:
 - Level 1: low intensity (25 % usable capacity)
 - Level 2: high intensity (75 % usable capacity)
- Page Type Factor:
 - Level 1: small size page
 - Level 2: small-medium size page
 - Level 3: medium-large size page
 - Level 4: large size page
- 5 Repetitions
- y_{ijk} : **average elapsed time** with the first factor at level j and the second factor at level i during the k -th repetition