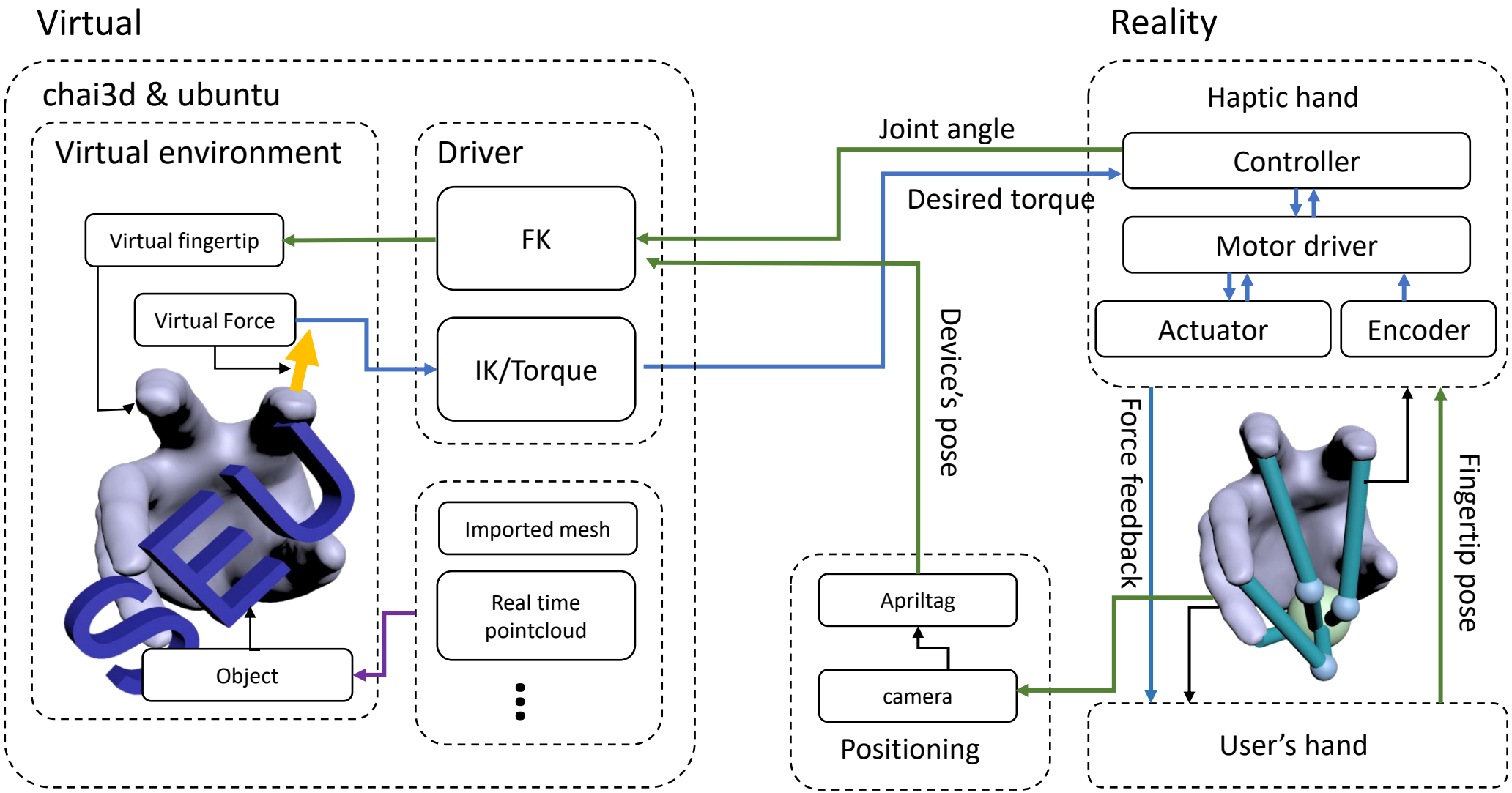
System diagram



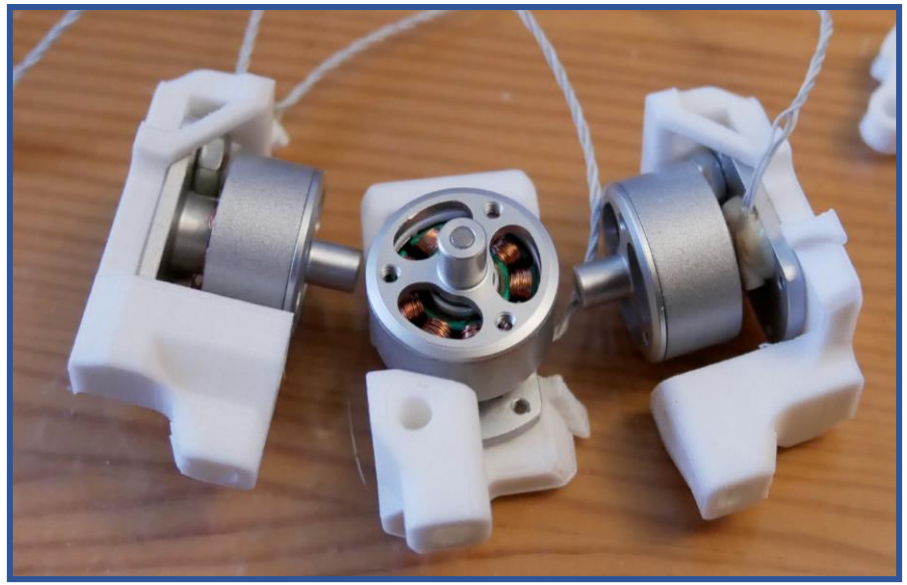
Actuator Motor selection & Capstan reducer Tendon based reducer

