Implementation of Kitchen-Assistant Robot

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RBE 501

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Background

- 4th industrial revolution leading to automation into new industries
- AI and Robotics hit an innovation, cost breakthrough point to enter more complex automation such as cooking
- Research by Samsung, Moley, and other researchers to implement cooking assistants that learn new recipes [1] [6] [7]

Samsung Cooking Robot [12]

Overview

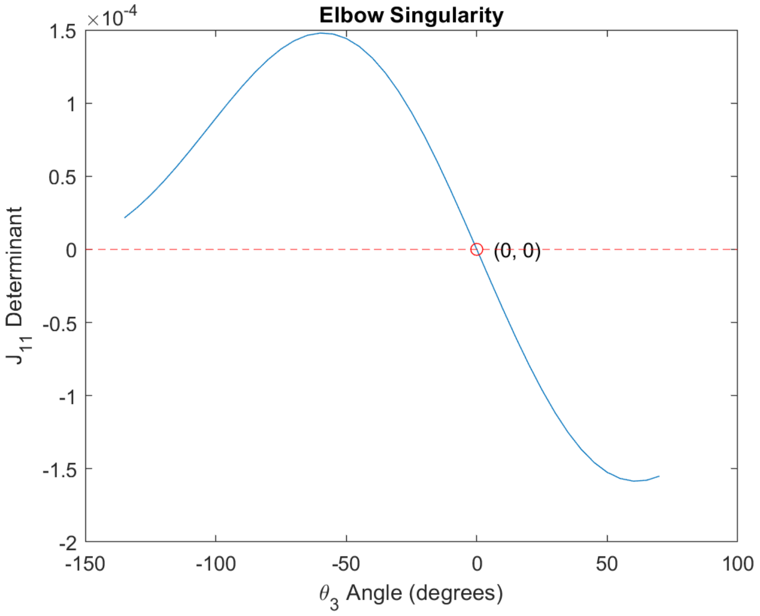
- **Objective** – to design and analyze a robotic arm that assists a chef with a cooking task.
- **Robot Used** – UR5e collaborative serial robot
  - Reach: 33.5”
  - Payload: 11lbs
  - Weight: 45.4lbs
  - Cost: $27,960 USD
- Assist a chef with the following tasks:
  - Picking up a burger
  - Placing on a stove
  - Flipping burger
  - Retrieving from the stove

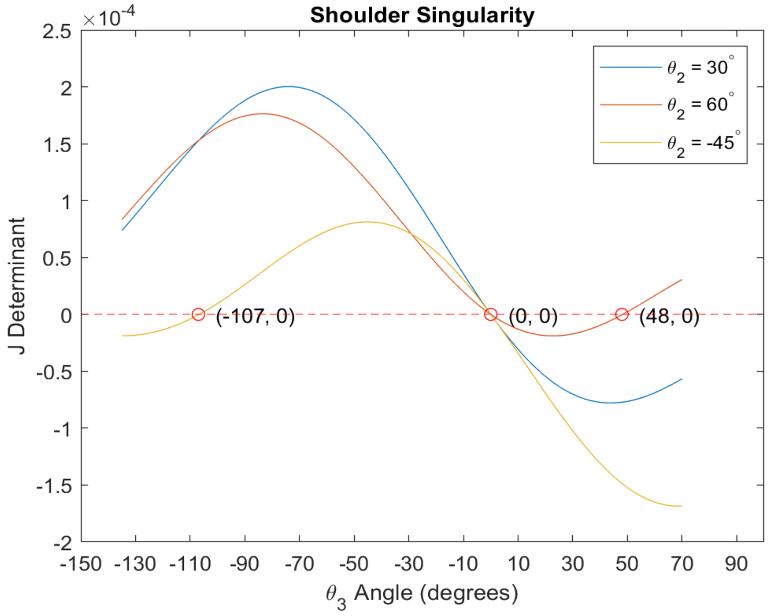
Please reference paper for the motion planning code and detailed analysis.

