Abstract: Modular manipulators are an intuitive solution to the increasing need for mass-customized manipulation tasks in construction environments. Specifically, these manipulators, composed of multiple interchangeable body modules, enable rapid and reversible assembly into various morphologies. Task performance significantly depends on the manipulator's mounted pose and morphology design, therefore posing the need of methodologies for selecting suitable modular robot configurations (M) and mounted pose (P_m) that can address the specific task requirements and required performance.

Introduction:
- Manipulation tasks were defined as trajectories in Cartesian space, consisting of a series of desired end-effector poses.
- Model Predictive Control (MPC) was utilized to control the robot in executing specified trajectories and to apply this controller in real experiments across varied morphologies.
- The execution's performance, assessed through designated evaluation metrics, is then leveraged to evaluate and optimize different morphology and mounted pose.

Optimization Formulation:
\[
\text{minimize: } F_{\text{eff}} = \frac{1}{N} \sum_{c=1}^{N} \sum_{j=1}^{d_c} |r(q_{c,j})| \\
\text{maximize: } M_{\text{max}} = \frac{1}{N} \sum_{c=1}^{N} \det(J(q_{c,j})J(q_{c,j})) \\
\text{subject to: } q_{c,j} \in [\bar{q}, \bar{q}], \\
||FK(M, P_m, q_{c,j})T_{\text{eff}}^{-1}||^2 \leq \xi, \forall i, \\
C(P_{c,j}) \geq d_{\text{off}}, \forall p_{c,j} \in \text{Robot}, \\
\forall i, ||\tau_i(q_{c,j}, \bar{q}_{c,j})|| < \dot{\tau}_{\text{max},i}
\]

minimizing joint effort: minimize energy consumption during manipulation
maximizing manipulability: address challenges related to singularity
minimizing joint effort and maximizing manipulability
joint limits
tracking threshold
collision avoidance
dynamic constraints
ensure the manipulator’s practical applicability

Optimization and Experiments Results:
CONCERT mobile modular manipulator equipped with a 10kg drilling end-effector continuously is able to executed drilling tasks at various locations. Despite the heavy payload in executing such tasks and two drilling points close to the base link’s horizontal level, the computational results still ensure collision-free with the mounted platform and satisfy dynamic constraints of the robot.

<table>
<thead>
<tr>
<th>Optimization Objective</th>
<th>Morphology</th>
<th>Mounted Pose</th>
<th>$[w_{\text{max}}, w_{\text{eff}}]$</th>
<th>$M_{\text{max}}$</th>
<th>$F_{\text{eff}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximizing manipulability and minimizing joint effort</td>
<td>C-1</td>
<td>[-0.15, 0.21, 1.57]</td>
<td>[1.00, 0.01]</td>
<td>0.41</td>
<td>198.7</td>
</tr>
<tr>
<td>solely maximizing manipulability</td>
<td>C-2</td>
<td>[0.29, -0.03, 2.2]</td>
<td>[1.00, 0.00]</td>
<td><strong>0.83</strong></td>
<td>329.5</td>
</tr>
<tr>
<td>solely minimizing joint effort</td>
<td>C-3</td>
<td>[0.13, 0.09, 1.57]</td>
<td>[0.00, 0.01]</td>
<td>0.35</td>
<td><strong>186.6</strong></td>
</tr>
</tbody>
</table>

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