Actuator requirements -

Good back-drive-ability

High power density

Brushless motor - 6.8g 130kv

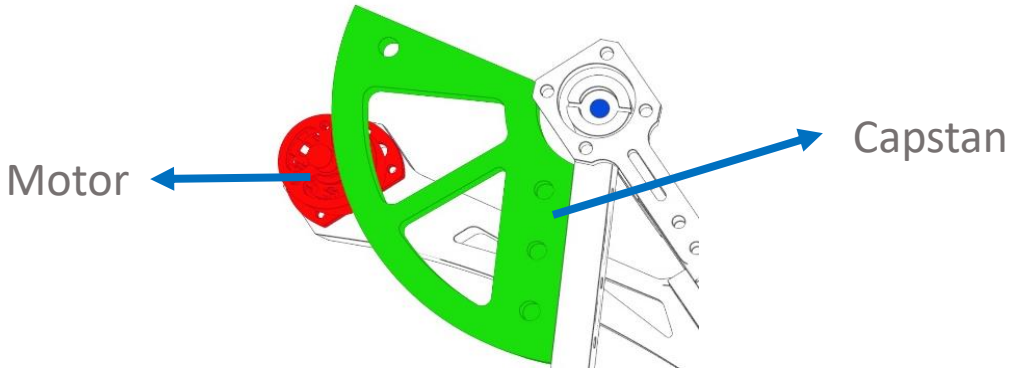


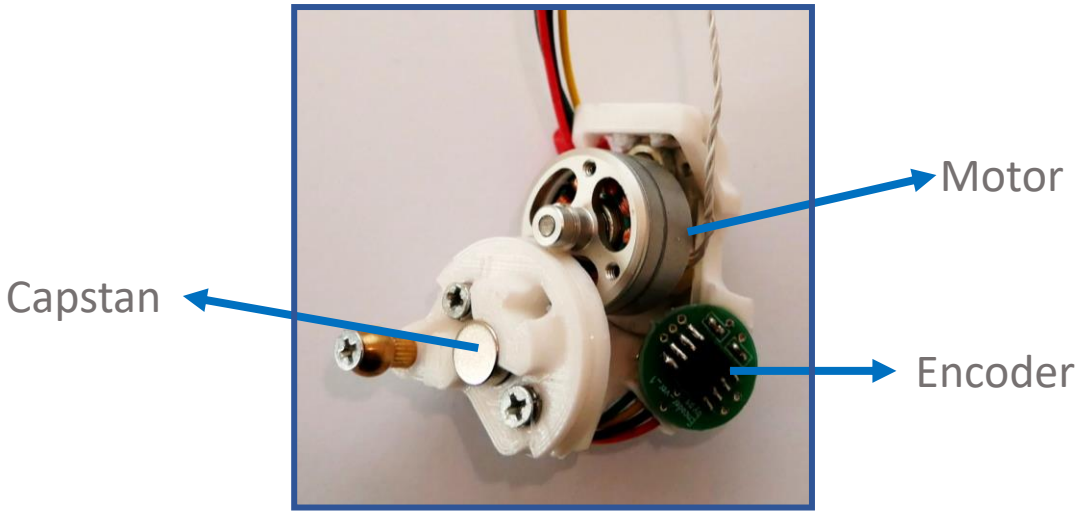
Torque control via current feedback

When friction of reducer is small enough to ignore

Capstan reducer -

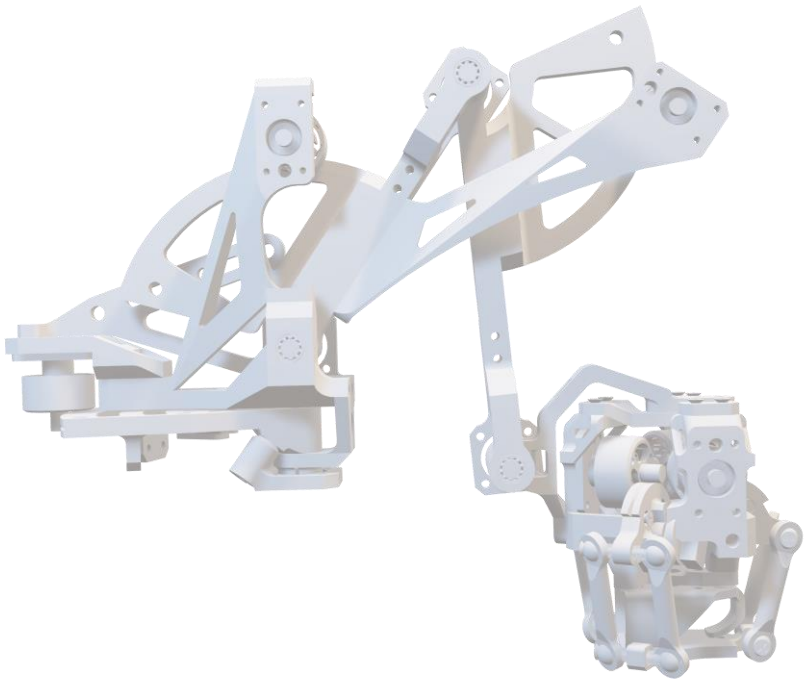
Zero backlash, Low rotational inertia

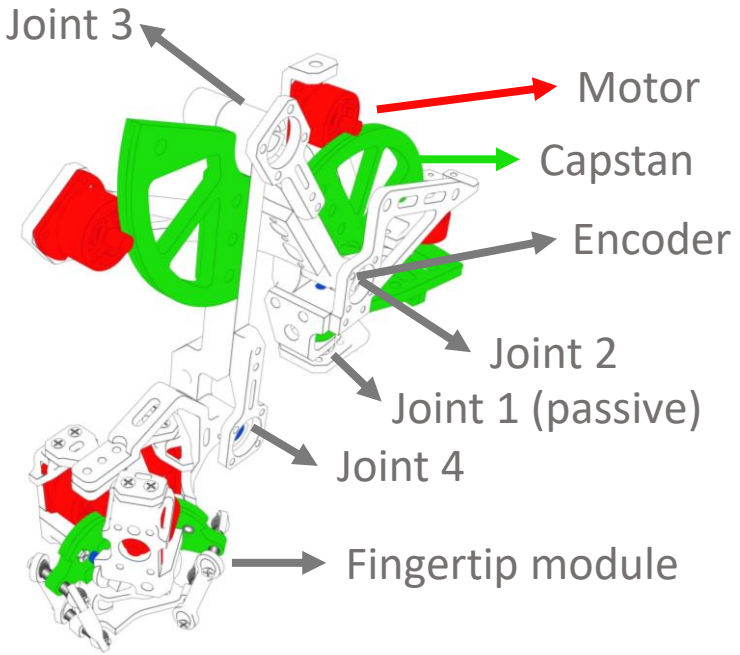


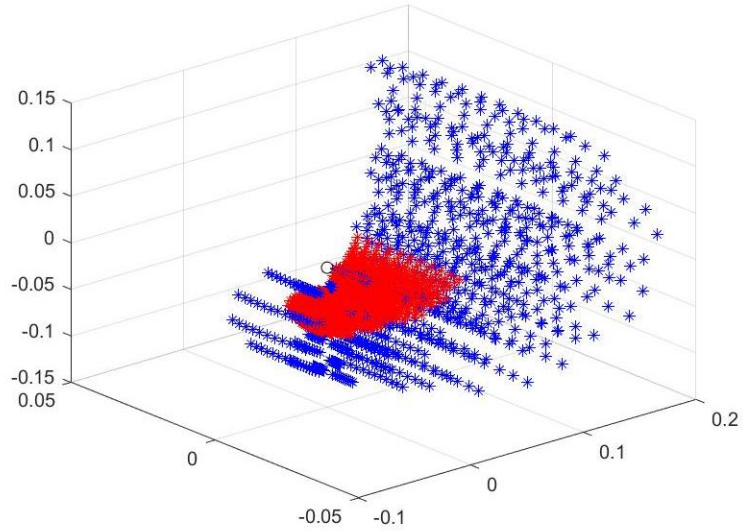