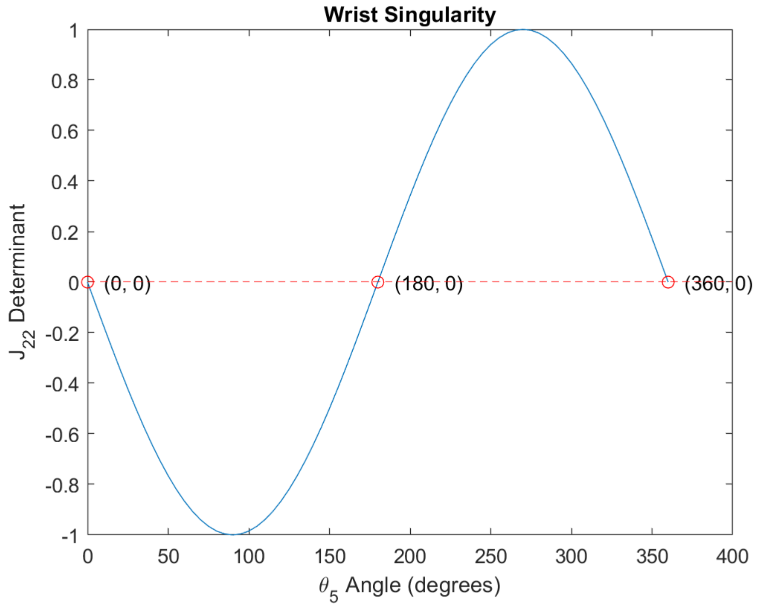
UR5e Robot [11]

Singularity Positions

- Must avoid singularity positions of any serial robot for safety and performance
- Singularity occurs when the determinant of Jacobian is zero
  - The equations of the robot can not determine how the robot should move in these positions
  - Robot locks up! Restricts motion

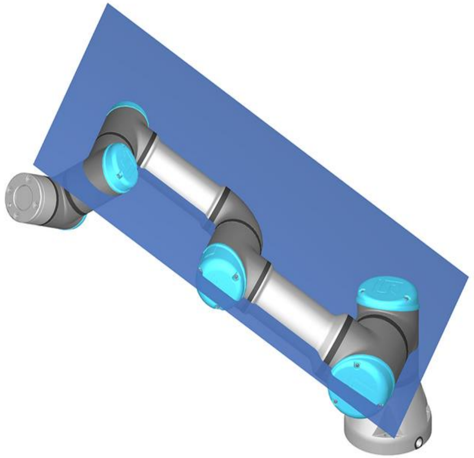




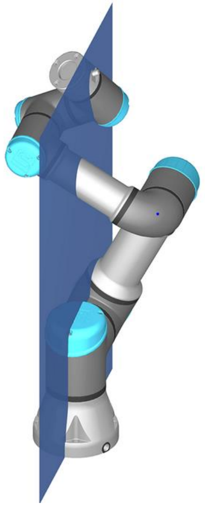


Singularity Positions (cont.)

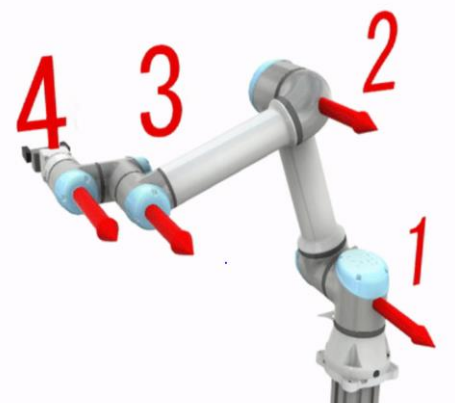
- UR5 Singularity Positions
  - Elbow
    - $\Theta_3=0^\circ$
  - Shoulder
    - Joint 5 and 6 pass through joints and 2 axes
  - Wrist
    - $\Theta_5=0^\circ, \pm 180^\circ, \pm 360^\circ$



Elbow Singularity[10]



