NYU

Introduction to Robot Intelligence [Spring 2023]

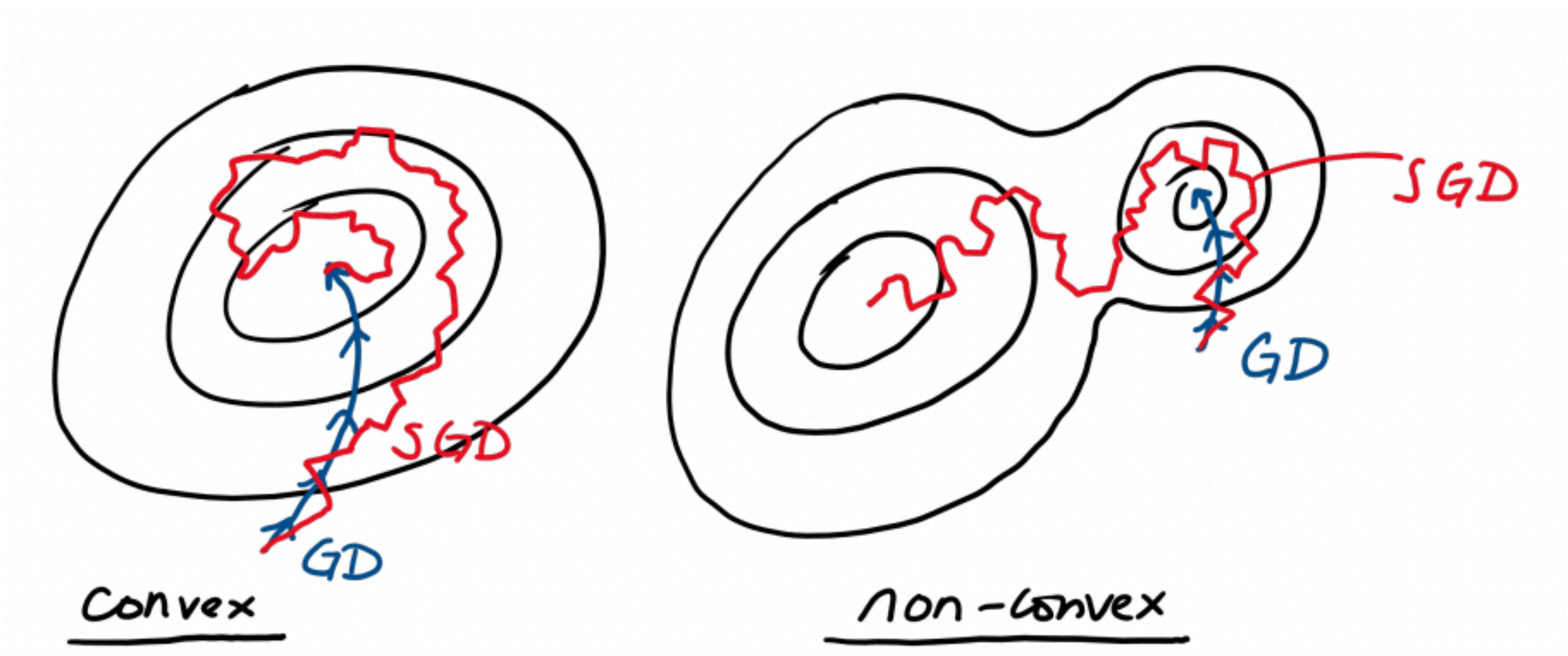
Control

March 21, 2023

Lerrel Pinto

What have we learned so far?

