11 Force Sensing Fitness Metrics

Table 1: Variable Definitions

Variable	description	unit
$\max$	maximum value of a set	-
$\min$	minimum value of a set	-
$\tilde{\mathbf{F}}$	measured force vector	N
$\mathbf{F}_{\mathrm{r}}$	actual force vector (based on $F = mg$)	N
t	measured time	s
t_0	first time stamp of a measurement row	s
t_{x}	timestamps for drift evaluation	s

Table 2: Metric Definitions

| Metric	name	description	eq.	unit	best[1]
A_{F}	Force Sensing Accuracy	deviation between actual force and maximum values of $3\,\mathrm{s}$ measurement	$\max_N \left(\max_t \mid \|\bar{\mathbf{F}}\| - \|\mathbf{F}_{\mathrm{r}}\| \mid \right)$	N	0.1
P_{F}	Force Sensing Precision	repeatability of the maximum values of $3\,\mathrm{s}$ measurements in 30 trials	$\mu_{\mathbf{l}} + 3\sigma_{\mathbf{l}}$, $l_{\mathrm{i}} = \max_N\|\bar{\mathbf{F}}\| - \frac{1}{N}\sum_{i=1}^{N}\max_t\|\bar{\mathbf{F}}\|$	N	0.01
RS_{F}	Force Sensing Resolution	measurement fluctuation within one measurement	$\max_N \left(\max_t\|\bar{\mathbf{F}}\| - \min_t\|\bar{\mathbf{F}}\| \right)$	N	0.01
SD_1	Sensing Drift 1	force sensing drift within $1\,\mathrm{s}$ after force is applied	$\mid \|\bar{\mathbf{F}}(t_1)\| - \|\bar{\mathbf{F}}(t_0)\| \mid$	N	0.001
SD_2	Sensing Drift 2	force sensing drift between $1\,\mathrm{s}$ -$10\,\mathrm{min}$	$\mid \|\bar{\mathbf{F}}(t_2)\| - \|\bar{\mathbf{F}}(t_1)\| \mid$	N	0.001
SD_3	Sensing Drift 3	force sensing drift between $10\,\mathrm{min}$ - $90\,\mathrm{min}$	$\mid \|\bar{\mathbf{F}}(t_3)\| - \|\bar{\mathbf{F}}(t_2)\| \mid$	N	0.001
SD_4	Sensing Drift 4	force sensing drift between $1.5\,\mathrm{h}$ - $8\,\mathrm{h}$	$\mid \|\bar{\mathbf{F}}(t_4)\| - \|\bar{\mathbf{F}}(t_3)\| \mid$	N	0.001
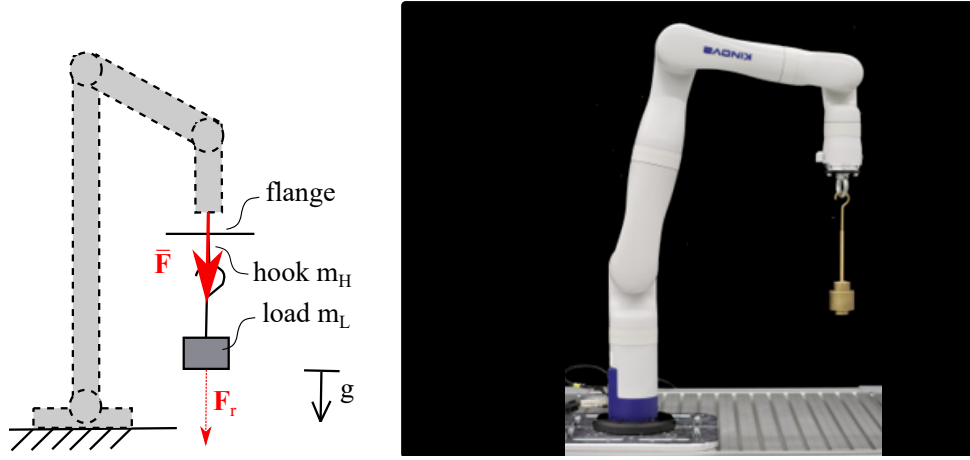
Figure 1: Reference system for measuring force sensing metrics with real world example.

