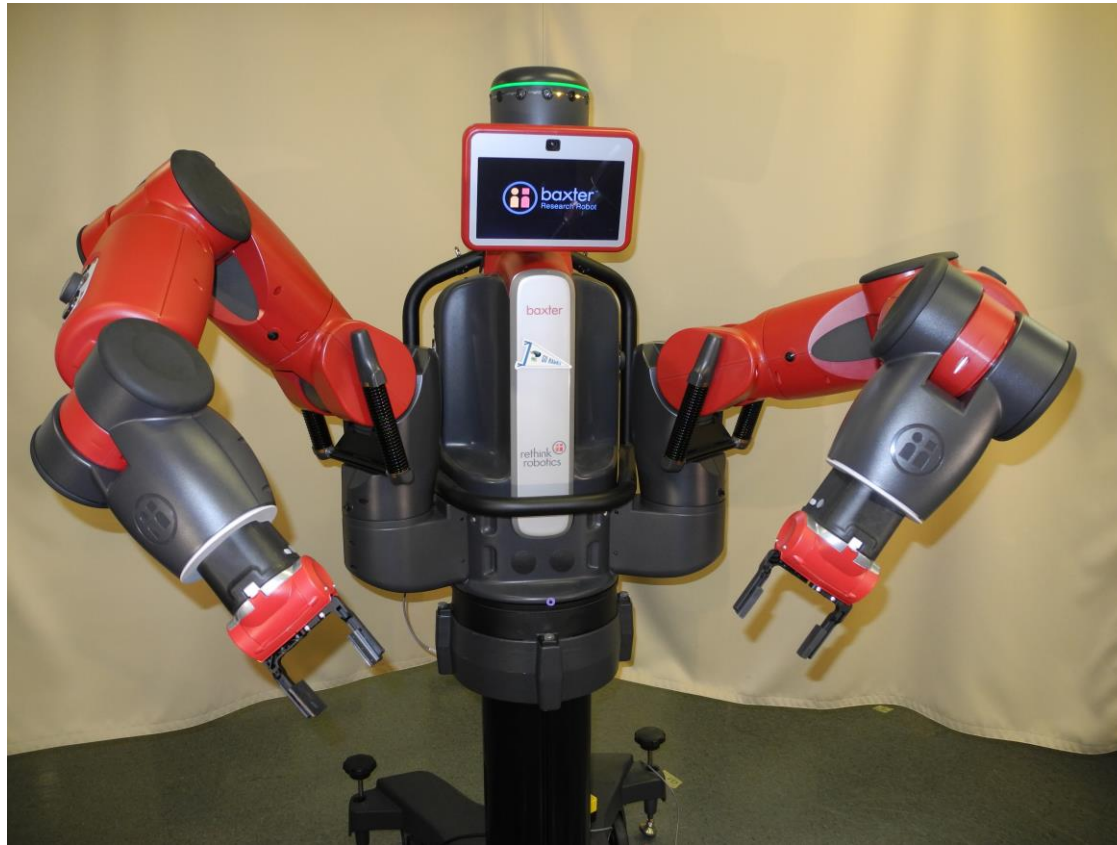# Baxter's Arm Control Modes

Control Overview

Joint Command Overview

Baxter's arm controls flow through four layers

1. User Code running via workstation or SSH

2. Joint Control Listeners via ROS topic

3. Real-Time Motor Control Loop

4. Joint Control Boards

Layers 2,3,4 are not accessible by user for modification

# Control Overview (cont.)

Joint Command Timing

- 1.6ms for the Command to publish over ROS to the Joint Controller over rostopic (via network)

- 1ms for the Joint Controller Listener to command the Motor Controller (MC), running an asynchronous real time loop of 1KHz

- 1ms for the MC to transfer to the Joint Control Board (JCB) and evaluate the command

- 1ms for the JCB to read the updated status and give a response to the MC

- 1ms for the MC to report back to the Joint Controller Publisher

- 1.6ms for the Joint Controller to publishing the State back over rostopic (via network)