Finger module Force feedback

3 DOF mechanic provides force feedback for user's fingertip
3 actuated joints with 1 passive joint



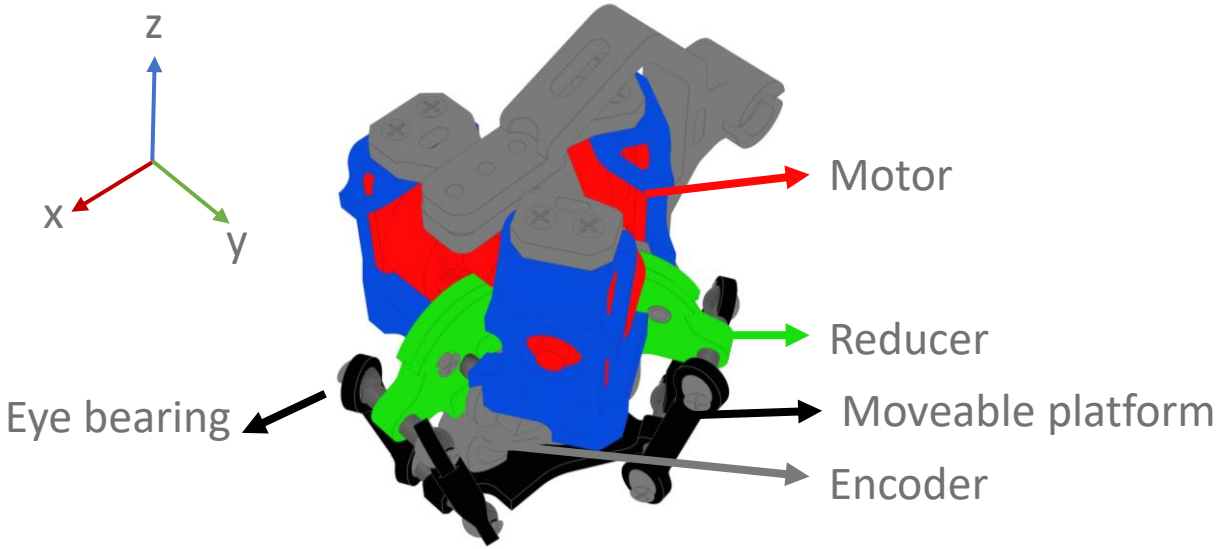




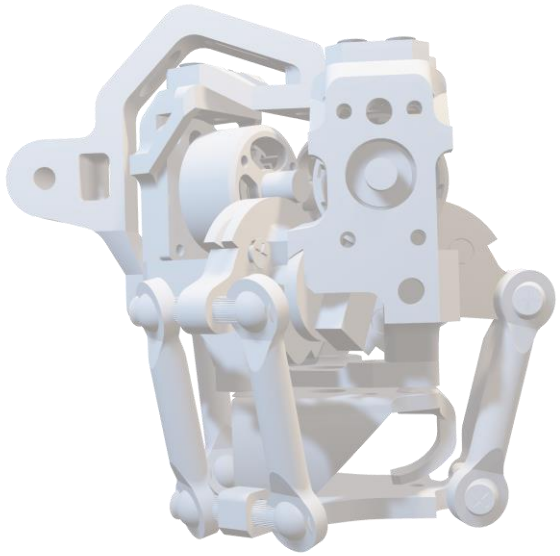
Finger module's workspace
Red – User finger Blue – Finger module

Fingertip module Tactile feedback

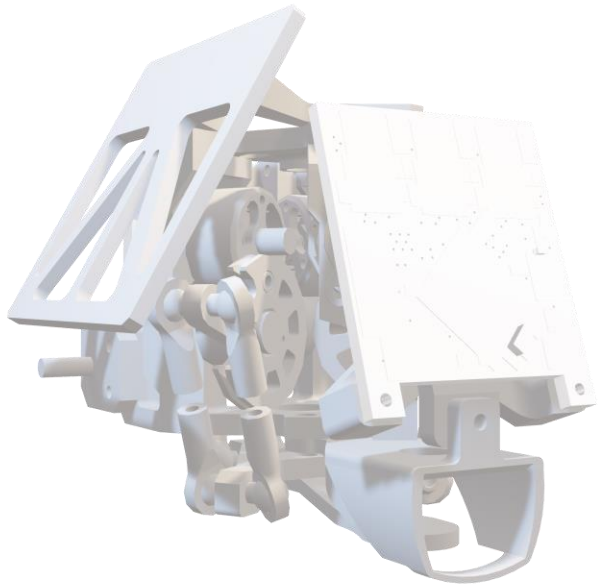
A parallel 3DOF translate mechanism in order to deliver useable tactile feedback to the user's fingertip.



