#2

$$\min \|Ax-b\|^2$$

$$\|Ax-b\|^2 = (Ax-b)^T(Ax-b)$$

$$(Ax-b)^T(Ax-b) = (x^TA^T - b^T)(Ax-b)$$

$$(x^TA^TAx - b^TAx - x^TA^Tb + b^Tb)$$

gradient = 0

$$\nabla(x^TA^TAx - b^TAx - x^TA^Tb + b^Tb) = 0$$

$$2A^TAx - A^Tb - A^Tb = 0$$

$$2A^TAx = 2A^Tb$$

$$A^TAx = A^Tb \quad \text{normal equations:}$$

(*)

$$\begin{bmatrix} I_m & A \\ A^T & 0 \end{bmatrix}\begin{bmatrix} r \\ x \end{bmatrix} = \begin{bmatrix} b \\ 0 \end{bmatrix}$$

$$r = b - Ax$$

$\Rightarrow$ components of x (**) satisfy the normal equations. (*)