- Total 7.2ms roundtrip ROS User Publisher to ROS User Subscriber

Baxter's Arm Control Modes

Baxter's arms can be controlled by four modes

- Joint Position Control

- "Raw" Joint Position Control

- Joint Velocity Control

- Joint Torque Control

Joint Position Control
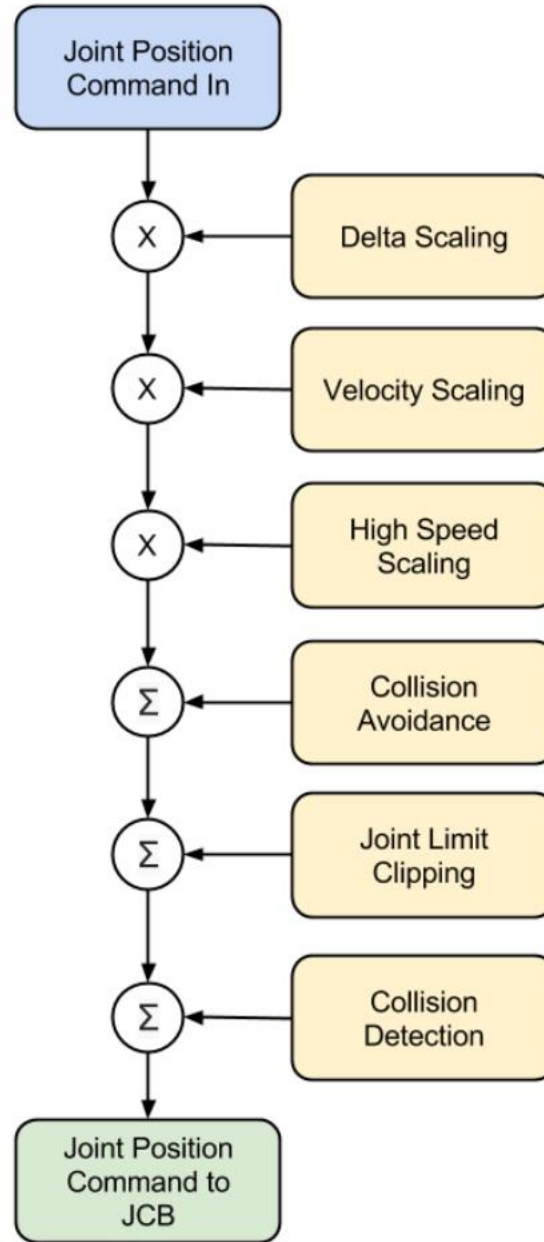
Delta Scaling:
Scale setpoint based on which joint is going to take the longest to achieve. Allows all joints to arrive simultaneously.

Velocity Scaling:
'Speed Ratio' describes the overall velocity scaling.

High Speed Scaling:
High speed scaling reduces execution speed when commanded speed exceeds a high speed velocity threshold **and** the arm's high-speed collision links are in collision.

Collision Avoidance:
Applies offsets to joint commands based on depth of intersection between arm collision geometries and the opposing arm or torso.
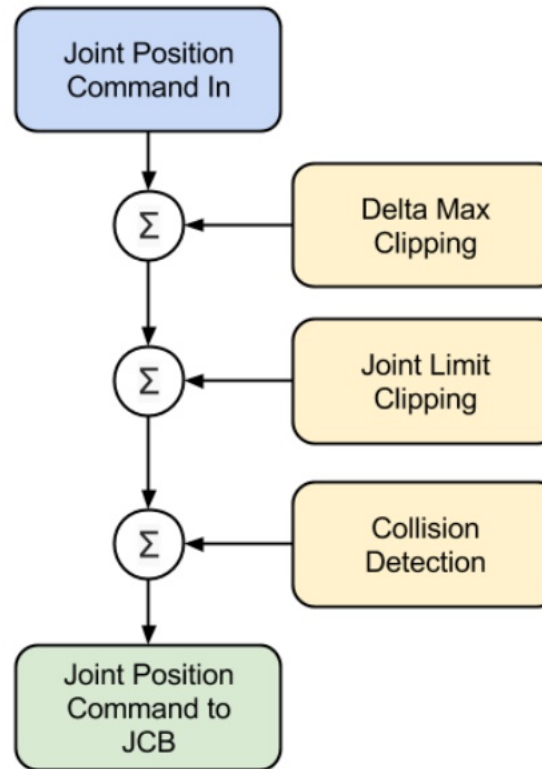
Joint Limit Clipping:
If the joint command is beyond limits, clip the command to respect joint limits.

Collision Detection:
If collision (impact) is detected, set position command to hold current compensating for the impact.

