VC CONTINUA | **VC DISCRETA**

$f_{\underline{z}}(\underline{z}) = f_{xy}(x,y)$ | $p_{ij} = P(x = x_i, y = y_j)$

$\iint f_{xy}(x,y) = 1$ | $\sum_i \sum_j p_{ij} = 1$ CONGIUNTA

$f_x(x) = \int_{-\infty}^{+\infty} f_{x,y}(x,y)\,dy$ | $q_i = \sum_{j=1}^{m} p_{ij}$ MARGINALI

$f_y(y) = \int_{-\infty}^{+\infty} f_{x,y}(x,y)\,dx$ | $r_j = \sum_{i=1}^{m} p_{ij}$

$f_{xy}(x,y) = f_x(x) f_y(y)$ | $p_{ij} = q_i r_j$ COND NeS stoc.

MEDIA $\quad \underline{z} = \begin{bmatrix} x \\ y \end{bmatrix} \quad \underline{\mu}_z = \begin{bmatrix} \mu_x \\ \mu_y \end{bmatrix}$

$\mu_x = \sum_i x_i q_i = M_x[x]$ | $\mu_x = \int x f(x)\,dx$

$\mu_y = \sum_j y_j r_j = M_y[y]$ | $\mu_y = \int y f(y)\,dy$

TEO MEDIA

$\underline{\mu}_{\underline{w}} = \begin{bmatrix} \iint g_1(x,y) f(x,y) \\ \iint g_2(x,y) f(x,y) \end{bmatrix}$ | $\underline{\mu}_{\underline{w}} = \begin{bmatrix} \sum_i \sum_j g_1(x_i, y_j)\, p_{ij} \\ \sum_i \sum_j g_2(x_i, y_j)\, p_{ij} \end{bmatrix}$

MAT COVARIANZA $\quad$ COEFF COVARIANZA

$C_{\underline{zz}} = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} \\ \sigma_{xy} & \sigma_y^2 \end{bmatrix} \qquad \sigma_{xy} = M_{xy}\left[(x-\mu_x)(y-\mu_y)\right]$

- LINEARE

Prop. varianza $\quad \underline{w} = A\underline{z} + \underline{b}$

Prop. covar. $\quad C_{\underline{ww}} = A\, C_{\underline{zz}}\, A^t$

$\underline{\mu}_{\underline{w}} = A\underline{\mu}_z + \underline{b}$

- NON LINEARE

var $\quad \underline{w} \cong J_{\underline{z}} + b$

covar $\quad C_{ww} \cong J C_{H} J^t = J C_{zz} J^t$

INDIPENDENZA STOCASTICA

$C_{zz} = \begin{bmatrix} \sigma_x^2 & 0 \\ 0 & \sigma_y^2 \end{bmatrix} \Leftarrow$

Mat cov diag $\not\Rightarrow$ comp. stocast ind $\Rightarrow \exists$ dip. lineare

COEFF DI CORR. LINEARE

$\rho_{xy} = \dfrac{\sigma_{xy}}{\sigma_x \sigma_y} \qquad -1 \leq \rho_{xy} \leq 1$

NON LINEARE $\rho_{xy} = 0$ $\quad$ LINEARE $\rho_{xy} = \pm 1$

TEO CENTRALE DELLA STATISTICA

$x_m = \sum^{m} x_i \qquad \lim_{m \to \infty} f_{x_m}(x_m) = N\left[m\mu, m\sigma^2\right]$

ERRORE ACCIDENTALE DI MISURA $\quad y = \sum_i y_i$

TEORIA DELLA STIMA

Descrive esp m rip INDIP di un esp descritto da VC x

VAR. CASUALE CAMPIONARIA $\quad \underline{y} = \begin{bmatrix} x_1 \\ x_m \end{bmatrix}$

fddp $\quad L(\underline{y}) = \prod_{i=1}^{m} f_{x_i}(x_i)$

funz verosim $L(\underline{x}, \theta)$ → Stabilire proprietà che avvicinano al valore θ

stimatore $\hat{\theta} = \hat{\theta}(x_1, \ldots x_m)$ → Stabilire la forma → criteri

CORRETTO $M[\hat{\theta}] = \theta$ (es media camp $M[m] = \mu$) Non garantisce unicità

CONSISTENTE $\lim_{m \to \infty} M[\hat{\theta}(x_m)] = \theta$ $\lim_{m \to \infty} \sigma^2[\hat{\theta}(x_m)] = 0$ Non garantisce unicità

