

1 | A real valued matrix

$$\text{Let } A = \begin{pmatrix} 2 & 1 \\ 3 & 2 \end{pmatrix}$$

$$AA^T = \begin{pmatrix} 2 & 1 \\ 3 & 2 \end{pmatrix} \begin{pmatrix} 2 & 3 \\ 1 & 2 \end{pmatrix} = \begin{pmatrix} 5 & 8 \\ 8 & 13 \end{pmatrix}$$

$$A^T A = \begin{pmatrix} 2 & 3 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} 2 & 1 \\ 3 & 2 \end{pmatrix} = \begin{pmatrix} 13 & 8 \\ 8 & 5 \end{pmatrix}$$

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} a & c \\ b & d \end{pmatrix} = \begin{pmatrix} a^2 + b^2 & ac + bd \\ ac + bd & c^2 + d^2 \end{pmatrix}$$

Then, $A^T A$ is the same thing, but with b, c swapped.

2 | For complex matrices

$$\begin{pmatrix} a + bi & c + di \\ f + gi & j + ki \end{pmatrix} \begin{pmatrix} a + bi & f + gi \\ c + di & j + ki \end{pmatrix} = (a^2 - b^2 + 2abi)$$

$$(a + bi)^2 = a^2 - b^2 + 2abi$$