Table 3: Setup definitions

component	considered quantity	value	accuracy requirements
reference weight	mass m_L [kg]	0.8	$\pm\, 0.005$
hooked adaptor	mass m_H [kg]	0.182	$\pm\, 0.01$
robot sensing interface	output frequency f [Hz]	300-1000	
	timestamp t [s]		adequate to f
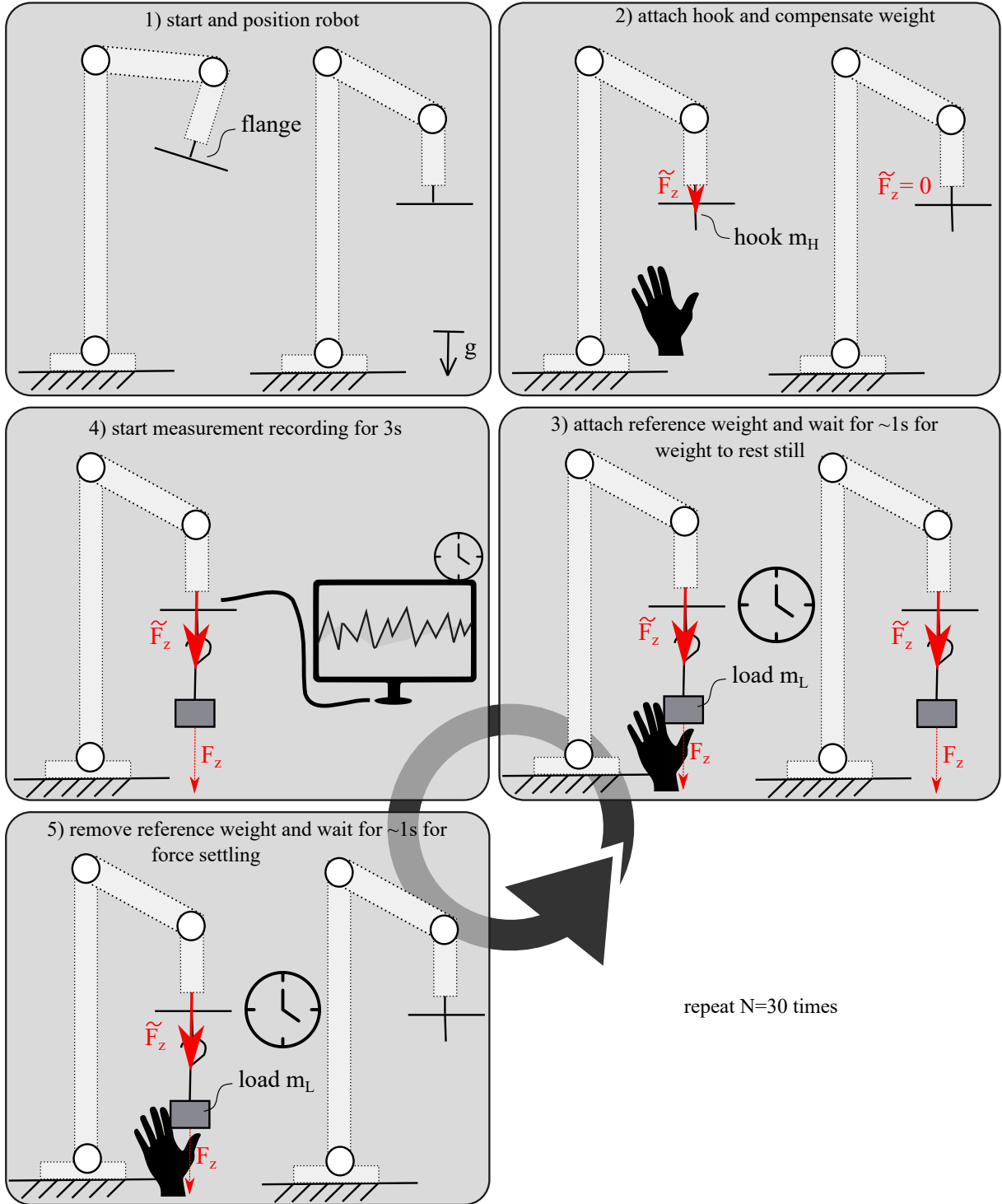
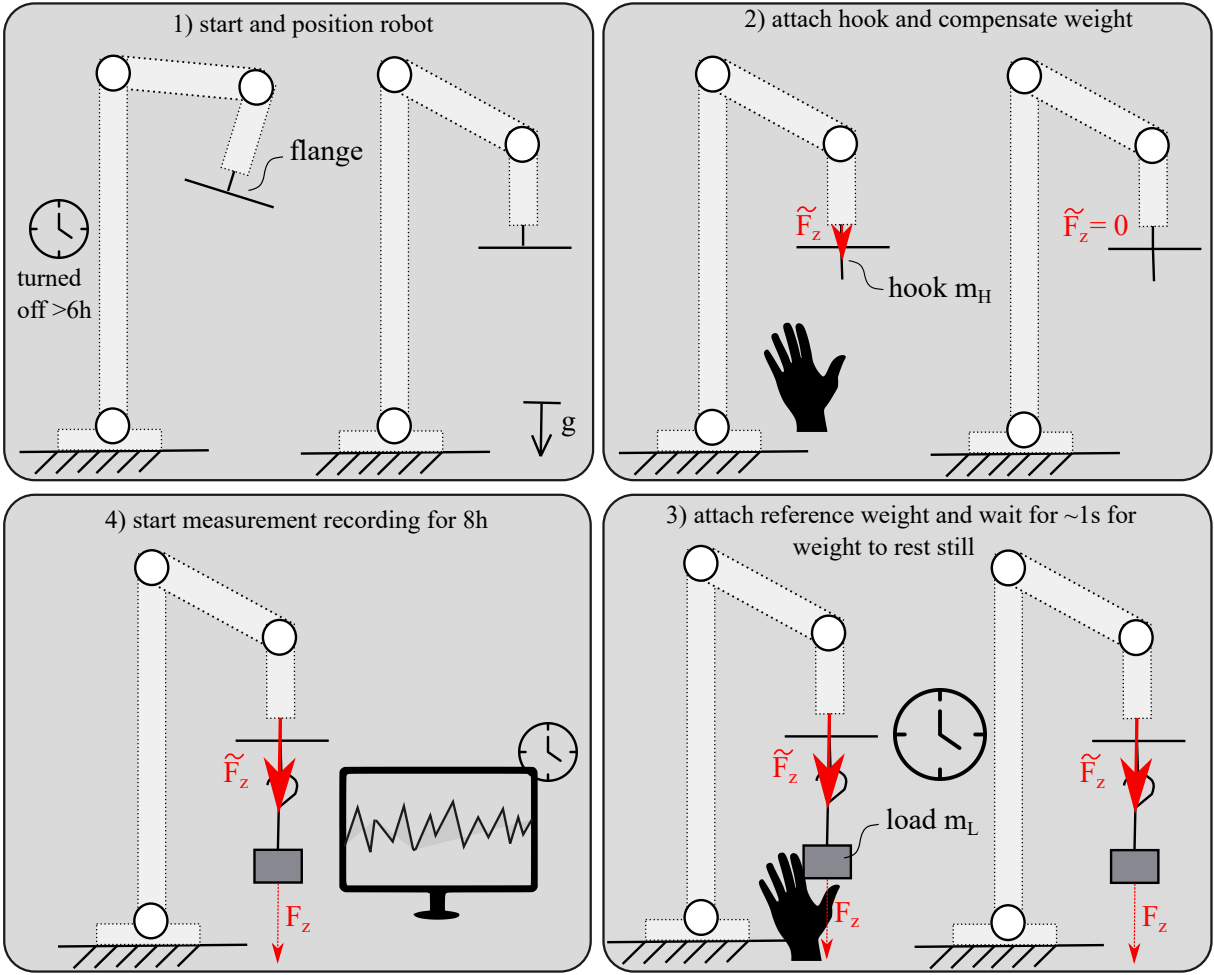Figure 2: Measurement Procedure for A_{F}, P_{F}, and RS_{F}.

Figure 3: Measurement Procedure for SD_{1-4}.