CRITERIO MASSIMA VEROSIMIGLIANZA

$L(\underline{x}, \hat{\theta}(\underline{x})) = MAX\, L(\underline{x}, \theta(\underline{x}))$ stimatore di θ inc = VC (funz VC campionaria) che max funz di verosimiglianza

VC STIMATORE	STIMA
A priori VC funzione della VC camp. la cui forma è ottenuta con un criterio di stima	A posteriori V S (numero) sostituendo estraz VC camp

CRITERIO STIMA MIN QUADRATI

VC α^* dim $\alpha^* = m$ Non conosco fddp $C_{\alpha^*\alpha^*} = \sigma^2\, Q_{\alpha^*\alpha^*}$

MAT DI COVARIANZA INCOGNITA MAT COFATTORI (NOTA)

Se misure, comp. di α indipendenti e di ugual precisione ⇒ $Q = I$

Determinare stimatori dei valori medi di $\underline{\alpha}^*$ e di $\underline{x}$ (medi) $Q = I$ LINEARE

- Problema $\begin{cases} \sum(\alpha_i - \hat{\alpha}_i)^2 = (\underline{\alpha} - \hat{\underline{\alpha}})^T(\underline{\alpha} - \hat{\underline{\alpha}}) = \min \\ \hat{\underline{\alpha}} = A\hat{\underline{x}} + \underline{L} \quad \text{vincolo} \end{cases}$ $(m > n)$

- Soluzioni

A MATRICE DISEGNO Rettangolare dim $\bar{x} = n$, dim $\bar{\alpha} = m$ $A_{m \times n}$

N NORMALE Quadrata $N_{n \times n}$

υ VETTORE DEGLI SCARTI $\upsilon = \alpha - \hat{\alpha}$

$m - n$ RIDONDANZA sempre > 0

$$\begin{cases} \hat{\underline{x}} = N^{-1}A^T(\underline{\alpha} - \underline{L}) & \hat{\underline{\alpha}} = A\hat{\underline{x}} + \underline{L} & \hat{\sigma}^2 = \dfrac{\upsilon^T\upsilon}{m-n} \\ C_{\hat{\underline{x}}\hat{\underline{x}}} = \hat{\sigma}^2 N^{-1} & C_{\hat{\underline{\alpha}}\hat{\underline{\alpha}}} = \hat{\sigma}^2 A N^{-1}A^T & C_{\upsilon\upsilon} = \hat{\sigma}^2[I - AN^{-1}A^T] \end{cases}$$

STIMATORE min q con param agg.

$C_{\hat{x}_0\hat{x}_0} = \hat{\sigma}_0^2 N^{-1}$ $C_{\hat{\alpha}_0\hat{\alpha}_0} = \hat{\sigma}_0^2 A N^{-1}A^T$ $C_{\upsilon_0\upsilon_0} = \hat{\sigma}_0^2[I - AN^{-1}A^T]$

STIMA

$Q \neq I$

Problema $\begin{cases} (\underline{\alpha} - \hat{\underline{\alpha}})^T Q^{-1}(\underline{\alpha} - \hat{\underline{\alpha}}) = \min \\ \hat{\underline{\alpha}} = A\hat{\underline{x}} + \underline{L} \end{cases}$ $Q = Q_{\alpha\alpha}$

$N = A^T Q^{-1} A$ simm quadrata $n \times n$

$$\begin{cases} \hat{x} = N^{-1}AQ^{-1}(\underline{\alpha} - \underline{L}) & \hat{\underline{\alpha}} = A\hat{\underline{x}} + \underline{L} & \hat{\sigma}^2 = \dfrac{\upsilon^T Q^{-1}\upsilon}{m-n} \\ C_{\hat{\underline{x}}\hat{\underline{x}}} = \hat{\sigma}^2 \underbrace{N^{-1}} & C_{\hat{\underline{\alpha}}\hat{\underline{\alpha}}} = \hat{\sigma}^2 \underbrace{AN^{-1}A^T} \end{cases}$$

$C_{\hat{x}_0\hat{x}_0} = \hat{\sigma}_0^2 N^{-1}$ $C_{\hat{\alpha}_0\hat{\alpha}_0} = \hat{\sigma}_0^2 AN^{-1}A^T$ $\hat{\sigma}_0^2 = \dfrac{\upsilon_0^T Q^{-1}\upsilon_0}{m-n}$

A $\to$ dipende da disegno rete, dalla posizione relativa dei punti e dal tipo di osservazioni

Q $\to$ dipende dagli strumenti che si utilizzano e dalle tecniche di rilievo

FASE DI SIMULAZIONE

Calcolo MAT COFATTORI

$Q_{\hat{x}\hat{x}}$ stime PARAMETRI — Identifico misure strett. necess.