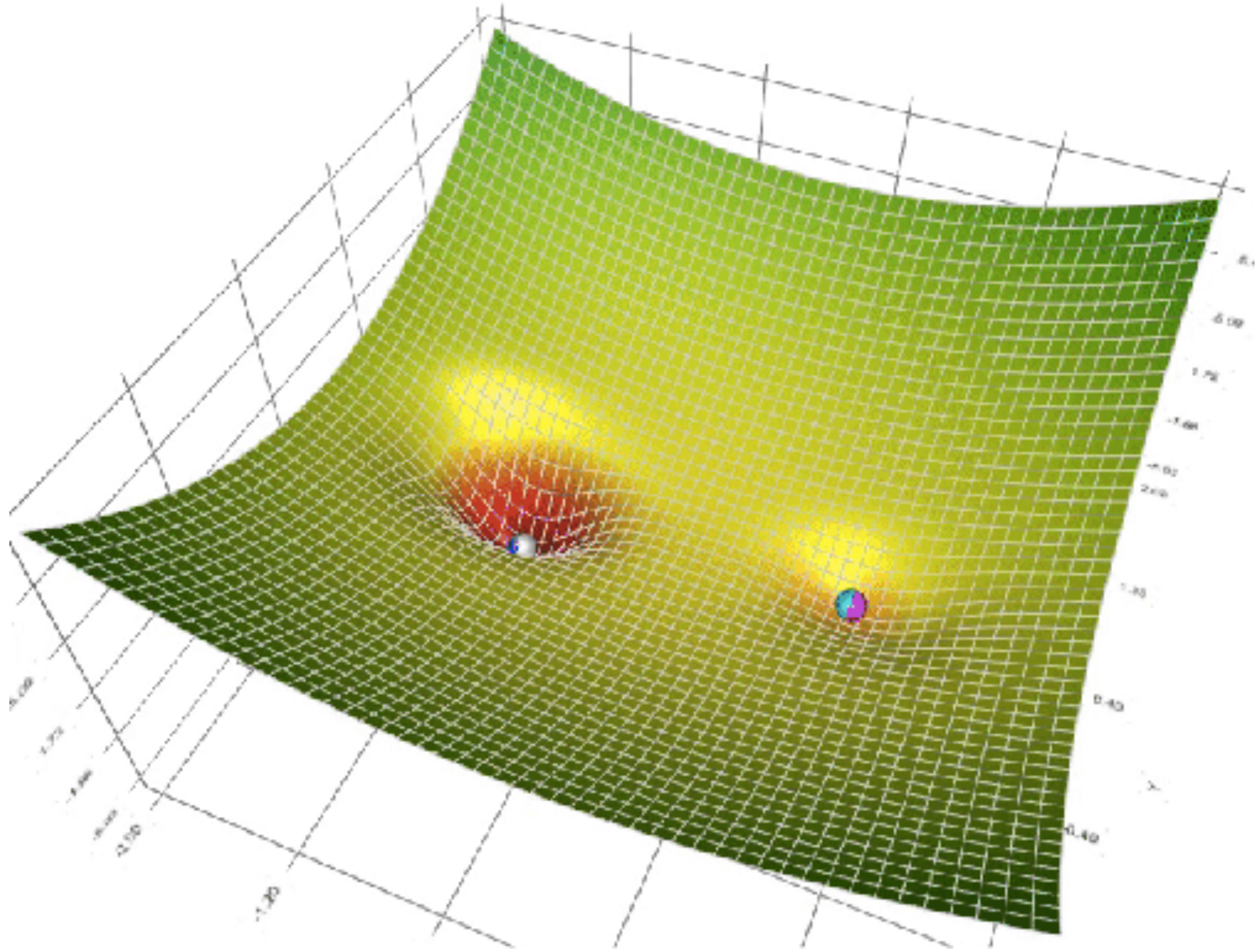
Gradient Descent Algorithm



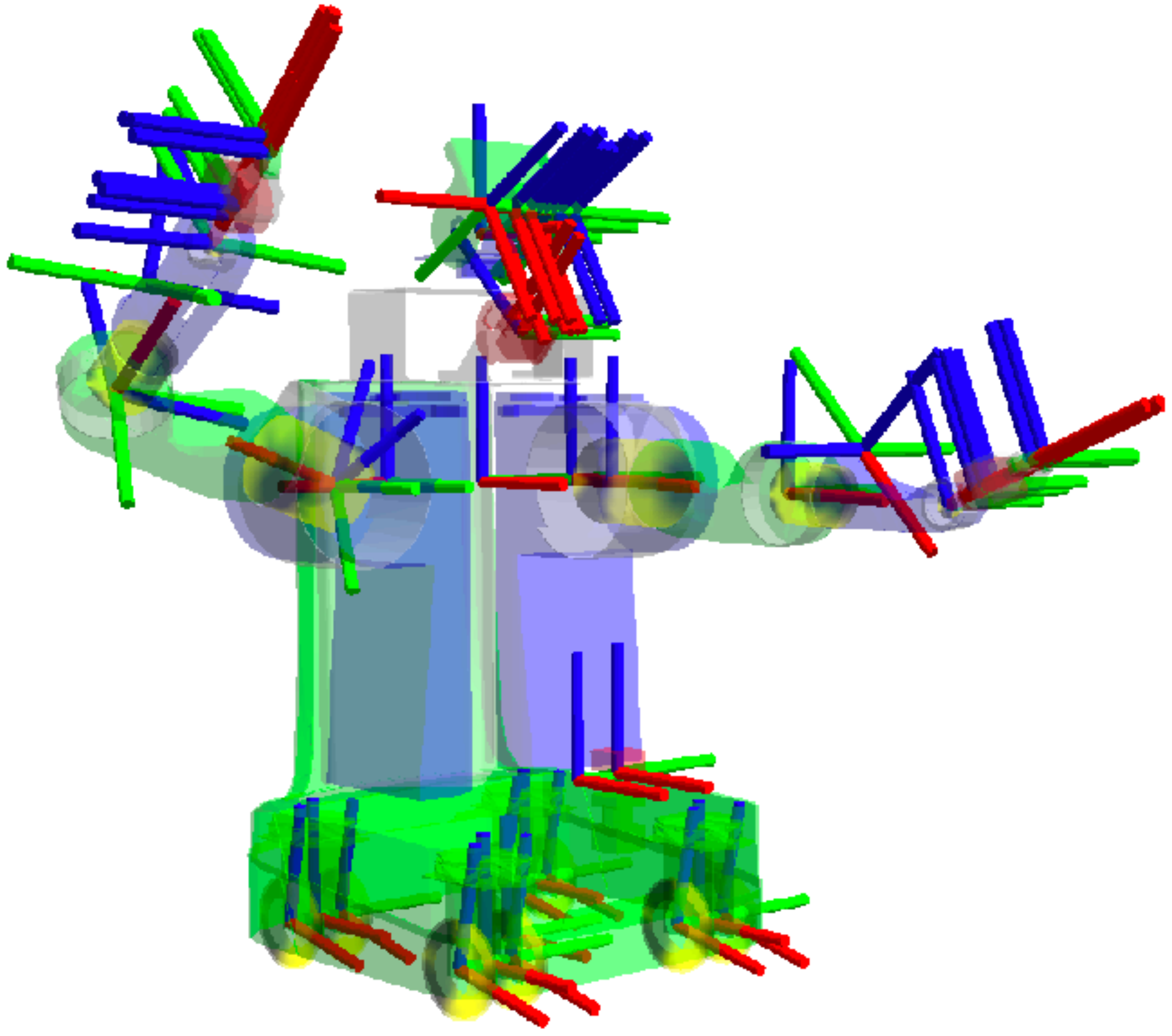
Credits: Stanley Chan

Gradient Descent Algorithm

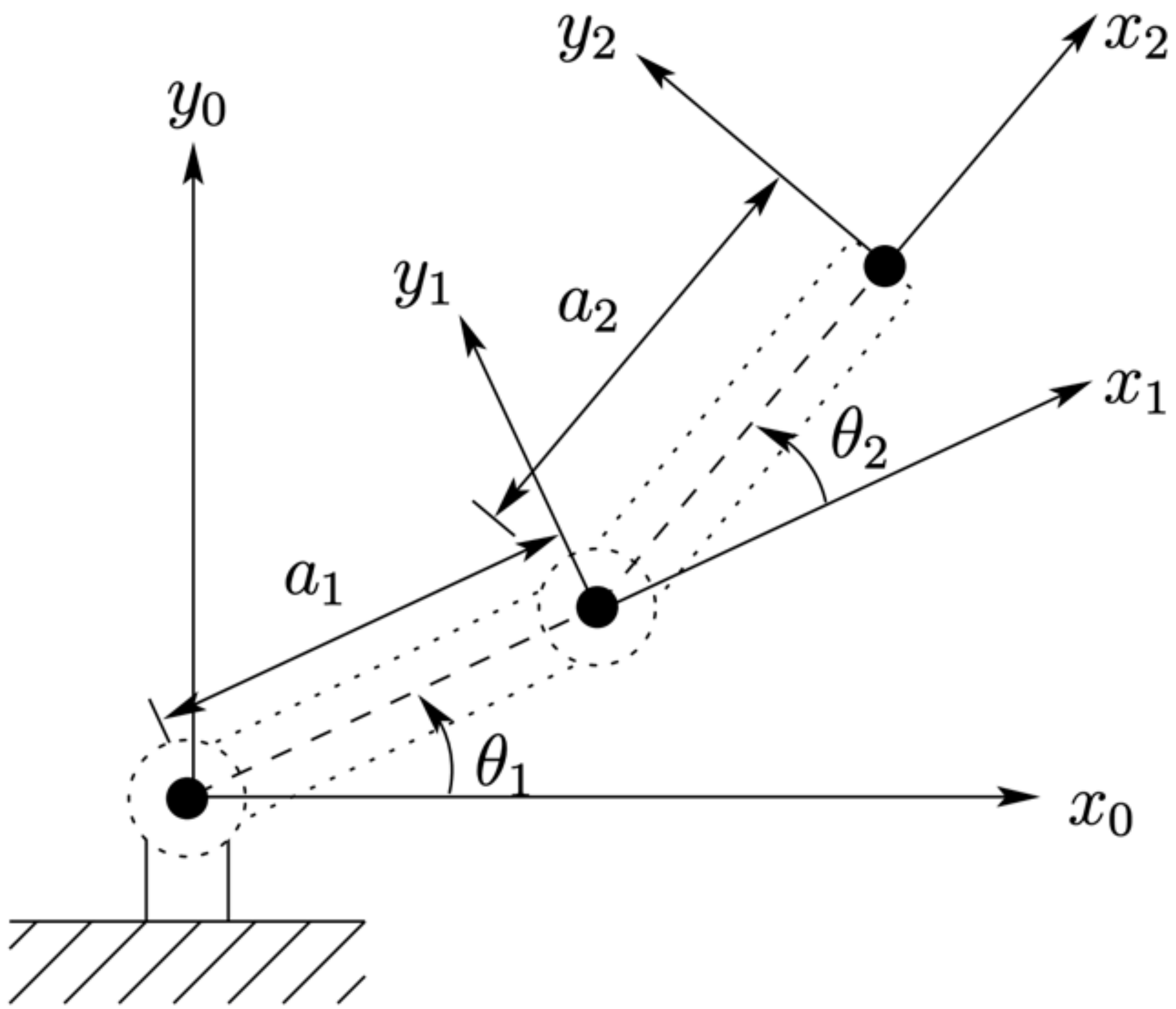
- Given: cost / loss/ objective function $f(\overrightarrow{\theta})$. Where $\overrightarrow{\theta} \in \mathbb{R}^d$.
- Goal: find $\overrightarrow{\theta}*$ such that $f(\overrightarrow{\theta}*) = \min_{\overrightarrow{\theta}} f(\overrightarrow{\theta})$.
- Gradient descent solution:
  - Start from initial guess $\overrightarrow{\theta}^0$ and learning rate α
  - Update $\overrightarrow{\theta}^{i+1} \leftarrow \overrightarrow{\theta}^i - \alpha \nabla f(\overrightarrow{\theta})$
  - Repeat until change in θ is small, or maximum number of steps reached.



Robot as a collection of rigid bodies + transformations!