Design 1

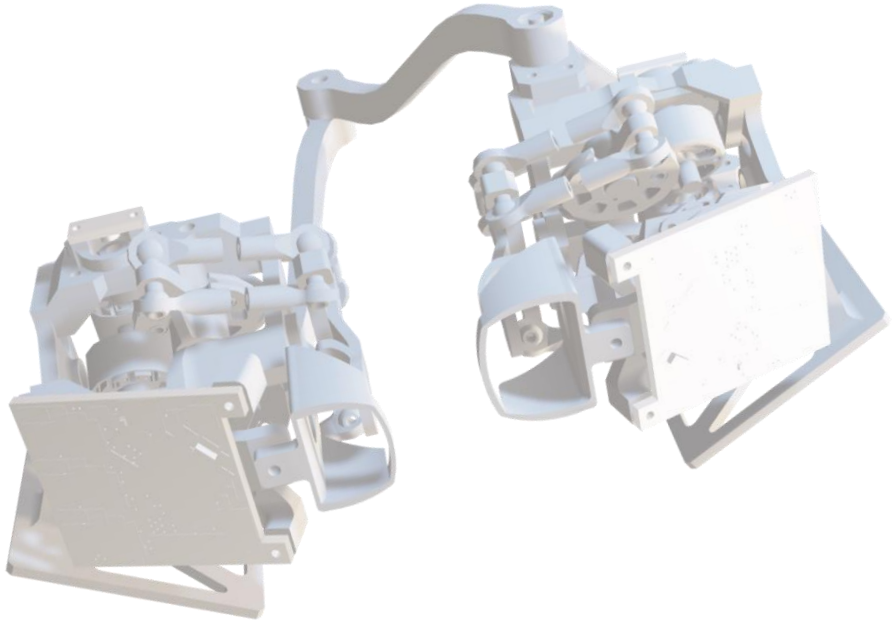


Design 2

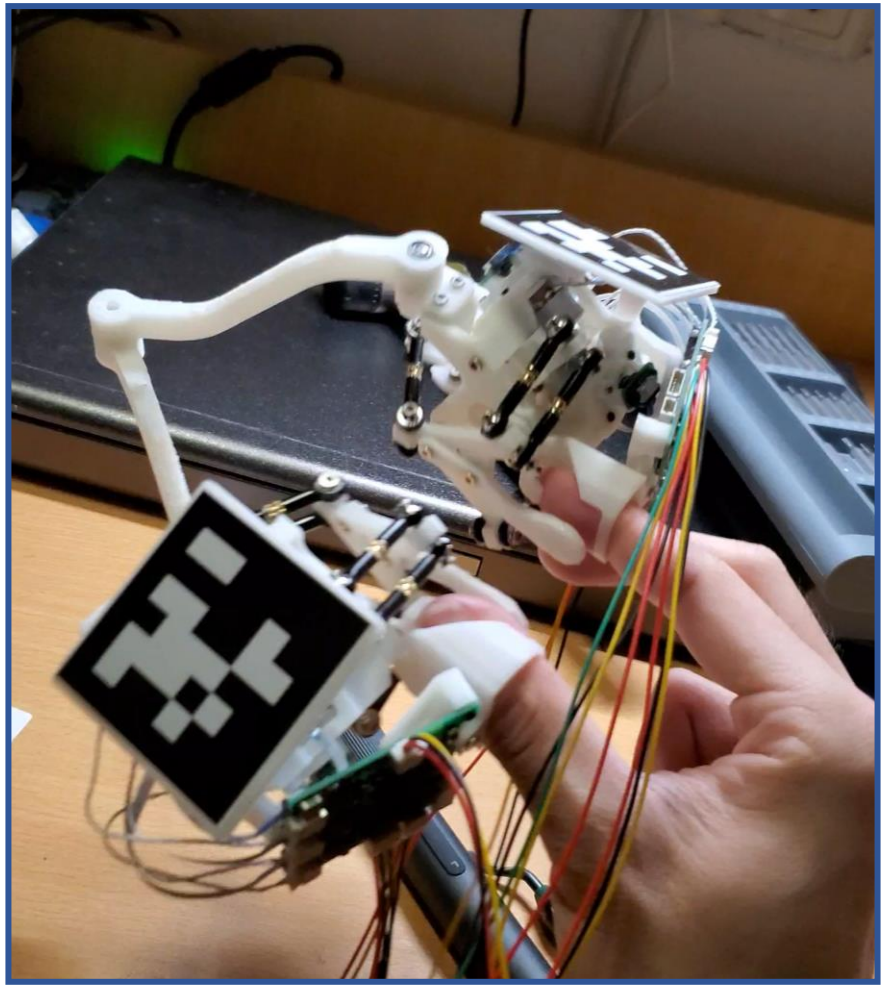


Fingertip module Tactile feedback

Fingertip module can be used alone, without finger module
Example of thumb/index fingertip module assembly