$Q_{\hat{\alpha}\hat{\alpha}}$ stime OSSERVAZIONI

Q_{ω} stime SCARTI delle equazioni

RIDONDANZA $m - M > 0$ $\dim \underline{\alpha} = m > \dim \underline{x} = M$

2 EFFETTI
- si ottiene stima affidabile I
- si migliora la precisione della stima II

I • se non $\exists$ errori grossolani (OUTLIER) $U_i = N(0, \sigma^2_{U_i})$

• se U_i NORMALE $P(-2\sigma_{U_i} < U_i < 2\sigma_{U_i}) \sim 95\%$

$U_i > 2\sigma_{U_i}$ $\to$ osserv. α_{0i} OUTLIER

VARIANZA DELLO SCARTO $\sigma^2_{0U_i} = \hat{\sigma}^2_0 \left[Q - AN^{-1}A^T\right]_{ii}$

se $|U_{0i}| > 2\sigma_{0U_i}$ α_{0i} OUTLIER

NON LINEARE

$\underline{\bar{\alpha}} = f(\underline{\bar{x}})$ $\underline{\bar{\alpha}} \simeq f(\underline{\tilde{x}}) + f_x(\underline{\tilde{x}})(\underline{\bar{x}} - \underline{\tilde{x}})$

$\underline{\bar{\alpha}} \simeq \boxed{L} + A\ \underline{\bar{\varepsilon}}$

Vett termini noti:

$$\underline{L} = f(\underline{\tilde{x}}) = \begin{bmatrix} f_1(\tilde{x}_1, & \tilde{x}_M) \\ f_m(\tilde{x}_1, & \tilde{x}_M) \end{bmatrix}$$

Mat der parziali calcolate nei val approx $\underline{\tilde{x}}$

$$A = f_x(\underline{\tilde{x}}) = \begin{bmatrix} \frac{df_1}{dx_1} & \frac{df_1}{dx_M} \\ \frac{df_m}{dx_1} & \frac{df_m}{dx_M} \end{bmatrix}_{\underline{\tilde{x}}}$$

Vett correzioni

$$\underline{\bar{\varepsilon}} = (\underline{\bar{x}} - \underline{\tilde{x}}) = \begin{bmatrix} \bar{x}_1 - \tilde{x}_1 \\ \bar{x}_M - \tilde{x}_M \end{bmatrix}$$

Soluzioni

$\underline{\hat{\varepsilon}}_0 = N^{-1}A^TQ^{-1}(\underline{\alpha_0} - \underline{L})$ $C_{\hat{\varepsilon}\hat{\varepsilon}} = \hat{\sigma}^2_0 N^{-1}$ $\hat{\sigma}^2_0 = \dfrac{U^TQ^{-1}U}{m - M}$

• Processo iterativo $\underline{\hat{\varepsilon}}_{01}$ $\underline{\hat{x}}_{01} = \underline{\tilde{x}} + \underline{\hat{\varepsilon}}_{01}$ $\underline{\tilde{x}}_{02} = \underline{\tilde{x}}_{01} + \underline{\hat{\varepsilon}}_{02}$

$\underline{\tilde{x}}_{01} = \underline{\hat{x}}_{01}$ $\underline{\bar{\alpha}} \simeq \underline{L}_1 + A_1 \underline{\hat{\varepsilon}}_{02}$ $\underline{\hat{\varepsilon}}_{0k}$ + trascurabile

• Ricalcolo solo $\boxed{L}$ se sol converge $\underline{x}_k \to \underline{x}$

$\underline{\hat{x}} = \underline{\tilde{x}} + \underline{\hat{\varepsilon}}$ $\underline{\hat{\alpha}} = A\underline{\hat{\varepsilon}} + L$ $\underline{\hat{U}} = \underline{\alpha_0} - \underline{\hat{\alpha}}$

Test verifica di ipotesi

1) VC x fddp $\in f(x,\theta)$ θ incognito
2) $\hat{\theta}$ stimatore di θ di cui conosco fddp $\hat{\theta} = \hat{\theta}(\underline{x})$
3) $H_0: \theta = \theta_0$ ip + verifico ip sulla base del fatto che un campione n abbia fornito un valore empirico (stima) t_0 di θ
4) H_0 vera $\to$ conosco fddp di $\hat{\theta}$ $\to$ fisso α (LIVELLO SIGNIFICATIVITA') $\to$ determino per $\hat{\theta}$ un intervallo I contenente θ_0 t.c. $P(\hat{\theta} \in I) = 1-\alpha$
5) Regola $t_0 \in I \Rightarrow H_0$ accettata $t_0 \notin I \Rightarrow H_0$ rifiutata

