Mobile Manipulation Calibration

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1 Introduction

The frames of interest are listed in Table 1.

Table 1: Coordinate frames.

Name	Subscript
World	w
Mobile base	b
Base of arm	a
End effector	e
Tool	t

The pose $\boldsymbol{T}_{wt}$ of an arbitrary tool attached to the end effector can be computed using the sequence of transforms

$$\boldsymbol{T}_{wt} = \boldsymbol{T}_{wb}(\boldsymbol{q}_b)\boldsymbol{T}_{ba}\boldsymbol{T}_{ae}(\boldsymbol{q}_a)\boldsymbol{T}_{et}, \tag{1}$$

where $\boldsymbol{T}_{wb}$ depends on the base configuration $\boldsymbol{q}_b = [x_b, y_b, \theta_b]^T$ and $\boldsymbol{T}_{ae}$ depends on the arm configuration $\boldsymbol{q}_a$.

2 Base Calibration

We need to calibration the Vicon measured base poses $\hat{\boldsymbol{q}}_b$ so that the origin of $\boldsymbol{T}_{wb}$ is correct. We have

$$\boldsymbol{T}_{wb}(\boldsymbol{q}_b) = \begin{bmatrix} \boldsymbol{C}_z(\theta_b) & \boldsymbol{r}_b \\ \boldsymbol{0}^T & 1 \end{bmatrix}, \tag{2}$$

where $\boldsymbol{C}_z(\theta) \in SO(3)$ is a rotation about the z-axis and $\boldsymbol{r}_b = [x_b, y_b, z_b]^T$ with z_b a constant. Our goal in this section is to calibrate the origin (x_b, y_b) so that it is located at the point of rotation of θ_b.

Given a starting configuration $\boldsymbol{q}_{b,0}$, we will move the base to a sequence of desired configurations $\boldsymbol{q}^d_{b,i}$ and obtain the corresponding measured configurations $\hat{\boldsymbol{q}}_{b,i}$[1]. We would like to find an offset $\Delta\boldsymbol{q}_b$ such that

$$\boldsymbol{q}^d_{b,i} = \hat{\boldsymbol{q}}_{b,i} + \Delta\boldsymbol{q}_b \tag{3}$$

is satisfied as closely as possible for each i. We will do so by solving the least squares problem

$$\underset{\Delta\boldsymbol{q}_b}{\operatorname{argmin}} \frac{1}{2} \sum_i \|\boldsymbol{q}^d_{b,i} - \hat{\boldsymbol{q}}_{b,i} - \Delta\boldsymbol{q}_b\|^2. \tag{4}$$

3 Arm–End Effector–Tool Calibration

[1] In practice, we need only use desired configurations that differ in rotation; the position is arbitrary and can remain fixed.