Advanced Velocity Control for a Robot Arm Using the RRMC Approach

# Short description

Implement advanced velocity control following the RRMC approach.

# Motivating statement

In today's fast-paced industries, robotic arms need to be both precise and adaptable to effectively handle complex tasks. Traditional control methods often struggle in dynamic environments, where conditions can change rapidly. Resolved-Rate Motion Control (RRMC) offers a promising solution by converting desired end-effector movements into joint velocities with precision. By implementing an advanced velocity control system using RRMC, we can significantly improve the performance and flexibility of robotic arms. This enhancement is crucial for applications in fields like manufacturing, healthcare, and logistics, where efficiency and accuracy are paramount. This project aims to explore and implement the RRMC approach, using MathWorks tools to achieve reliable and precise control of a robotic arm.

# Project description

develop and implement an advanced velocity control system for a robotic arm using the Resolved-Rate Motion Control (RRMC) approach. This involves designing a control algorithm that translates desired end-effector velocities into joint velocities, ensuring precise motion control.

**Suggested Steps**

1. Define the Application Environment
   * Identify and define the specific application environment for the robotic arm, such as pick-and-place operations in manufacturing facilities, or sorting and packaging in logistics.
   * Understand the operational requirements and constraints specific to the chosen industry.
2. Robot simulation
   * Simulate a robot from the available list in the [Robotics System Toolbox Library](https://www.mathworks.com/matlabcentral/fileexchange/98714-robotics-system-toolbox-robot-library-data)
   * Import the robot’s rigid body tree model using the [importrobot](https://www.mathworks.com/help/robotics/ref/importrobot.html#bvlvwcs-1-filename) function
3. **Kinematic Modeling**
   * Use the Robotics System Toolbox to model the kinematics of the robotic arm, including forward and inverse kinematics.
   * Develop equations that relate end-effector velocities to joint velocities using the Jacobian matrix, and compute the pseudo-inverse for solving the inverse velocity kinematics problem.
4. **Design of the RRMC Algorithm**
   * Define the desired velocity vector for the robot's end-effector in task space. This includes both linear and angular velocities that the end-effector should achieve.
   * Compute the Jacobian matrix for the robotic arm, which relates joint velocities to end-effector velocities. This matrix is essential for converting task-space velocities into joint-space velocities.
   * Use the pseudo-inverse of the Jacobian matrix to calculate the joint velocities required to achieve the desired end-effector velocities. This step involves solving the inverse kinematics problem in a differential manner.
   * Derive the joint velocity commands from the pseudo-inverse operation. These commands specify how each joint should move to accomplish the task-space objectives.
   * Implement a low-level joint-space controller to execute the computed joint velocity commands accurately.
   * Enforce joint limits, prevent collisions, and handle dynamic constraints to ensure safe and reliable robot operation.
5. Visualize the robot and its task using Sim3D

**Advanced project work:**

1. Add null space projection terms to manage redundancy and optimize secondary objectives, such as obstacle avoidance or joint limit avoidance.
2. Prototype efficient algorithmic solutions for computing the Jacobian pseudo-inverse and Hessian terms needed for advanced controllers.

# Background material

* Robotics System Toolbox
* Robotics library
* Robotics arm control examples
* Sim3D example

Suggested readings:

J. Haviland and P. Corke, "Manipulator Differential Kinematics: Part I: Kinematics, Velocity, and Applications," in *IEEE Robotics & Automation Magazine*, doi: 10.1109/MRA.2023.3270228. [[pdf](https://arxiv.org/pdf/2207.01796)]

J. Haviland and P. Corke, "Manipulator Differential Kinematics: Part 2: Acceleration and Advanced Applications," in IEEE Robotics & Automation Magazine, doi: 10.1109/MRA.2023.3270221. [[pdf](https://arxiv.org/pdf/2207.01794)]