α LIVELLO SIGNIFICATIVITA' - Rischio di rifiutare ip quando e' vera

INTERVALLO FIDUCIARIO I di tutti i valori teorici che portano ad accettare l'ipotesi per lo stesso campione e per lo stesso α

TEST A 2 CODE Scarto ip sia per valori troppo grandi, sia per valori piccoli

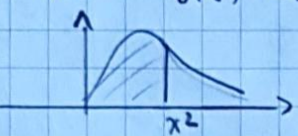
TEST A 1 CODA Ip non verificata $\to$ si hanno valori campionari solo troppo grandi o troppo piccoli

CHI-QUADRO

$y = \sum_{i}^{n} z_i^2$ $\quad z_i = N(0,1)$ $\quad y = \chi^2_n$ $\quad f(y) = c_n\, y^{(n/2)-1} e^{-y/2}$ MEDIA n

VARIANZA $2n$

fddp non simmetrica

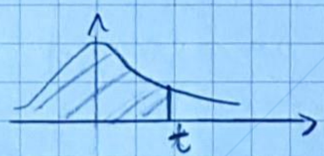


T DI STUDENT

$t_n = \dfrac{z}{\sqrt{\dfrac{\chi^2_n}{n}}}$ $\quad$ fddp $f(t) = \cos t_n \left(1+\dfrac{t^2}{n}\right)^{-\frac{(n+1)}{2}}$ simmetrica rispetto a

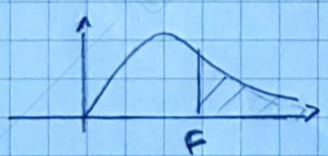
MEDIA 0

VARIANZA $\dfrac{n}{n-2}$



F DI FISHER

$F_{m,n-m} = \dfrac{\chi^2_m}{\chi^2_{n-m}}$ $\quad y = \dfrac{\dfrac{\chi^2_1}{m_1}}{\dfrac{\chi^2_2}{m_2}}$



TEOREMI

$\chi^2_{(n-1)} = (n-1)\dfrac{\bar{s}^2}{\sigma_0^2}$ $\quad t_{n-1} = \dfrac{m-\mu}{\bar{s}/\sqrt{n}}$ $\quad F_{1,2} = t_2^2 = \dfrac{\dfrac{\chi^2_1}{1}}{\dfrac{\chi^2_2}{2}} = \dfrac{z^2}{\dfrac{\chi^2_2}{2}}$ $\quad t_n = \dfrac{z}{\sqrt{\dfrac{\chi^2_n}{n}}}$

VERIFICA IP PER MEDIA TEORICA DI VC CON fddp NORMALE

VARIANZA NOTA $\quad H_0: \mu = \mu_0 \quad \alpha$ $\quad$ VARIANZA INCOGNITA

$$|z_0| = \left| \frac{m_0 - \mu_0}{\sigma / \sqrt{n}} \right| \le z_{0,5-\alpha/2} \qquad |t_0| = \left| \frac{m_0 - \mu_0}{\bar{s}_0 / \sqrt{n}} \right| \le t_{1-\alpha/2\,(n-1)}$$

VERIFICA IP PER MEDIA TEORICA DI VC DI fddp INCOGNITA, CAMPIONE NUMEROSO

VARIANZA NOTA $\quad H_0: \mu = \mu_0$ $\quad$ VARIANZA INCOGNITA

$$|z_0| \simeq \left| \frac{m_0 - \mu_0}{\sigma / \sqrt{n}} \right| \le z_{0,5-\alpha/2} \qquad |z_0| \simeq \left| \frac{m_0 - \mu_0}{\bar{s}_0 / \sqrt{n}} \right| \le z_{0,5-\alpha/2}$$

VERIFICA IP SUL CONFRONTO TRA MEDIE TEORICHE DI VC CON fddp NORMALE

VARIANZA NOTA $\quad H_0: \mu = \mu_0$ $\quad$ VARIANZA INCOGNITA

$$|z_0| = \left| \frac{(m_{01} - m_{02}) - (\mu_{01} - \mu_{02})}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} \right| \le z_{0,5-\alpha/2} \qquad |t_0| = \left| \frac{(m_{01} - m_{02}) - (\mu_{01} - \mu_{02})}{\sqrt{\frac{\bar{s}_{01}^2}{n_1} + \frac{\bar{s}_{02}^2}{n_2}}} \right| \le t_{1-\frac{\alpha}{2}(n_1+n_2-2)}$$