Forward Kinematics

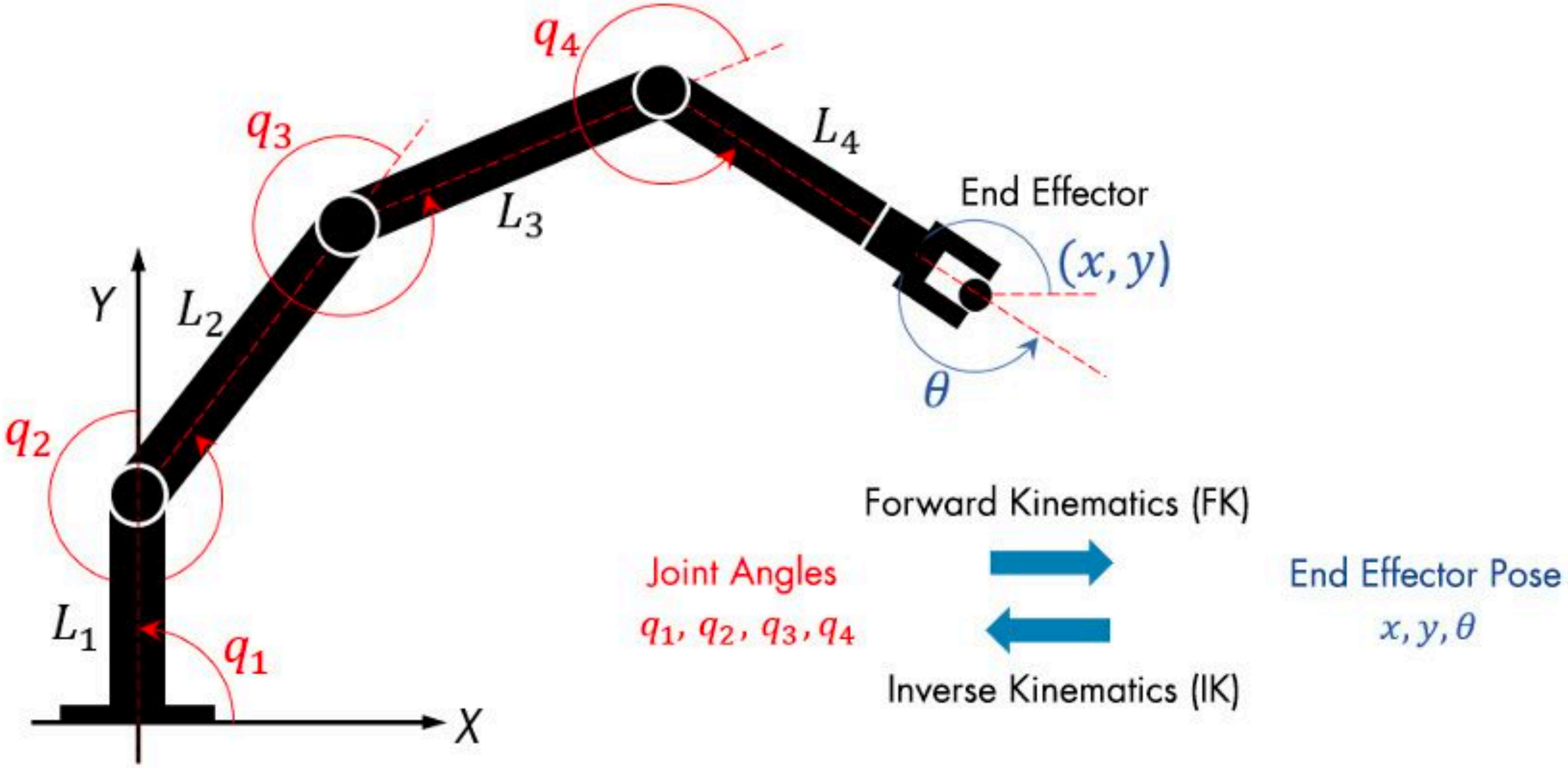


$$A_1 = \begin{bmatrix} c_1 & -s_1 & 0 & a_1c_1 \\ s_1 & c_1 & 0 & a_1s_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

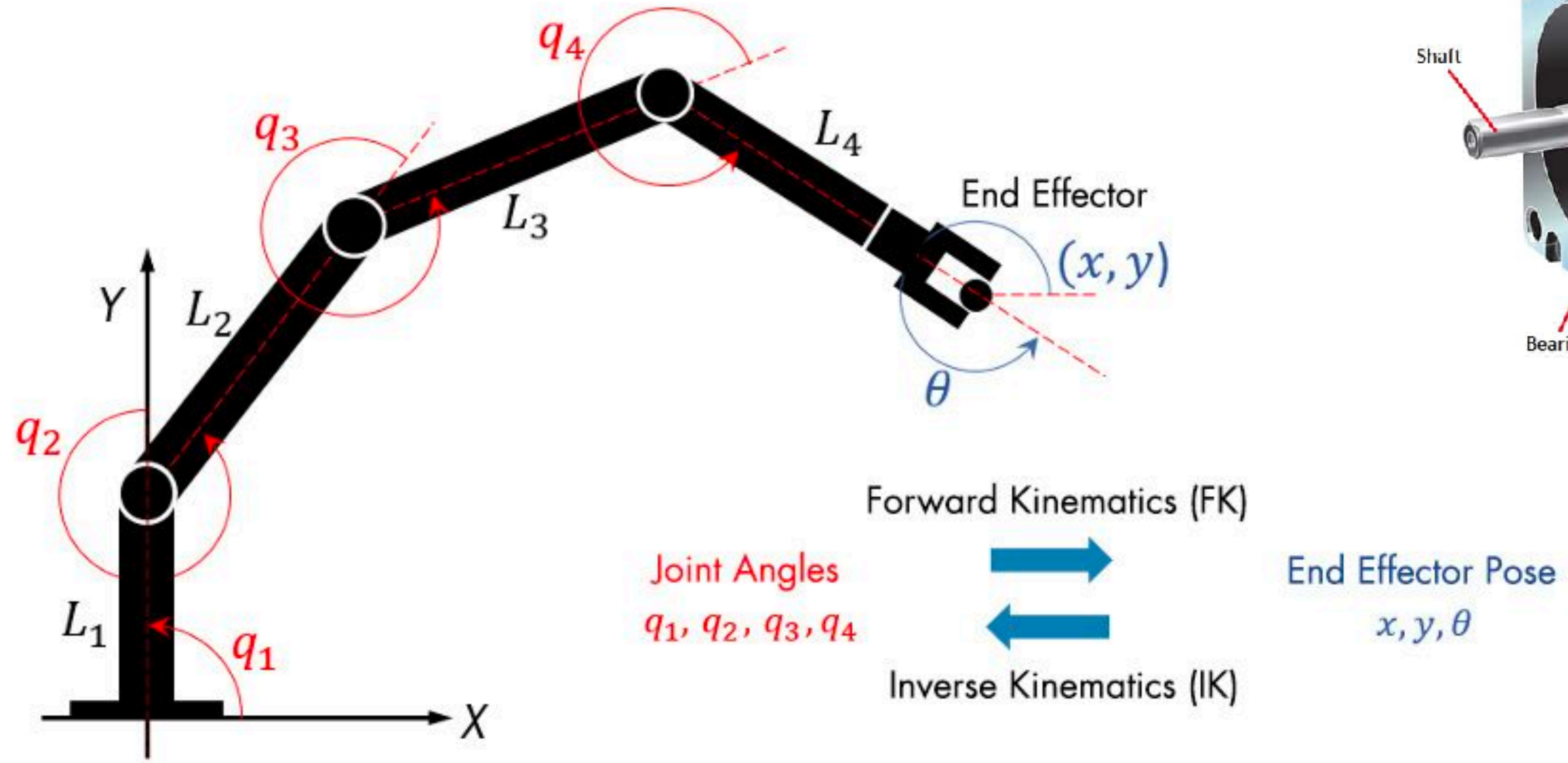
$$A_2 = \begin{bmatrix} c_2 & -s_2 & 0 & a_2c_2 \\ s_2 & c_2 & 0 & a_2s_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

