Targets

1. Range of motion
2. Time to complete event (pick up a block, move it, place it down)
3. Which fingers are being used to pick the block
4. Smoothness of motion

Determine Hand-Object Interaction

1. Box-block test uses unit cubes so vertices are shifted by 0.5.

$$b = \begin{bmatrix} 0.5 \\ 0.5 \\ 0.5 \end{bmatrix}$$

2. Transforms the query point into the cube's local space

$$p_{\text{local}} = R^{-1}(p - t)$$

3. Create SDF for block

$$SDF_{\text{block}}(p) = \|\max(p_{\text{local}})\|_2 + \min(\max(p_{\text{local}}), 0)$$

4. Filter keypoints for fingertips

```
thumb = kpts[4], fingers = [kpts[8], kpts[12], kpts[16], kpts[20]]
```

5. Function to determine if keypoint is in contact with block

$$\text{in\_contact}(x) = \text{SDF}_{\text{block}}(x) < \epsilon \quad \text{where } \epsilon = \text{distance threshold}$$

6. Hand is holding object if

```
in_contact(thumb) and any(in_contact(kpt) for kpt in fingers)
```

Range of motion

1. Concatenate 2D body keypoints with depth values to form 3D body keypoints
2. Track shoulder and elbow angles

$$\theta(A, B, C) = \arccos\left(\frac{(A - B) \cdot (C - B)}{\|A - B\|\|C - B\|}\right)$$

```
left_shoulder = kpts[8], kpts[6], kpts[12]
right_shoulder = kpts[9], kpts[7], kpts[13]
left_elbow = kpts[6], kpts[8], kpts[10]
right_elbow = kpts[7], kpts[9], kpts[11]
```

Time to complete event

Track last event and HOI state.

```
if hand is holding object:
    if hand wasn't holding object before:
        object has been picked up
    else if hand has moved moved past a certain threshold (to the other side):
        object has been moved
else:
    if hand was holding object:
        object has been dropped
```

Which fingers were used to pick up block

Can be checked when determining hand-object interaction

Smoothness of motion

1. Compute velocity

$$\texttt{velocities = diff(keypoints)} \leftarrow v_t = k_{t+1} - k_t$$

2. Compute acceleration

$$\texttt{accelerations = diff(velocities)} \leftarrow a_t = v_{t+1} - v_t$$

3. Compute jerk

$$\texttt{jerk = diff(accelerations)} \leftarrow j_t = a_{t+1} - a_t$$

4. Lower RMS means more smooth motion

```
rms = sqrt(mean(jerk ** 2))
```

$$j_{\text{rms}} = \sqrt{\frac{1}{n}\sum_{t=1}^{n} j_t^2}$$