VERIFICA IP SUL CONFRONTO TRA MEDIE TEORICHE DI VC CON fddp INCOGNITA CAMPIONI NUMEROSI

VARIANZA NOTA $\quad H_0: \mu = \mu_0$ $\quad$ VARIANZA INCOGNITA

$$|z_0| \simeq \left| \frac{(m_{01} - m_{02}) - (\mu_{01} - \mu_{02})}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} \right| \le z_{0,5-\alpha/2} \qquad |z_0| \simeq \left| \frac{(m_{01} - m_{02}) - (\mu_{01} - \mu_{02})}{\sqrt{\frac{\bar{s}_{01}}{n_1} + \frac{\bar{s}_{02}}{n_2}}} \right| \le z_{0,5-\alpha/2}$$

VERIFICA IP PER VARIANZA TEORICA DI UNA VC CON fddp NORMALE

$$H_0: \sigma^2 = \sigma_0^2$$

$$\chi^2_{\alpha/2\,(n-1)} < (n-1)\,\bar{s}_0^2 / \sigma_0^2 < \chi^2_{1-\alpha/2\,(n-1)}$$

VERIFICA IP SUL CONFRONTO DI VARIANZE TEORICHE PER VC CON fddp NORMALE

A 1 CODA $\quad H_0: \left(\frac{\sigma_y^2}{\sigma_x^2}\right) c \quad$ valore critico $F_{\alpha\,(n_x-1),(n_y-1)}$

valore campionario $F_0 = c\,\frac{\bar{s}_{0x}^2}{\bar{s}_{0y}^2}$

$$c\,\frac{\bar{s}_{0x}^2}{\bar{s}_{0y}} < F_{\alpha\,(n_x-1),(n_y-1)}$$ Accetto

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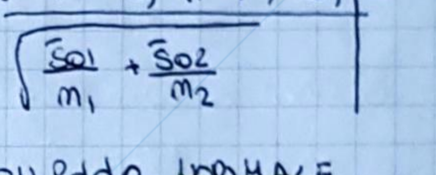
TEST SU VARIANZA



$$H_0: \sigma^2 = \sigma_0^2 \qquad \chi^2_{0(n-1)} = \frac{\bar{s}_0^2}{\sigma^2}(n-1)$$

TEST SUL CONFRONTO DI VARIANZE

$$F_{(n_x-1),(n_y-1)} = \left(\frac{\bar{s}_x^2}{\bar{s}_y^2}\right)\left(\frac{\sigma_y^2}{\sigma_x^2}\right)$$ Test a 1 coda

$H_0: \left(\frac{\sigma_y^2}{\sigma_x^2}\right) = c \quad \alpha \quad F_{\alpha(n_x-1),(n_y-1)}$ critico $\quad$ Estratto $F_0 = c\,\frac{\bar{s}_{0x}^2}{\bar{s}_{0y}^2} \quad F_0 < F_\alpha$ Accetto

TEST GLOBALE SUI PARAMETRI M.Q. CON σ^2 NOTO

$H_0: \underline{\mu}_x = \underline{\mu}_{x0}$ $\qquad \frac{1}{\sigma^2}(\underline{\hat{x}}_0 - \underline{\mu}_{x0})^T N (\underline{\hat{x}}_0 - \underline{\mu}_{x0}) = \chi^2_{0m}$

A 1 CODA $\qquad$ valore critico $\chi^2_{1-\alpha(m)}$

$\chi^2_0 \leq \chi^2_{1-\alpha(m)}$ Accetto

$\chi^2_0 > \chi^2_{1-\alpha(m)}$ Rifiuto

TEST GLOBALE SUI PARAMETRI M.Q. CON σ^2 INCOGNITO

$H_0: \underline{\mu}_x = \underline{\mu}_{0x}$ $\qquad \frac{(\underline{\hat{x}}_0 - \underline{\mu}_{0x})^T N (\underline{\hat{x}}_0 - \underline{\mu}_{0x})}{m\, \hat{\sigma}^2_0} = F_{0(m, m-m)}$

valore critico $F_{\alpha(m, m-m)}$

$F_0 \leq F_{\alpha(m,m-m)}$ Accetto

$F_0 > F_{\alpha(m,m-m)}$ Rifiuto

TEST PUNTUALE SUI PARAMETRI M.Q. CON σ^2 INCOGNITO

$H_0: \mu_{x_i} = \mu^*_{x_i}$ $\qquad \frac{|\hat{x}_{0i} - \mu^*_{x_i}|}{\sqrt{\hat{\sigma}^2_0 N^{-1}_{ii}}} = t_{0(m-m)}$