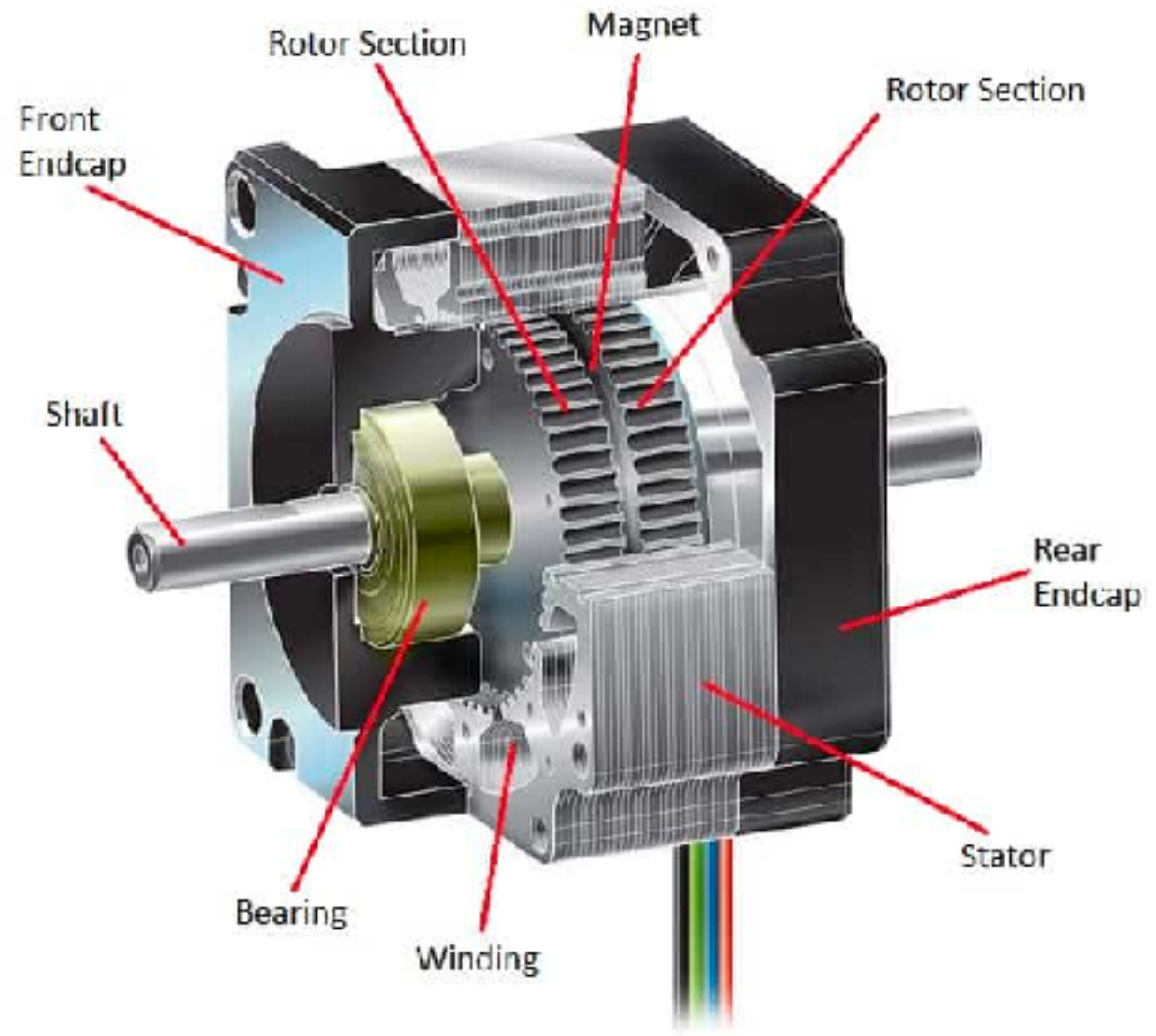
$$T_2^0 = A_1A_2 = \begin{bmatrix} c_{12} & -s_{12} & 0 & a_1c_1 + a_2c_{12} \\ s_{12} & c_{12} & 0 & a_1s_1 + a_2s_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

