

Finite Time High Precision Control of Robotic Arm Manipulator

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Digital Finite Time Control

- Finite time control (FTC)
 - Achieve a desired state within a **finite time window**
- Types of FTC
 - Sliding mode control (terminal, integral, adaptive, etc.)
 - Fuzzy/neural network technique
- Finite time stability
 - The origin is Lyapunov stable
 - The trajectory converges within finite time characterized by settling time function
 - $T(x_0) = \min\{t \in \mathbb{R}_+ : x(t) = 0\}$

Digital Finite Time Control

- Digital FTC
 - FTC technique should be digitally implemented
- Technical Gap
 - Transitioning from continuous to discrete FTC is not straightforward
 - Chattering effect
 - Instability
- Chattering**
 - A system oscillates back and forth with high frequency near the desired state
 - Chattering is even bigger issue for digital FTC due to the lack of smoothness
 - Chattering** can be caused by unmodeled dynamics or discrete time implementation

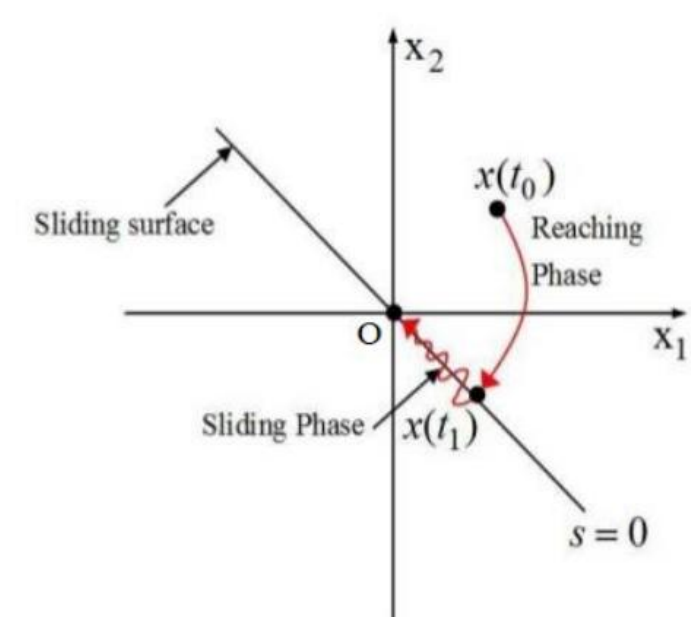


Figure 1. The chattering effect [2]

- Chatting suppression methods in CT [3]
 - Observer-based chattering suppression
 - State-dependent gain method
 - Equivalent-control dependent gain

Applications

- High precision control
 - Robotics (manufacturing)
 - Aerospace (satellite attitude control, missile guidance)
- FTC for multi-agent system
 - Mission with multiple subobjectives
- Digital implementation of FTC poses a big challenge

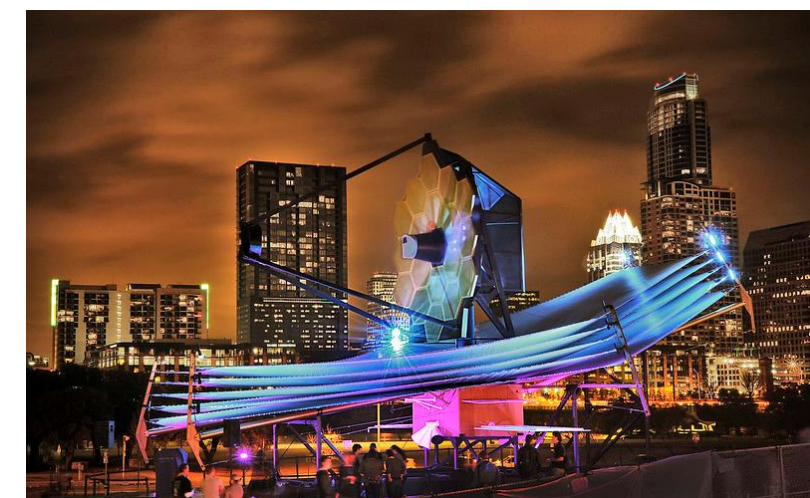


Figure 2. James Webb Space Telescope (credit: NASA JWST)