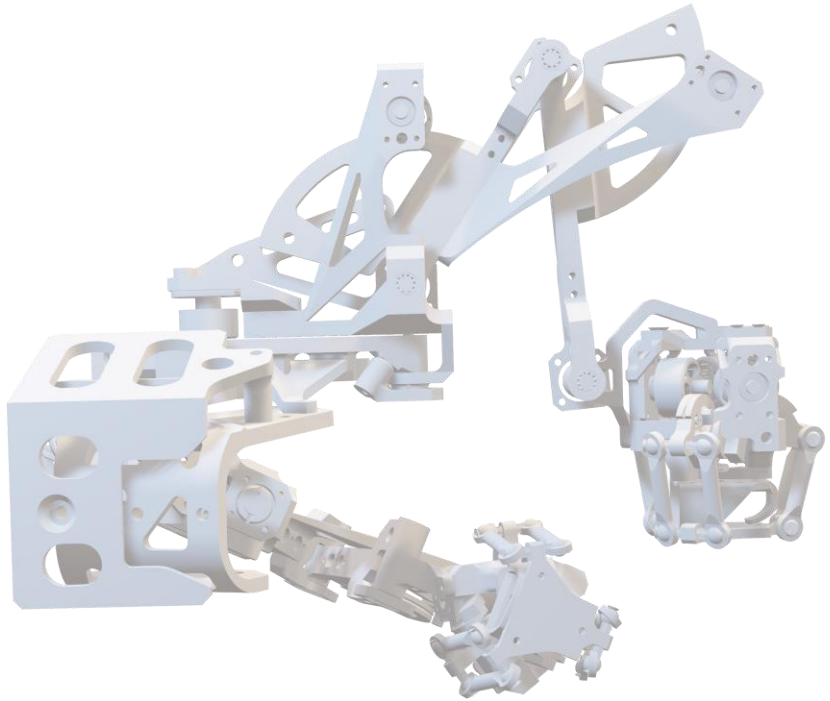


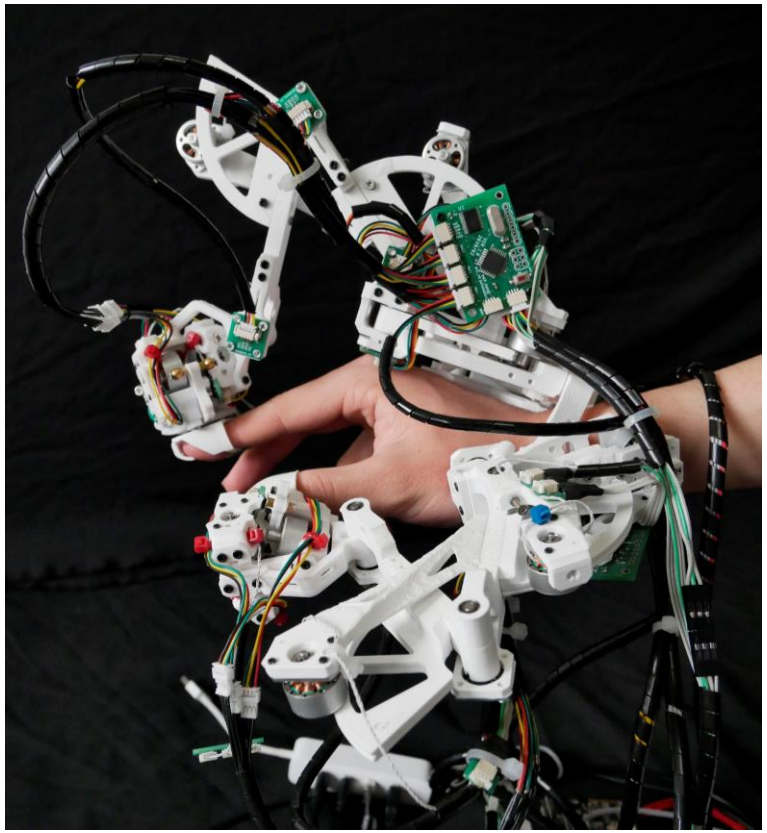
Device mounted on user



Finger & Fingertip module assembly Force & Tactile feedback

Thumb/index assembly

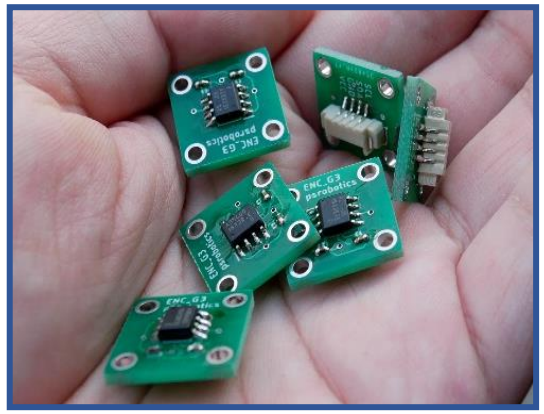




Encoder & Driver & Controller

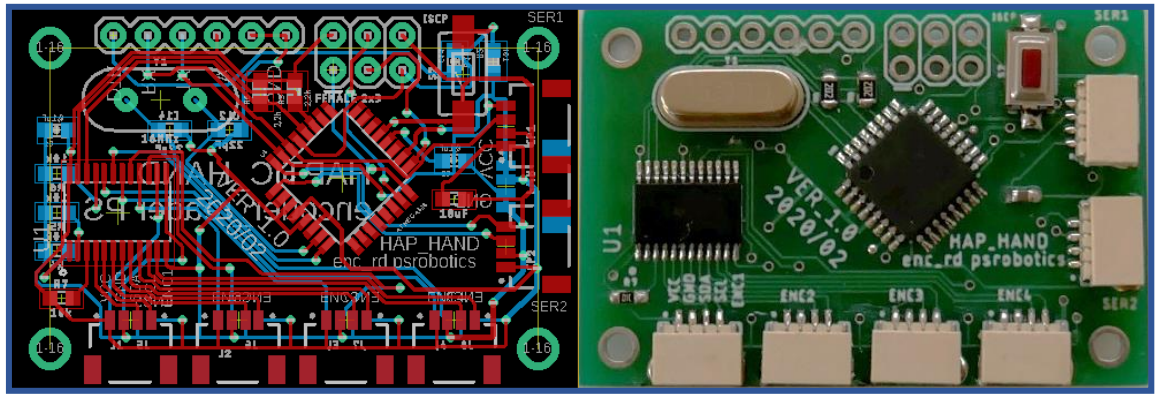
AMS magnetic encoder

12bit via IIC, easy to mount



Encoder hub

