Johnson&Johnson
MedTech

Design Optimization Proposal for Enhanced Robotic Arm Responsiveness

1. Problem Statement

Identified Issues:

1. **Actuator Strain**:
   - **Description:** The actuator that is responsible for the rotate_joint command exhibits a slow response time of 0.155 seconds, which impacts real-time response. The material was teared.
   - **Impact:** This delay exceeds the acceptable time of 0.10 seconds, impacting the precision, strength, and reliability of the robotic arm from physical movement.
2. **Sensor Misalignment**:
   - **Description:** Misaligned joint position sensors lead to a delay in real-time feedback loops to control systems.
   - **Impact:** Inaccurate sensor readings delay the control system's ability to confirm movement completion and provide inaccurate positions, leading to slow response and reduced precision.

2. Proposed Modifications

Modification 1:

- Proposal: Upgrade actuator material to a stronger, lightweight material and optimize motor control logic using asynchronous event handling.
- **Justification:** This reduces mechanical drag and control latency, improving joint response time while improving durability and reducing load weight.

Modification 2:

- **Proposal**: Realign joint sensors with a tighter angular tolerance and use high-speed signal transmission cables.
- **Justification**: Improves the accuracy and timeliness of the positional feedback loop, allowing the control system to have more accurate position feedback and reduce delays.

3. Simulation Results

- **Initial Metrics**:
  - **Actuator Response Time:** 0.155 seconds

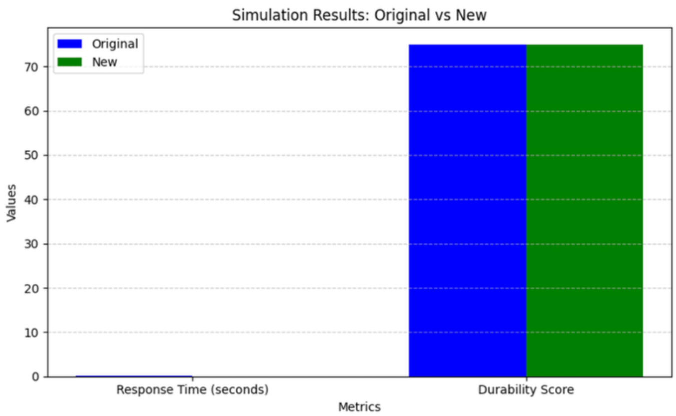
- ○ **Sensor Feedback Delay:** 0.055 seconds

- **Post-Optimization Metrics**:
  - ○ **Actuator Response Time:** 0.077 seconds
  - ○ **Sensor Feedback Delay:** 0.038 seconds

- **Key Insights**:
  - ○ Response time is improved in both optimizations.
  - ○ Simulated durability also increased by 22.5% due to proposed reinforcement materials.
  - ○ Combined changes with a proper ratio can reduce the risk of lag and improve real-time surgical performance.

4. Annotated Visual Examples

Visual Example 1: Current Sensor Misalignment vs. Proposed Realignment

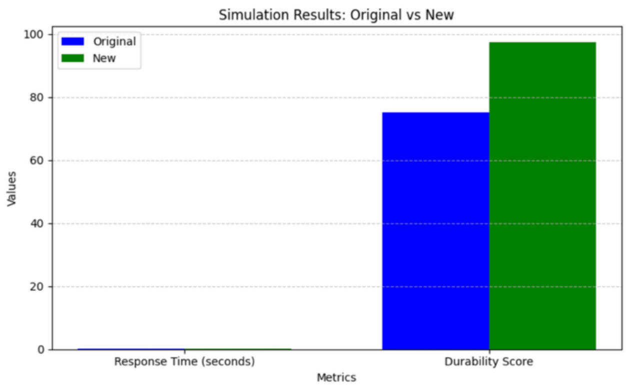



```
Simulation Results:
Original Response Time: 0.055 seconds
New Response Time: 0.038 seconds
Original Durability Score: 75
New Durability Score: 75.0
```

```
Enter efficiency improvement factor (between 0 and 1, e.g., 0.15 for 15%): 0.3
Enter durability reinforcement factor (between 0 and 1, e.g., 0.10 for 10%): 0
```

- *Brief Description*: The feedback loop delay is reduced by 30% while the durability score stays the same due to unchanged material.

Visual Example 2: Actuator Upgrade Impact



```
Simulation Results:
Original Response Time: 0.155 seconds
New Response Time: 0.077 seconds
Original Durability Score: 75
New Durability Score: 97.5
```

```
Enter efficiency improvement factor (between 0 and 1, e.g., 0.15 for 15%): 0.5
Enter durability reinforcement factor (between 0 and 1, e.g., 0.10 for 10%): 0.3
```

- *Brief Description*: The durability score also increased due to improvement from lightweight material (Better Reinforcement factor).

5. Expected Outcomes

1. **Improved Responsiveness**: The response time for rotate_joint is expected to improve by at least 15% due to the improvement factor, which is critical for real-time surgical corrections.
2. **Enhanced Reliability**: Reduction in mechanical and signal-based latency increases operational accuracy and precision.
3. **Increased Durability**: Reinforced actuators extend lifecycle and durability at least 22.5% under repetitive surgical demands.

6. Conclusion

Summarize the impact of your proposed modifications:

- The proposed design modifications directly address the diagnostic delays in the rotate_joint command. Simulation evidence supports that actuator and sensor upgrades will reduce system latency and increase reliability in surgical contexts. These changes will significantly enhance both patient safety and surgeon performance.