Inverse Kinematics



Lets go a step deeper

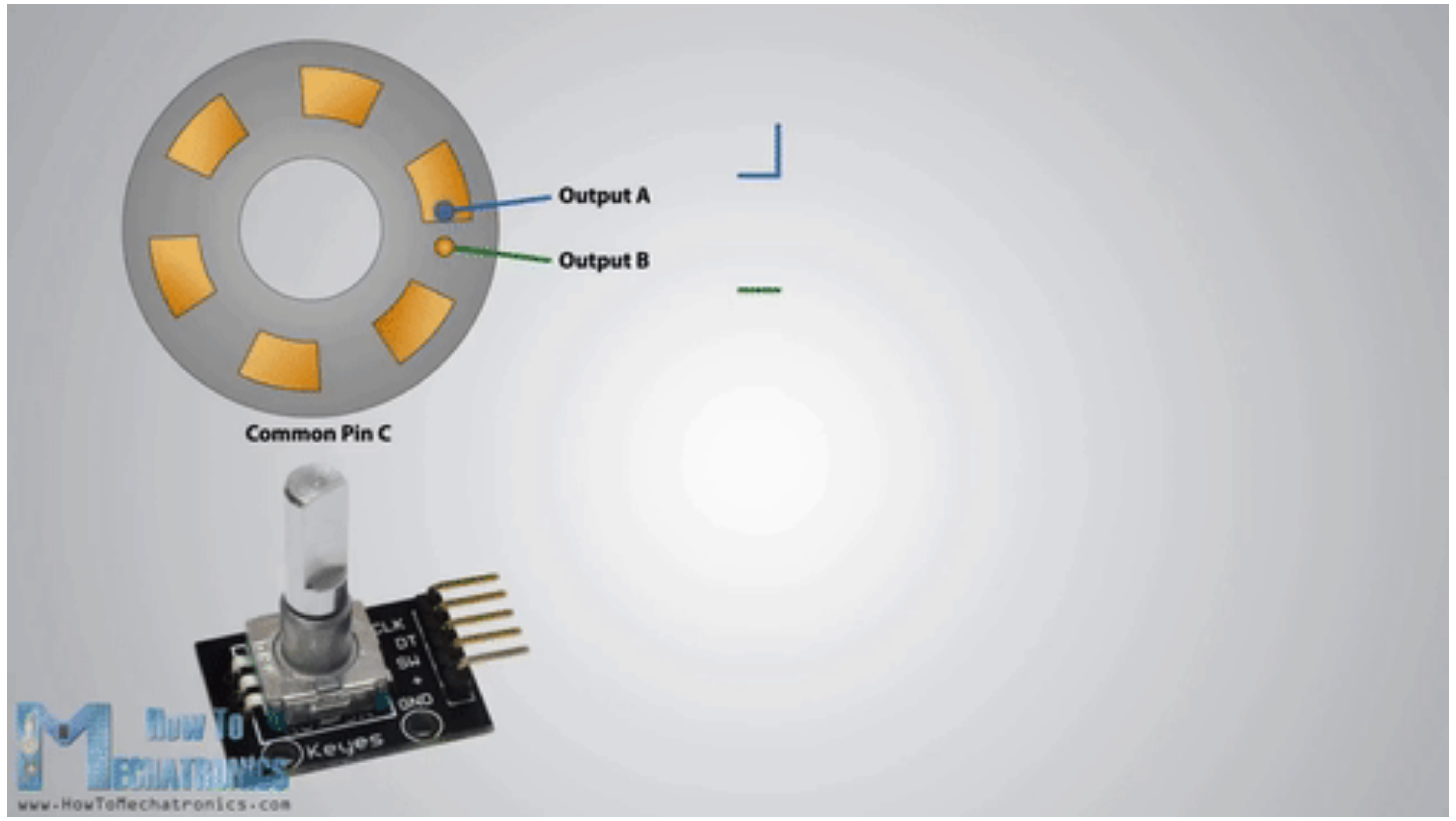




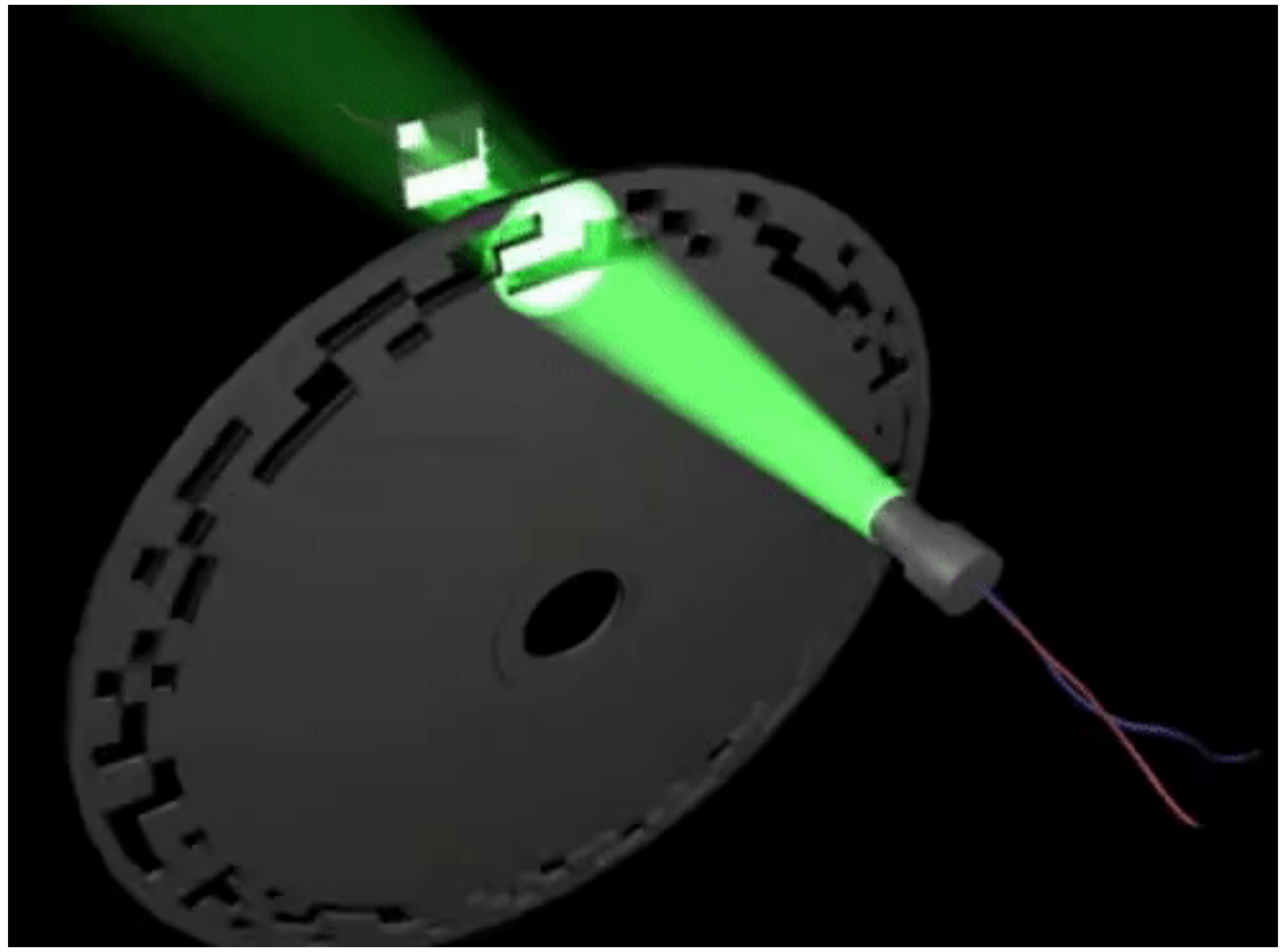
List of ideas

How does the robot know where it is?