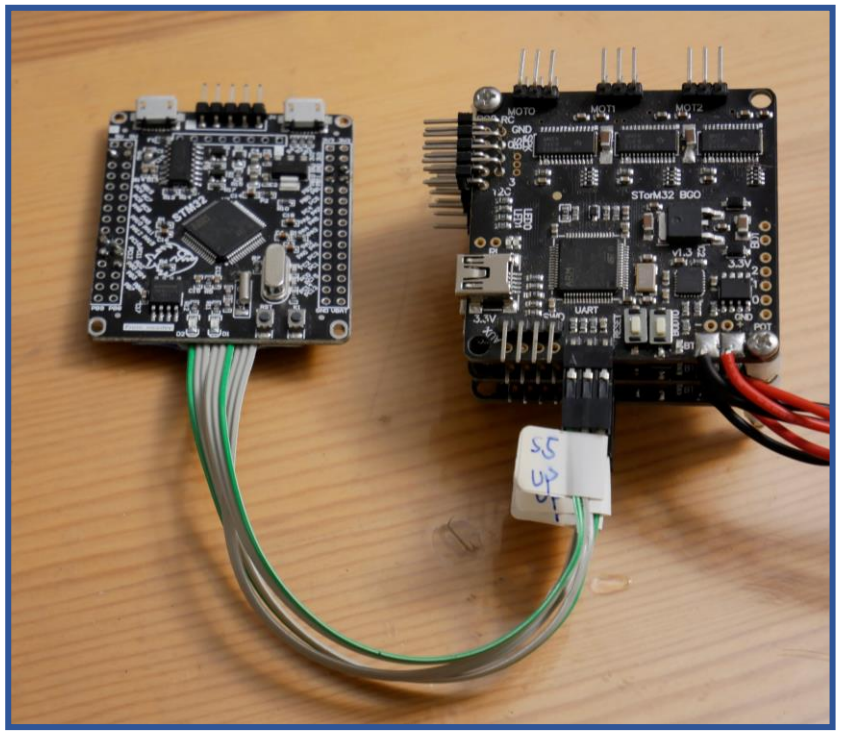
Read encoder data and sent to host computer



STM32F103 Motor driver , off the shelf part

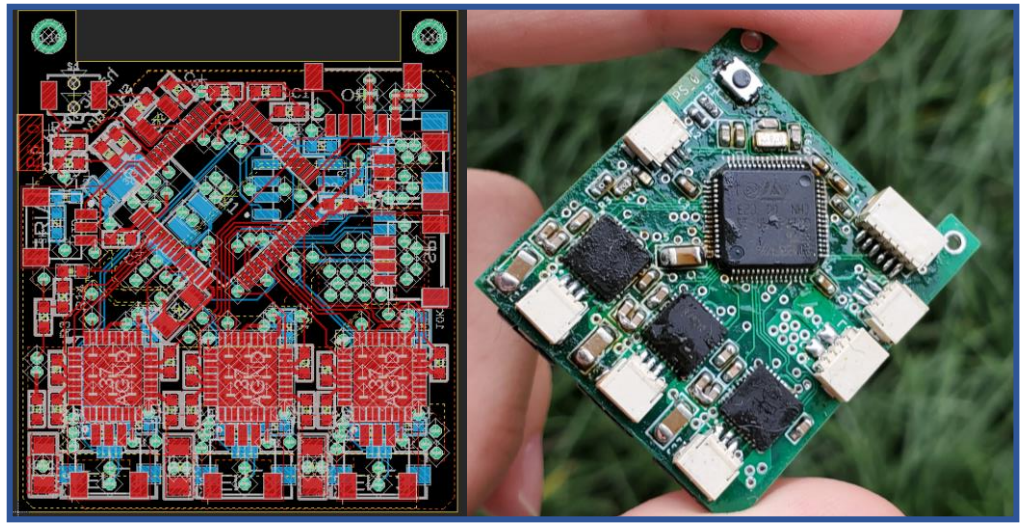
Version 1

No phase current feedback – no torque control mode



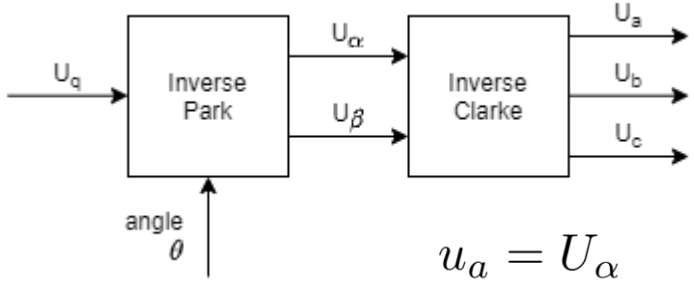
Encoder & Driver & Controller

STM32F446RE Driver & Controller
3*IIC \ 1*CAN \ 1*SPI \ 3*DRV8313
Version 2 with phase current feedback