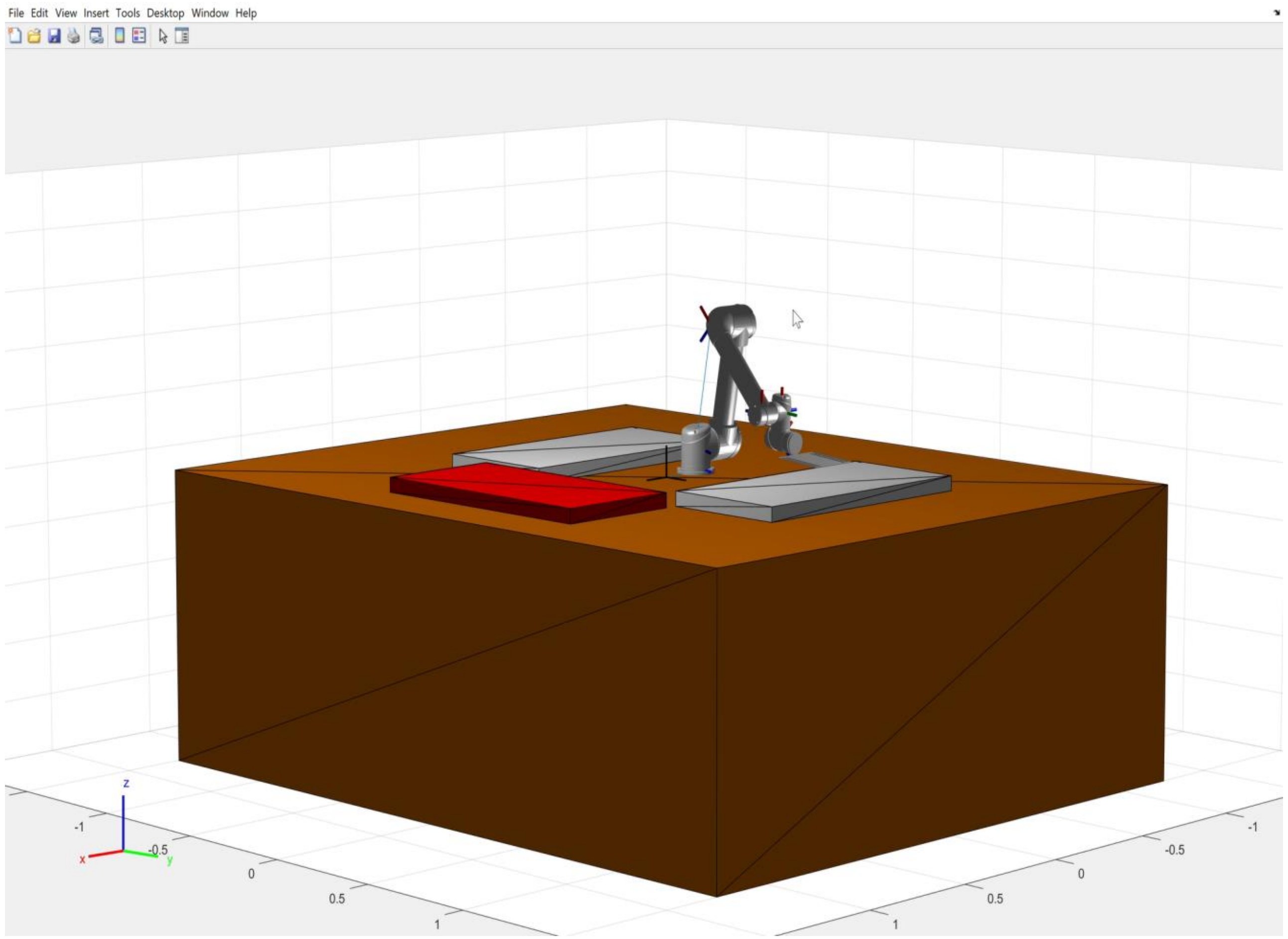
Shoulder Singularity[10]



Wrist Singularity[10]

Motion Planning Simulation Video

- Created cooking environment with collision boxes for robot to avoid
  - Red surface is stove
  - Grey surfaces are the pick and place locations
- Used trapveltraj function to smooth out the robot movement through waypoints



Dynamical Model

$$\begin{bmatrix}\tau_1\\ \vdots\\ \tau_n\end{bmatrix} = \begin{bmatrix}M(q) & M(q)\\ \vdots & \vdots\\ M(q) & M(q)\end{bmatrix}\begin{bmatrix}\ddot{\theta}_1\\ \vdots\\ \ddot{\theta}_n\end{bmatrix} + \begin{bmatrix}C(q,\dot{q})\\ \vdots\\ C(q,\dot{q})\end{bmatrix}\begin{bmatrix}\dot{\theta}_1\\ \vdots\\ \dot{\theta}_n\end{bmatrix} + \begin{bmatrix}G(q)\\ \vdots\\ G(q)\end{bmatrix}$$

Find the robot's homogenous transformation matrix H_n^0
Use H_n^0 to find the Jacobian
Apply the Jacobian to joint velocities $\dot{\theta}_1 \ldots \dot{\theta}_n$ to find end effector velocities $v_1 \ldots v_n$
Solve for the kinetic energy of each link using $k_i = \frac{1}{2} m_i {v_i}^2$
Solve for the potential energy of each link using $p_i = m_i g H_i^0(3,4)$
Sum all kinetic energies into k and all potential energies into p
Define the Lagrangian $L = k - p$
Find $\tau_1 \ldots \tau_n$ using $\tau_i = \frac{d}{dt}\frac{dL}{d\dot{\theta}_i} - \frac{dL}{d\theta_i}$
For $\tau_1 \ldots \tau_n$, gather the coefficients of $\ddot{\theta}$ and g. All other terms are Coriolis couplers.
Write the gathered terms in the final matrix form

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Thank You!