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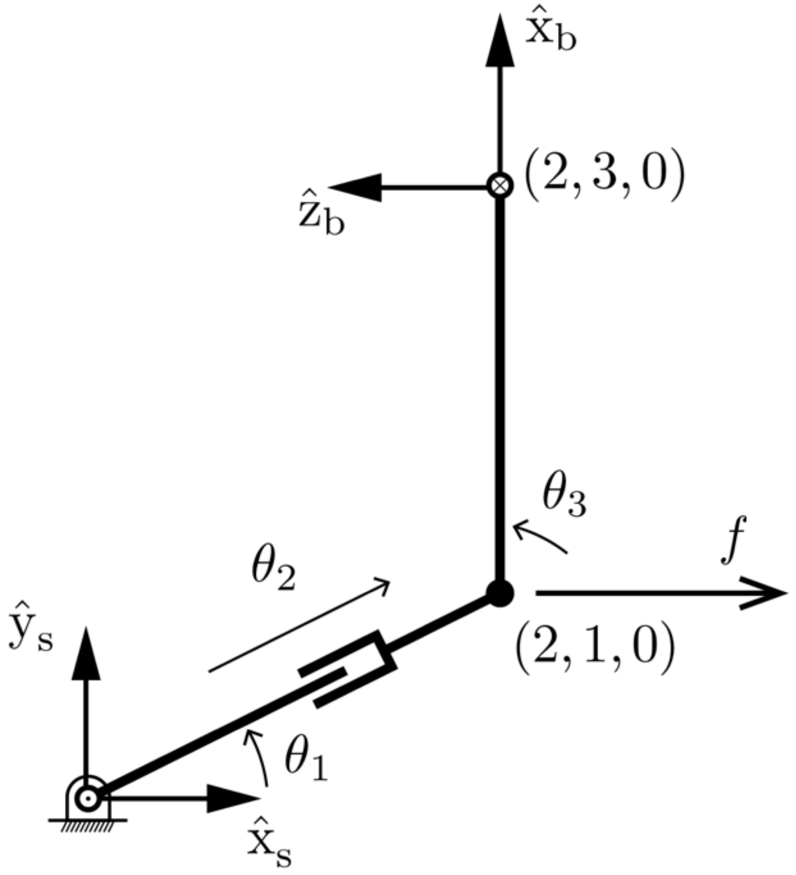
Important concepts, symbols, and equations

Robot statics: $\tau = J_*^{\mathrm{T}}(\theta)\, \mathcal{F}_*$, where $* = s$ or b.

Proper interpretation: if a wrench $-\mathcal{F}$ is applied to the last link, then $\tau = J^{\mathrm{T}}(\theta)\, \mathcal{F}$ is required to resist it.

If $J(\theta)$ has rank 6, then the robot can *actively* generate an end-effector wrench in any direction. The static equation is useful for force control.

If $J(\theta)$ has rank $k < 6$, then any applied wrench can be decomposed into the sum of components in k directions requiring motors to resist and components in $6 - k$ directions that are resisted by the bearings.



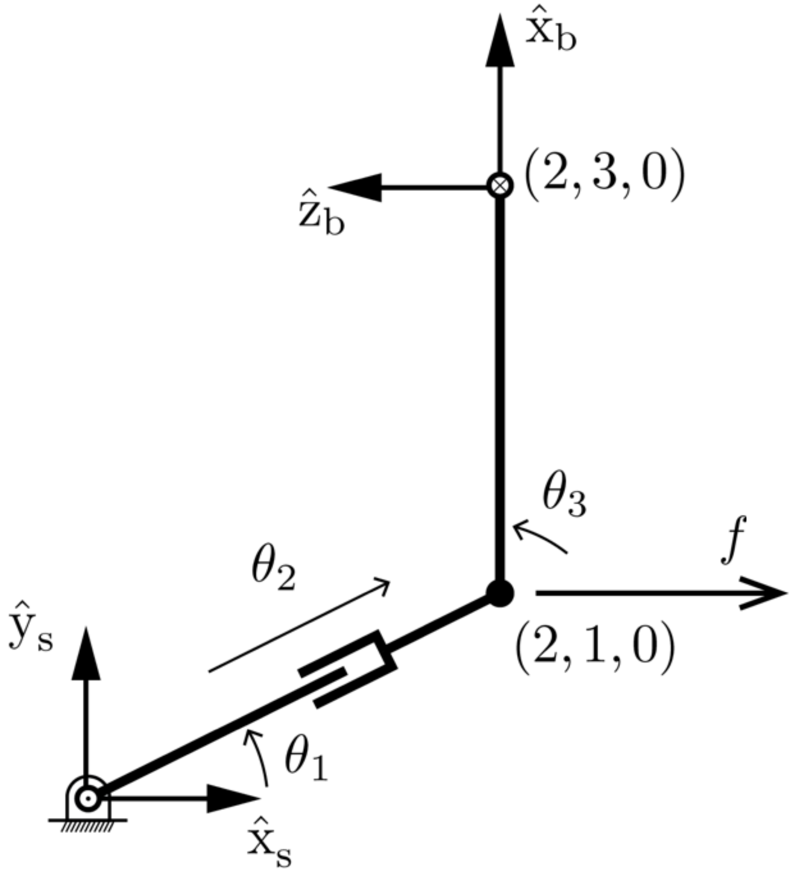
What is the 6×3 Jacobian J_b? What is its rank? What wrenches can be resisted without using the motors?

$$J_b = \begin{bmatrix} 0 & 0 & 0 \\ -1 & 0 & -1 \\ 0 & 0 & 0 \\ 2 & 1/\sqrt{5} & 0 \\ 0 & 0 & 0 \\ 3 & -2/\sqrt{5} & 2 \end{bmatrix}$$

rank = 3

columns are linearly independent

Any wrench out of the plane is resisted by bearings.



A linear force f to the right is applied to link 3 at the point shown. What is the corresponding wrench $-\mathcal{F}_b$? τ needed to resist it?

$$m_b = \begin{bmatrix} -2 \\ 0 \\ 0 \end{bmatrix} \times \begin{bmatrix} 0 \\ 0 \\ -f \end{bmatrix} = \begin{bmatrix} 0 \\ -2f \\ 0 \end{bmatrix}$$

$$-\mathcal{F}_b = \begin{bmatrix} 0 \\ -2f \\ 0 \\ 0 \\ 0 \\ -f \end{bmatrix}$$

$$\tau = J_b^T \mathcal{F}_b = \begin{bmatrix} 0 & -1 & 0 & 2 & 0 & 3 \\ 0 & 0 & 0 & 1/\sqrt{5} & 0 & -2/\sqrt{5} \\ 0 & -1 & 0 & 0 & 0 & 2 \end{bmatrix} \begin{bmatrix} 0 \\ 2f \\ 0 \\ 0 \\ 0 \\ f \end{bmatrix} = \begin{bmatrix} -2f+3f \\ -2f/\sqrt{5} \\ -2f+2f \end{bmatrix}$$

f

0

understand this τ...