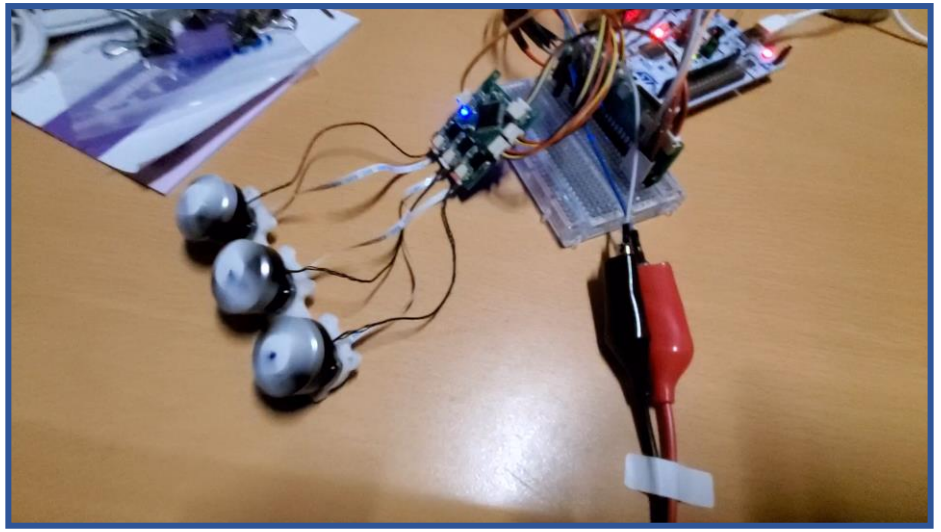
Smaller encoder

FOC driver



$$U_\alpha = -U_q sin(\theta)$$
$$U_\beta = U_q cos(\theta)$$

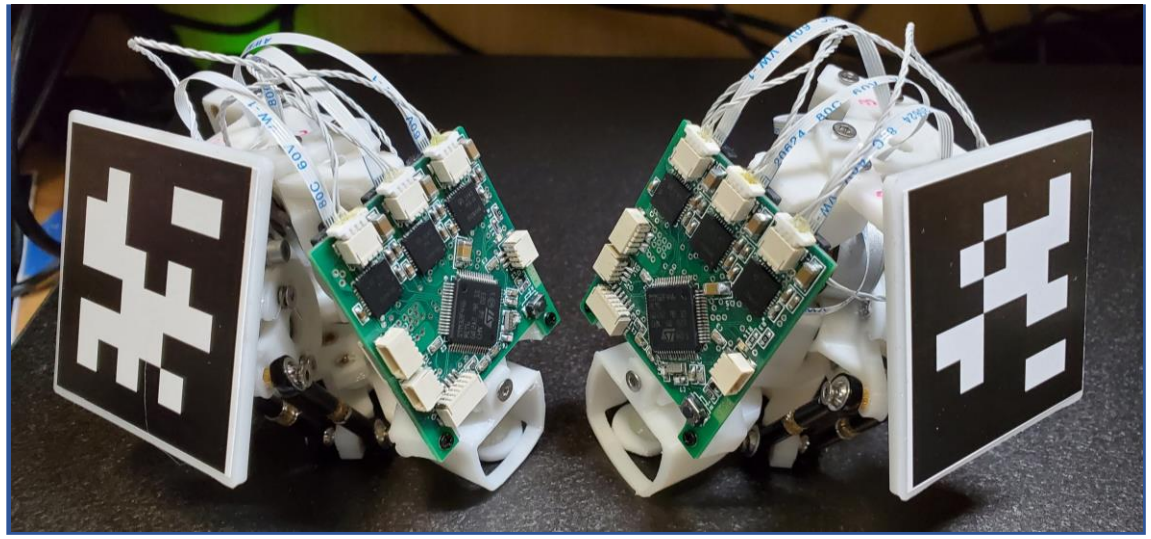
$$u_a = U_\alpha$$
$$u_b = \frac{-U_\alpha + \sqrt{3}U_\beta}{2}$$
$$u_a = \frac{-U_\alpha - \sqrt{3}U_\beta}{2}$$



Device tracking by vision

Using Apriltag https://april.eecs.umich.edu/software/apriltag.html
to get device's 3d pose