"Raw" Joint Position Control

Delta Max Clipping:
The joint command will be clipped based on the delta max (offset from current position defined by max joint velocity)
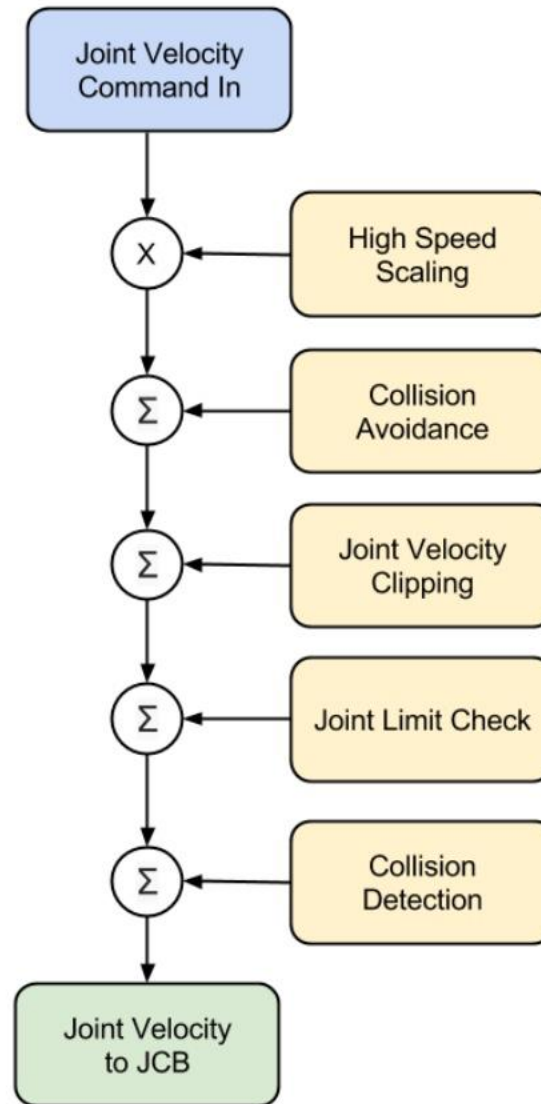
Joint Limit Clipping:
If the joint command is beyond limits, clip the command to respect joint limits.

Collision Detection:
If collision (impact) is detected, set position command to hold current compensating for the impact.

Joint Velocity Control

High Speed Scaling:
High speed scaling reduces execution speed when commanded speed exceeds a high speed velocity threshold **and** the arm's high-speed collision links are in collision.

Collision Avoidance:
Applies offsets to joint commands based on depth of intersection between arm collision geometries and the opposing arm or torso.

Joint Velocity Clipping:
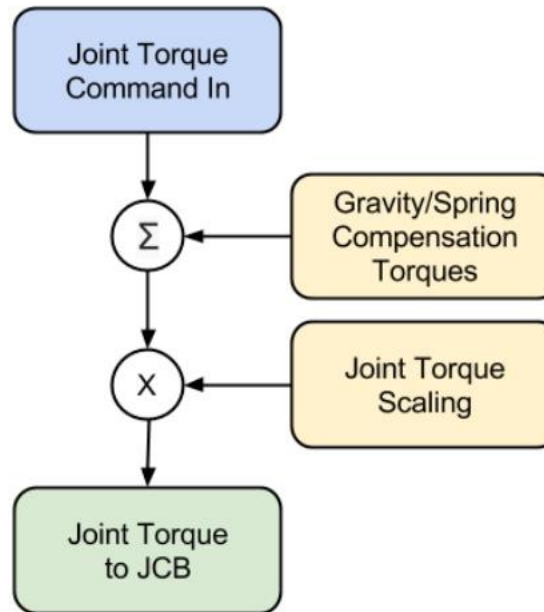Limits joint velocity command to not exceed maximum joint velocities.

Joint Limit Check:
Validates that resulting joint position will be within joint limits. If not, no velocity will be commanded to any joint.

Collision Detection:
If collision (impact) is detected, set position command to hold current compensating for the impact.

Joint Torque Control

```
┌─────────────────┐
│  Joint Torque   │
│  Command In     │
└─────────────────┘
         │
         ▼
        (Σ) ◄──────────  ┌─────────────────┐
         │               │  Gravity/Spring │
         │               │  Compensation   │
         │               │  Torques        │
         ▼               └─────────────────┘
        (X) ◄──────────  ┌─────────────────┐
         │               │  Joint Torque   │
         │               │  Scaling        │
         ▼               └─────────────────┘
┌─────────────────┐
│  Joint Torque   │
│  to JCB         │
└─────────────────┘
```

Gravity/Spring Compensation:
The joint torque command is applied in addition to the gravity and S1 spring compensation torques.

Joint Torque Scaling:
Scales all joint torques if a torque command exceeds the maximum allowable torque for that joint. This scaling ratio is defined as torque_max / torque_command.