A 2 CODE

Valore critico $t_{1-\alpha/2(m-m)}$

$|t_0| \leq t_{1-\alpha/2(m-m)}$ Accetto

$|t_0| > t_{1-\alpha/2(m-m)}$ Rifiuto

TEST SU CONFRONTO GLOBALE DI PARAMETRI M.Q. CON σ^2 INCOGNITA

$\underline{\alpha}_1 = A\underline{x}_1 + \underline{L}$ $\qquad \underline{\alpha}_2 = A\underline{x}_2 + \underline{L}$ $\qquad Q = Q_1 = Q_2$ $\qquad N_1 = N_2 = N$

$H_0: \underline{\mu}_{x_1} = \underline{\mu}_{x_2}$ $\qquad \frac{(\underline{\hat{x}}_2 - \underline{\hat{x}}_1)^T N (\underline{\hat{x}}_2 - \underline{\hat{x}}_1)}{m(\hat{\sigma}^2_1 + \hat{\sigma}^2_2)} = F_{m,2(m-m)}$ $\qquad F_0 \leq F_\alpha$ Accetto

TEST SU CONFRONTO PUNTUALE DI PARAMETRI M.Q. CON σ^2 INCOGNITA

$H_0: \mu_{x_i(1)} = \mu_{x_i(2)}$ $\qquad \frac{|\hat{x}_{i(2)} - \hat{x}_{i(1)}|}{\sqrt{(\hat{\sigma}^2_1 + \hat{\sigma}^2_2) N^{-1}_{ii}}} = t_{2(m-m)}$ $\qquad |t_0| \leq t_{1-\alpha/2}$ Accetto

TEST SULLA CORRETTEZZA DEL MODELLO M.Q.

$H_0: \sigma^2 = \sigma^2_0$ $\qquad (m-m)\frac{\hat{\sigma}^2}{\sigma^2_0} = \chi^2_{(m-m)}$

TEST A 1 CODA

Regola $\chi^2_0 = (m-m)\frac{\hat{\sigma}^2_0}{\sigma^2_0} \leq \chi^2_{1-\alpha(m-m)}$

$\chi^2_0 = (m-m)\frac{\hat{\sigma}^2_0}{\sigma^2_0} > \chi^2_{1-\alpha(m-m)}$

MODELLO MIN QUADRATI

$\underline{\bar{\alpha}} = A\underline{\bar{x}} + \underline{L}$ $\qquad C_{\alpha\alpha} = \sigma^2 Q$ $\qquad \dim \alpha = m$ $\quad \dim x = n$ $\quad m > n$

Stimatori corretti $\qquad \alpha \to$ distribuite normalmente $\qquad \underline{\alpha} = \underline{\hat{\alpha}} + \underline{\varepsilon} \to$ se acc. $f(\underline{\varepsilon}) = N[\mu_\varepsilon, \sigma^2_\varepsilon]$

$\underline{\hat{x}} = N^{-1}A^TQ^{-1}(\underline{\alpha} - \underline{L})$ $\qquad \underline{\hat{x}} = N[\underline{\mu}_x, \sigma^2 N^{-1}]$ $\qquad \underline{\hat{x}}\ \underline{\hat{v}}$ $\quad \underline{\hat{\alpha}}\ \underline{\hat{v}}$ indipendenti

$\underline{\hat{\alpha}} = A\underline{\hat{x}} + \underline{L}$ $\qquad \underline{\hat{\alpha}} = N[\underline{\mu}_\alpha, \sigma^2 AN^{-1}A^T]$ $\qquad \sigma^2\chi^2_m = (\underline{\hat{\alpha}} - \underline{\mu}_\alpha)^T Q^{-1}(\underline{\hat{\alpha}} - \underline{\mu}_\alpha)$

$\hat{v} = \underline{\alpha} - \underline{\hat{\alpha}}$ $\qquad \underline{\hat{v}} = N[0, \sigma^2(Q - AN^{-1}A^T)]$ $\qquad \sigma^2\chi^2_{m-n} = \hat{v}^T Q^{-1}\hat{v}$

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