Apriltag on device



Vision camera

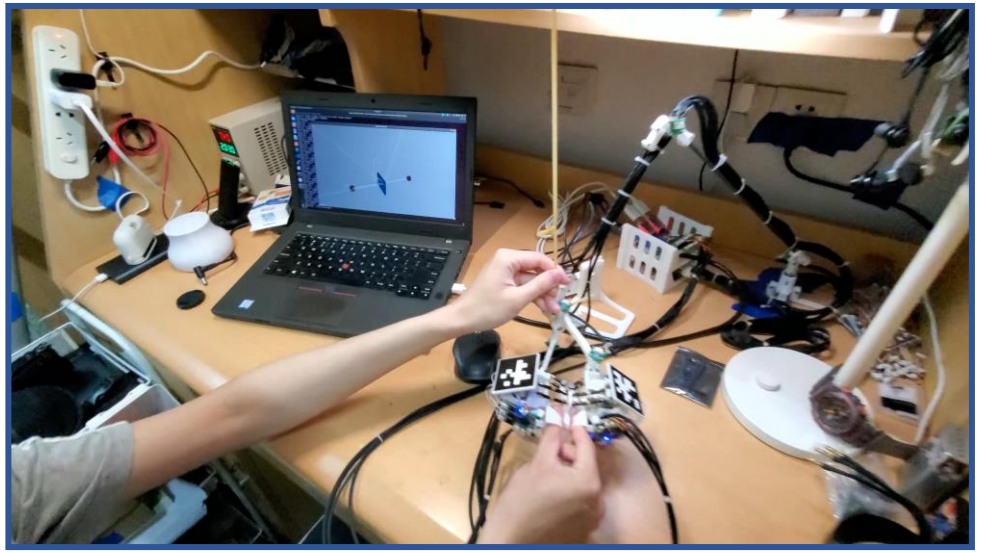
Other possible tracking solutions

HTC vive

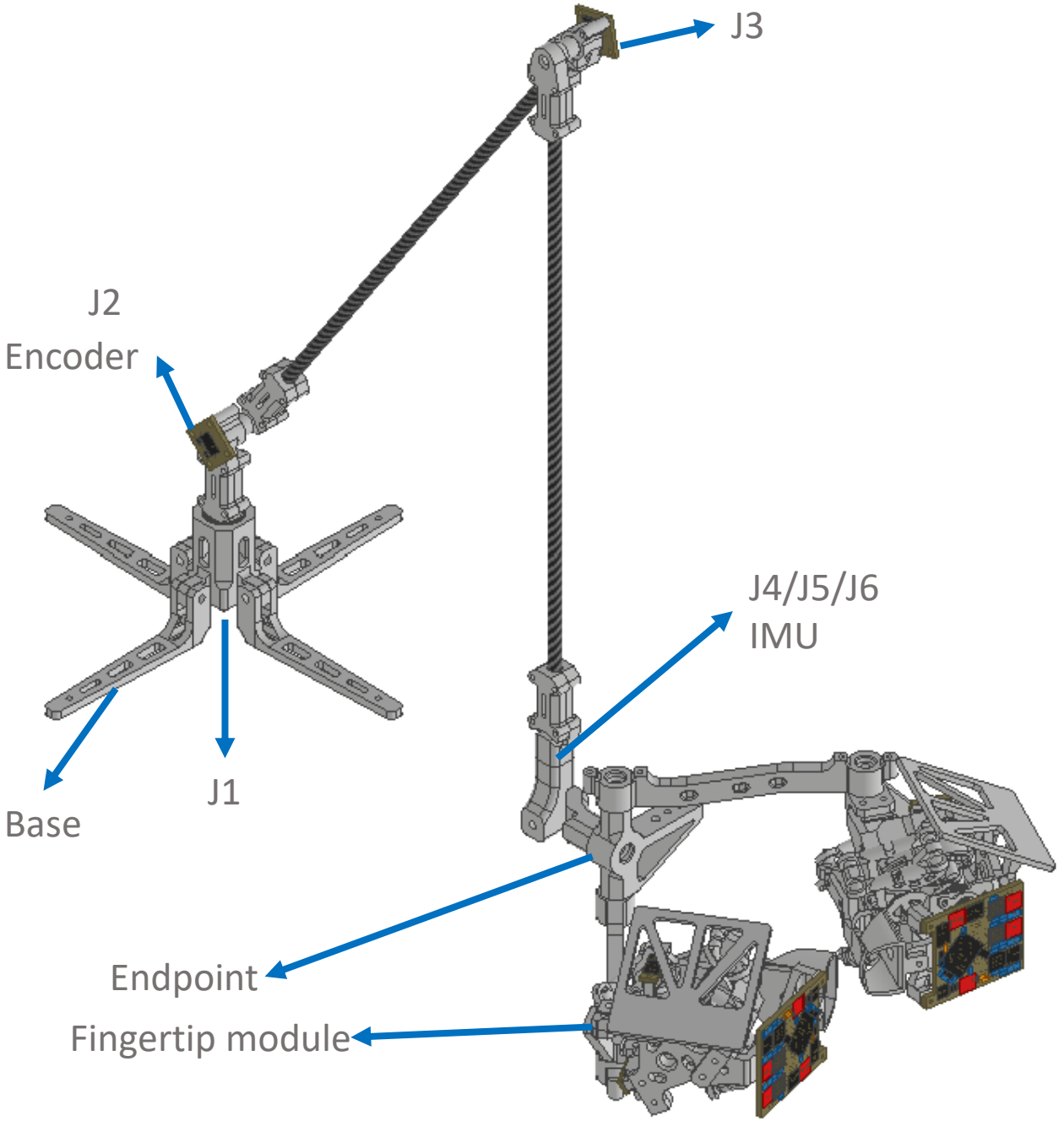
OptiTrack

Device tracking by hardware tracker

6DOF passive tracking arm to get device's pose



Higher refresh rate/accuracy compare to vision tracking solution



Application chai3d & Feedback force rendering

chai3d https://www.chai3d.org/

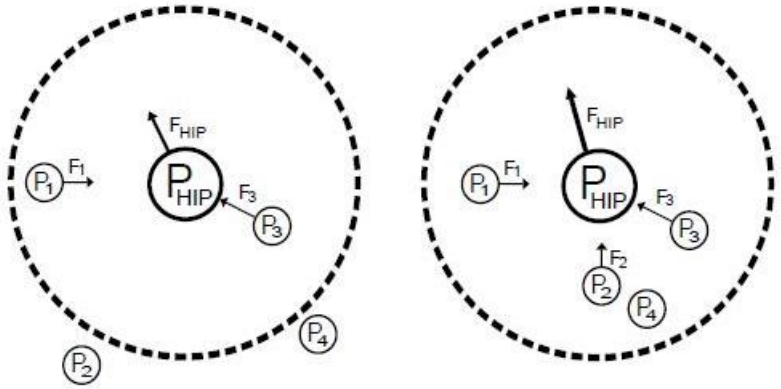
FK

$$\boldsymbol{P}_{hip} = \begin{bmatrix} \boldsymbol{R} & \boldsymbol{P} \\ \boldsymbol{0} & \boldsymbol{1} \end{bmatrix} \boldsymbol{T}_{base} \cdot \boldsymbol{T}_1^0 \cdot \boldsymbol{T}_2^1 \cdot \boldsymbol{T}_3^2 \cdot \boldsymbol{T}_4^3$$

Device's force to torque

$$\boldsymbol{\tau} = \begin{bmatrix} \tau_{j1} \\ \tau_{j2} \\ \tau_{j3} \end{bmatrix} = \boldsymbol{J}^T \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix}$$

For interacting with point cloud

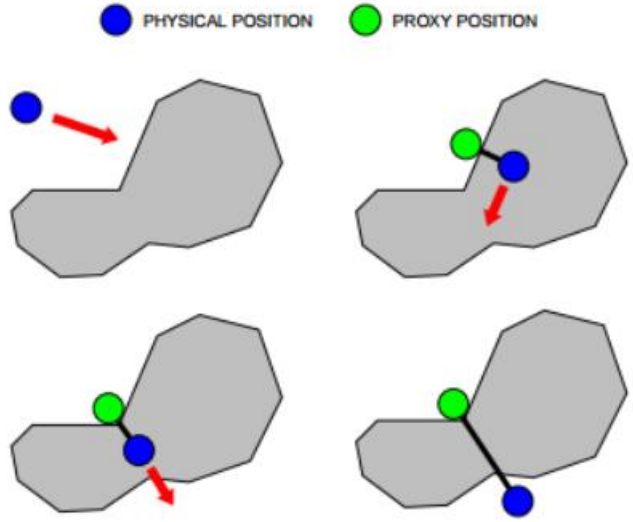


$$\boldsymbol{V}_{\mathrm{k}} = \boldsymbol{P}_{hip} - \boldsymbol{P}_k$$

$$\boldsymbol{F}_k = k \cdot \boldsymbol{V}_k$$

$$\boldsymbol{F}_{hip} = \sum_{k=1}^{N} \boldsymbol{F}_k$$

For interacting with mesh



Finger-proxy algorithm
by Ruspini and Khatib