Incremental Encoders

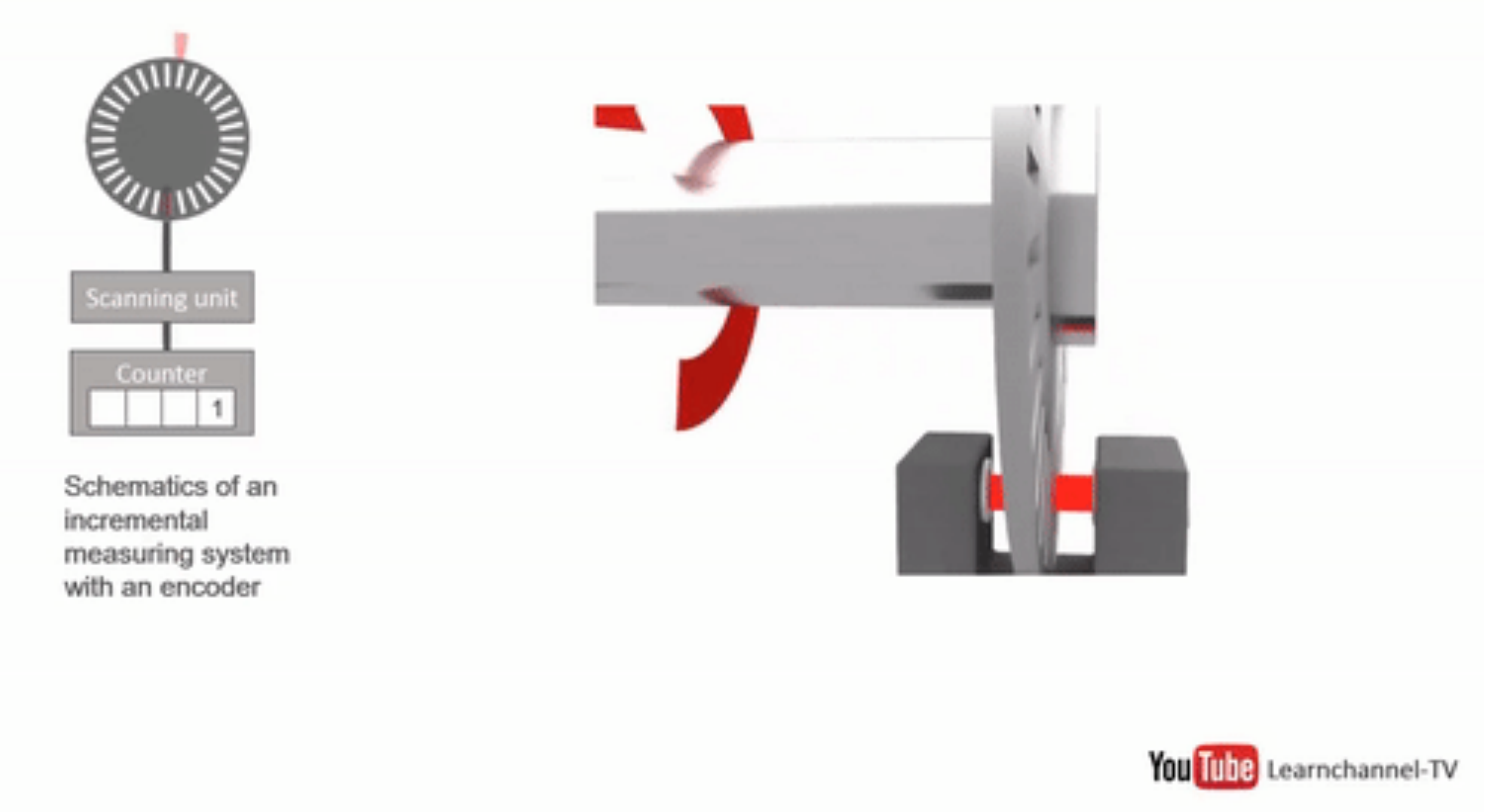


Absolute Encoders

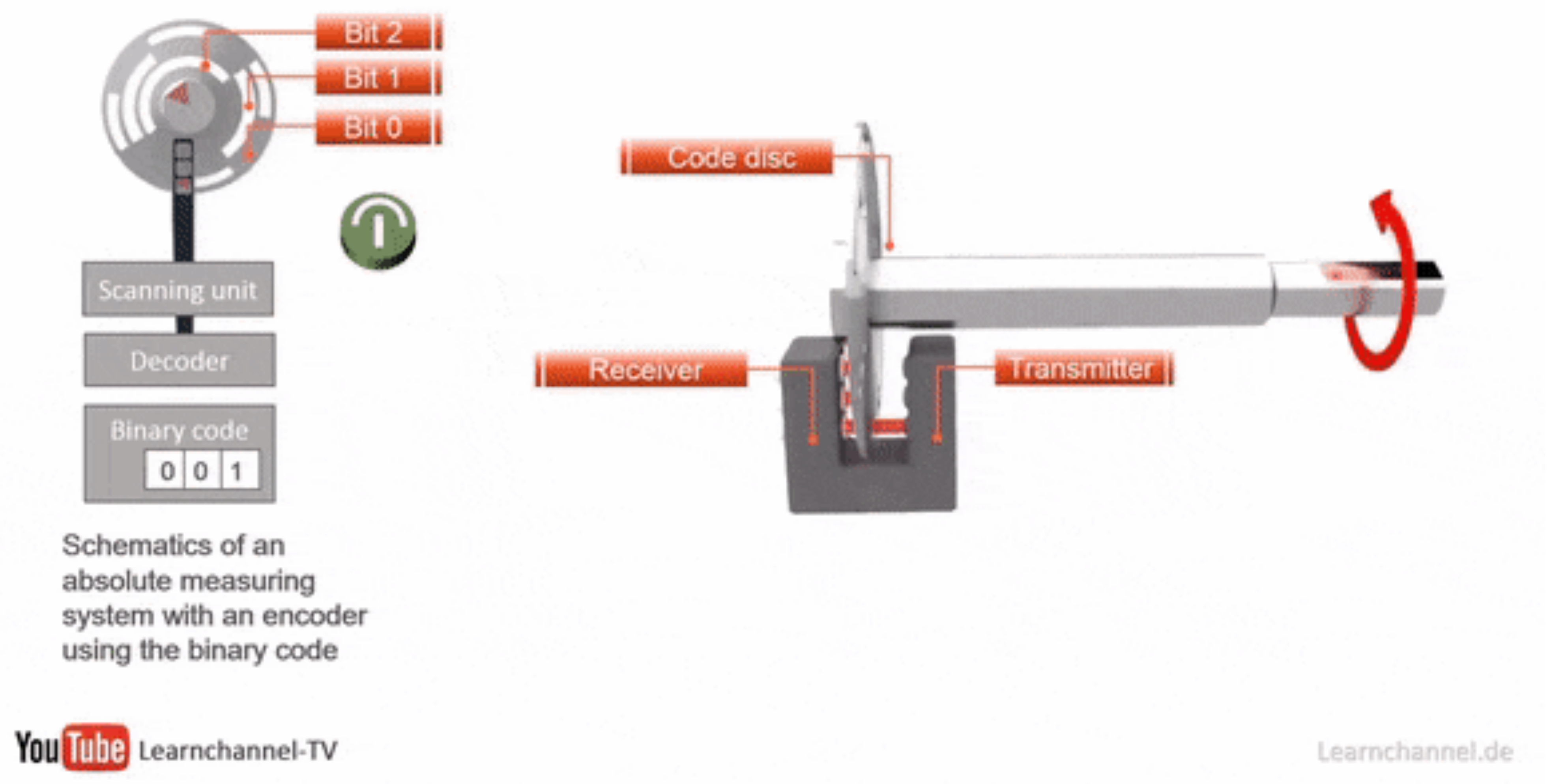


How does the robot know where it is?

Incremental Encoders



Absolute Encoders



Robot Control

- Input: encoder position, (velocity, acceleration etc.)
- Output: motor toques, forces, (voltages etc.)
- One instance of the control problem:
    - Achieve desired position by controlling motor torques.


Start Eq.
2
Target Eq.
7
Embedded Control Lab, Inha University, Incheon, Korea.

How can you achieve this?