Figure 3. Manufacturing robotic arm for semiconductor

Sliding Mode Control

- Sliding mode control (SMC)
 - System slides onto a desired surface [4]
 - Control law and the switching function
- General equations for SMC that represent the single dimensional motion [5]

$$\dot{x}_1 = x_2 \quad x_1(0) = x_{10}$$

$$\dot{x}_2 = u + f(x_1, x_2, t) \quad x_2(0) = x_{20}$$
 - u is the control force
 - $f(x_1, x_2, t)$ is the disturbance

TSMC Robotic Arm

- TSMC is a type of SMC that guarantee's a system's convergence within a finite time
- Based off the paper from [7] three methods of SMC of a two-joint robotic arm will be simulated and compared:
 - Nonsingular fixed-time TSMC (NFTSMC)
 - Robust fixed-time SMC (RFSMC)
 - Fast TSMC (FTSMC)
- For these examples ode45 from MATLAB will be used with a step size of 0.1 for a 2 joint, 2 DOF robotic arm..

TSMC Robotic Arm

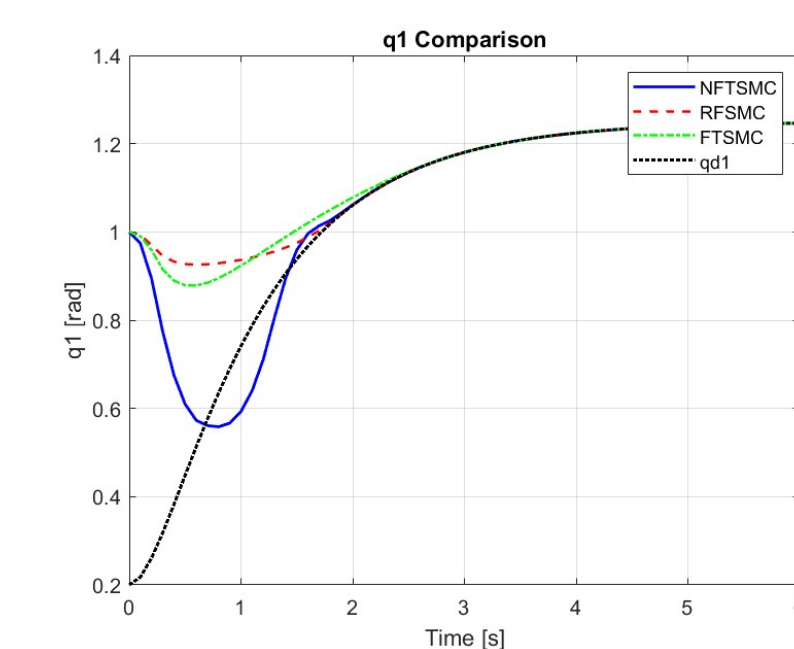


Figure 4. Joint 1 vs. time

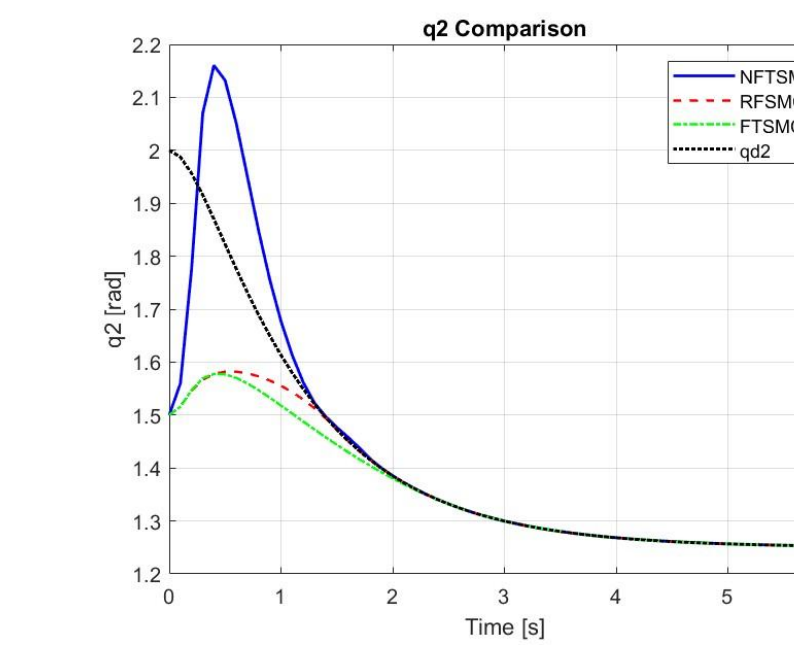


Figure 5. Joint 2 vs. time

- Figure 4 and 5 respectively show joint 1 and joint 2 vs. time

Ongoing Study

- [8] is a paper that uses the IRB-120 robot manipulator dynamics and produces both a 3 joint and 6 joint study
- Based off the paper a 6 joint study comparing the implicit and explicit Runge-Kutta methods will be stimulated with a step size of 0.05

