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

	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

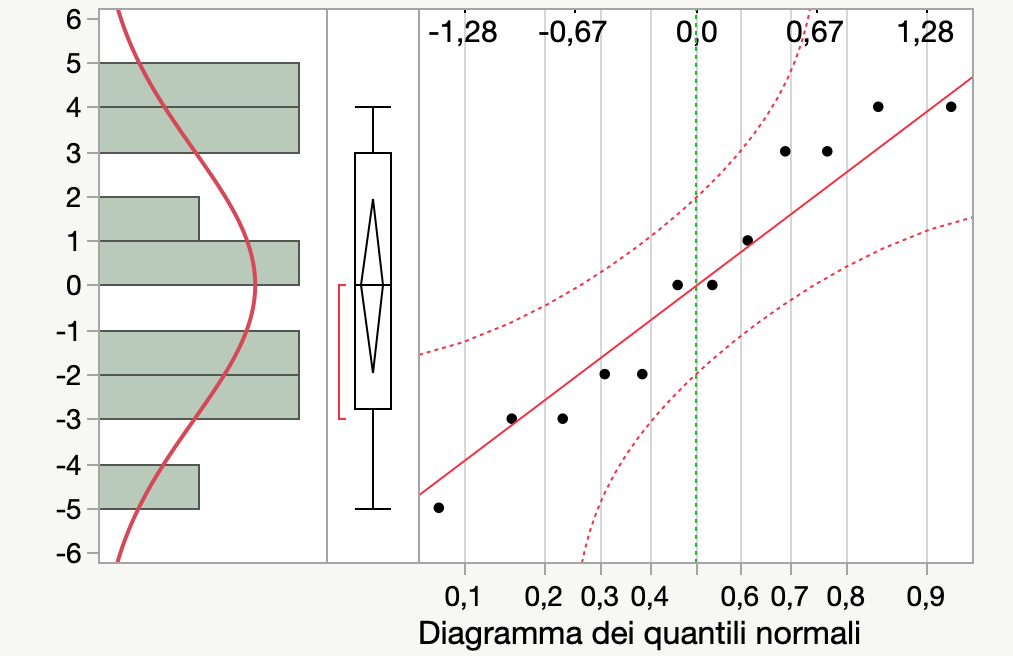
Origine	Nparm	DF	Somma dei quadrati	Rapporto F	Prob > F
Memoria	1	1	5547,0000	435,0588	<,0001*
Cache	1	1	1083,0000	84,9412	<,0001*
Memoria*Cache	1	1	300,0000	23,5294	0,0013*

JMP

- Analizza → Stima Modello → Incrocia I fattori per calcolare l'interazione → Enfasi su leverage degli effetti

- Risposta Y → Salva Colonne → Residui (per verificare la normalità)

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

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- 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]	19,5098	1	10	0,0013*
Brown-Forsythe	27,3973	1	10	0,0004*
Levene	31,2478	1	10	0,0002*
Bartlett	3,8454	1	.	0,0499*
Test F bilaterale	7,1818	5	5	0,0495*

Memory

Test	Rapporto F	Num DF	Den DF	p-value
O'Brien[.5]	18,9576	1	10	0,0014*
Brown-Forsythe	27,7778	1	10	0,0004*
Levene	29,4118	1	10	0,0003*
Bartlett	0,9718	1	.	0,3242
Test F bilaterale	2,5633	5	5	0,3248

Cache

Homoscedasticity rejected for both factors

Case 3: Parametric and Heteroscedastic

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 significative

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 significative

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- Analizza Y rispetto a X → Analisi ad una via Y rispetto fattore → Varianze Uguali

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

- 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 >= 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 th*e k-th* repetition