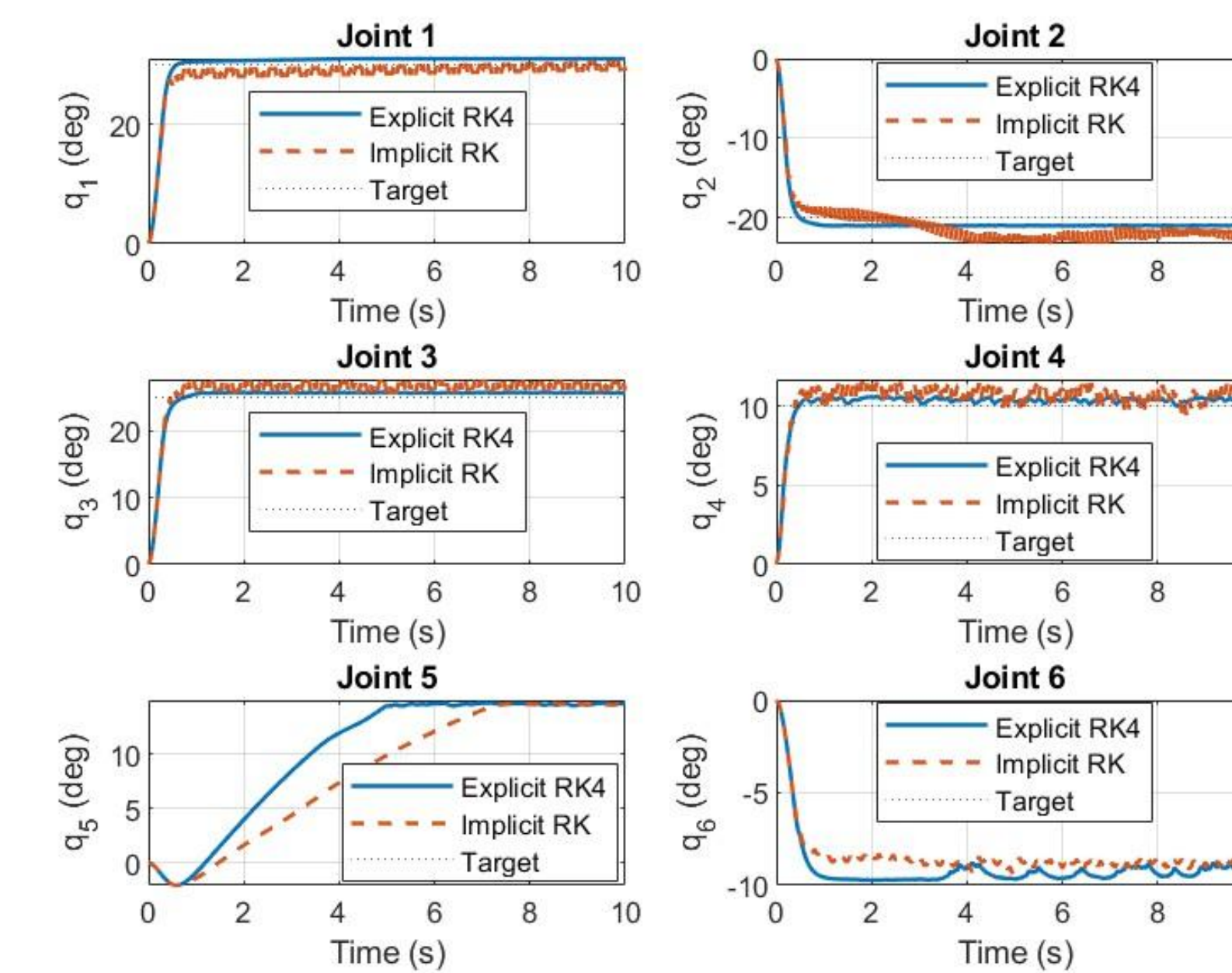


Figure 6. Joint Position vs. time



Figure 7. Mechatronics 270 m5

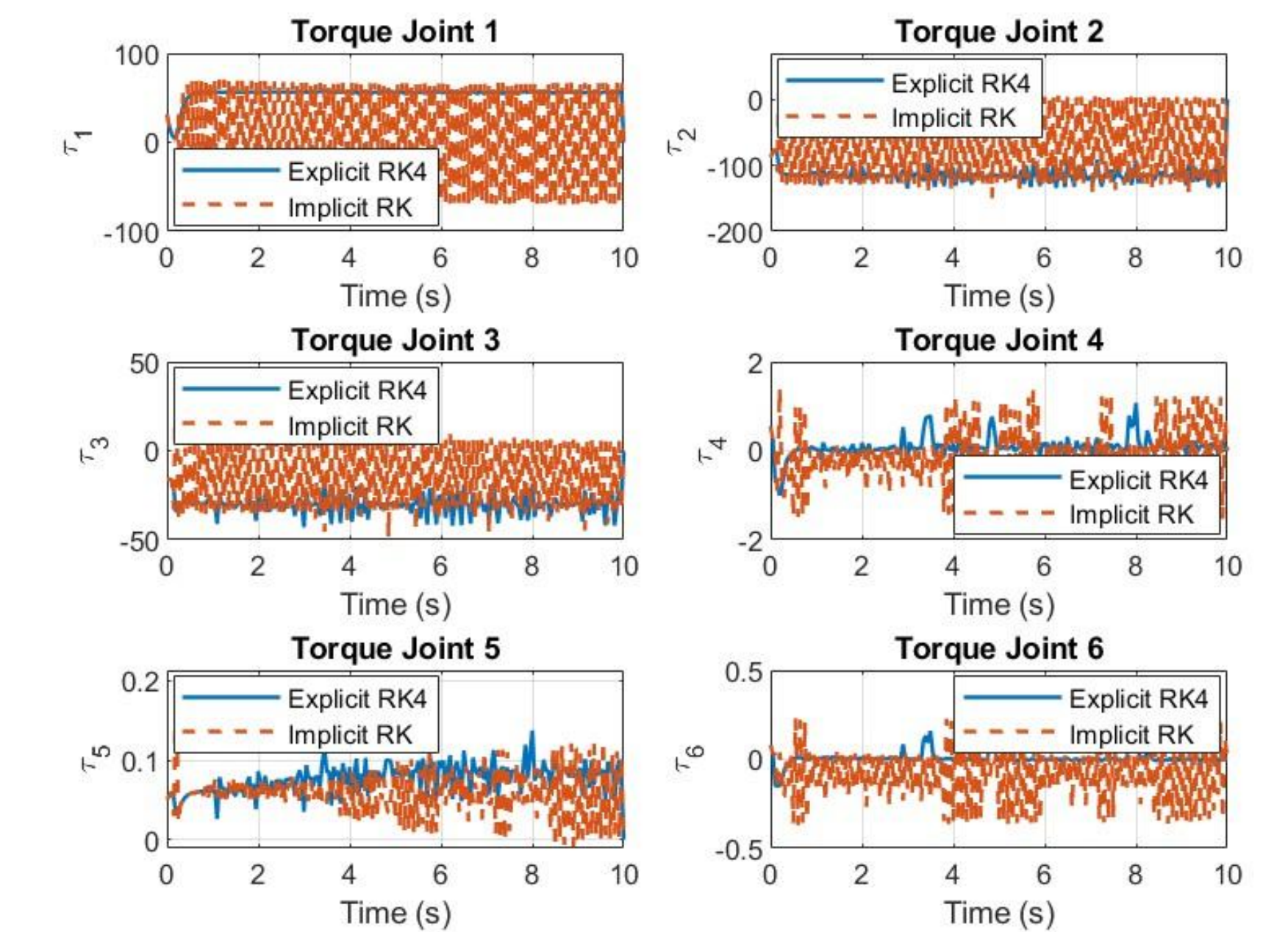


Figure 8. Torque vs. time

Future Study

- The current simulation needs to be improved and finalized
- The dynamics and interaction effects of the Mecham 270 m5 need to be implemented in the current simulation
- Setting up the robotic arm testbed
- Test the simulated results to confirm their accuracy and adjust future simulations as needed

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