Gesture Recognition Using Chipless RFID Tag Held in Hand

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Outline

- Motivation
- Principle of Operation
- Measurements and Gesture Recognition
- Video Demonstrations
- Conclusions

Motivation For Gesture Recognition

- Gaming
- Sign language
- Virtual manipulation
- Daily assistance
- Palm verification
- Human robot interaction

Meta Oculus Quest Hand Tracking

- If hands are hidden ?
- In bad light conditions ?

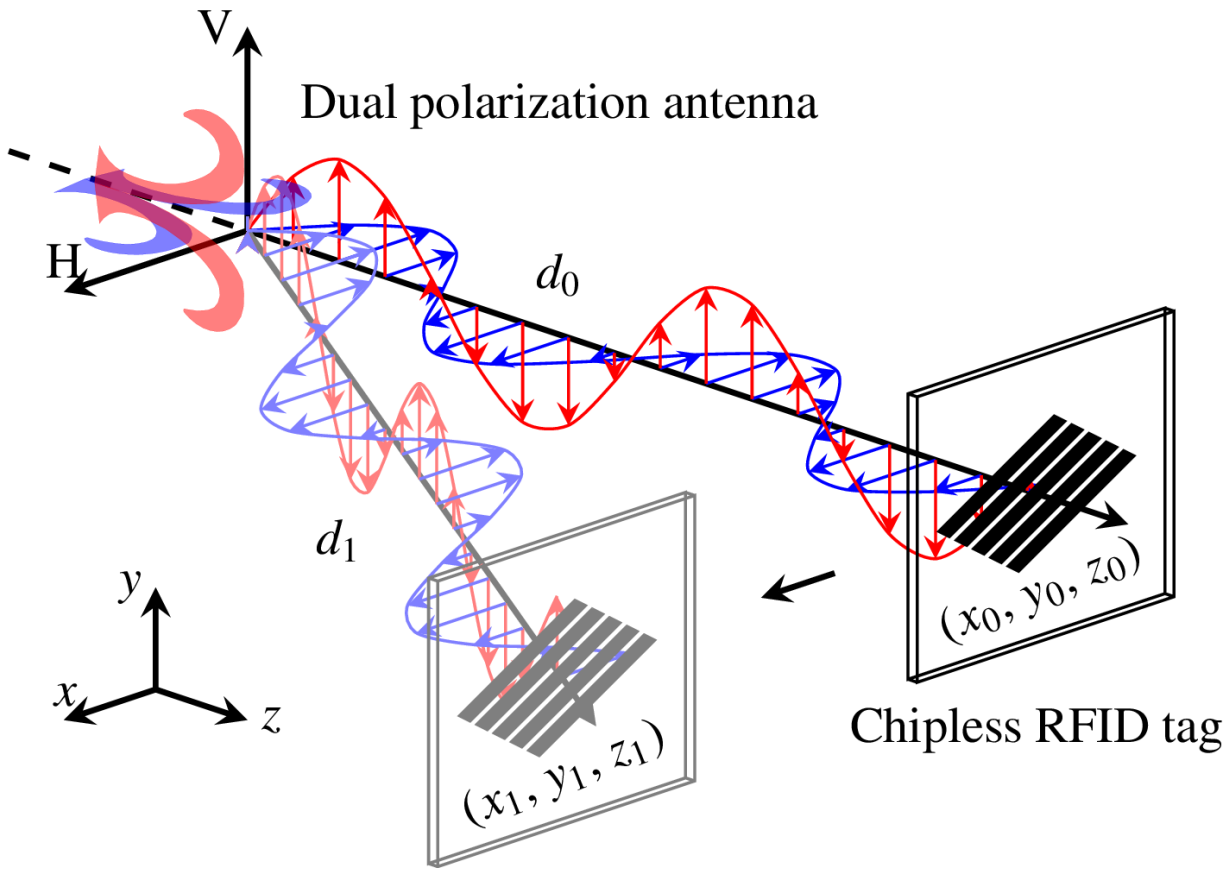
Principle of Operation

Mathematical model

$$\Delta d = d_1 - d_0 = -\frac{1}{2k}\arg\left(\frac{M_{\mathrm{VH}}^{d_1}}{M_{\mathrm{VH}}^{d_0}}\right) \quad (1)$$

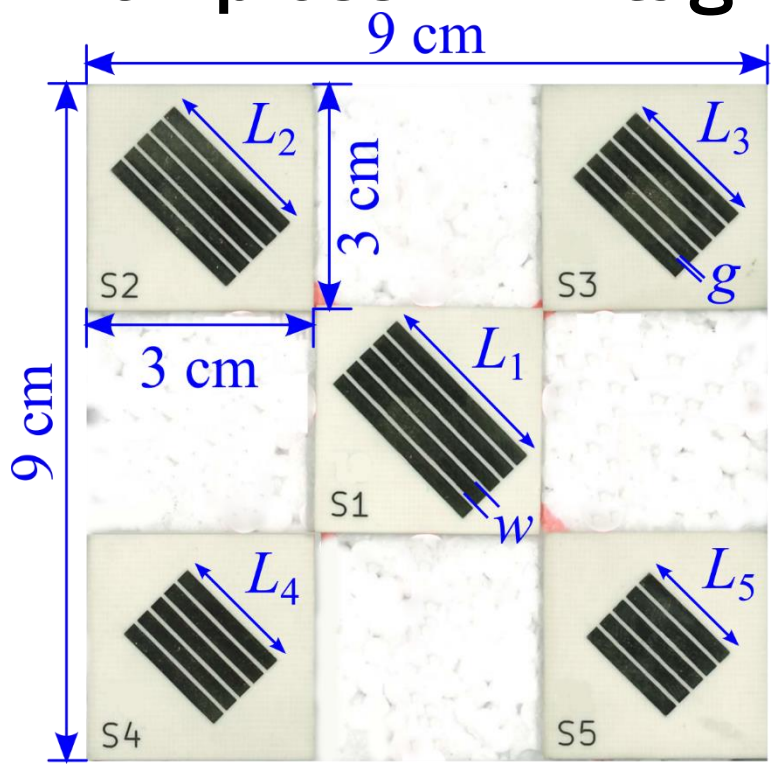
where

- $k = 2\pi/\lambda$,
- $M_{VH}^{d_0} = S_{VH}^{d_0} - I_{VH}$,
- $M_{VH}^{d_1} = S_{VH}^{d_1} - I_{VH}$.
- $S_{VH}^{d_0}$ correspond to tag signal at d_0,
- $S_{VH}^{d_1}$ correspond to tag signal at d_1,
- I_{VH}correspond to clutter.



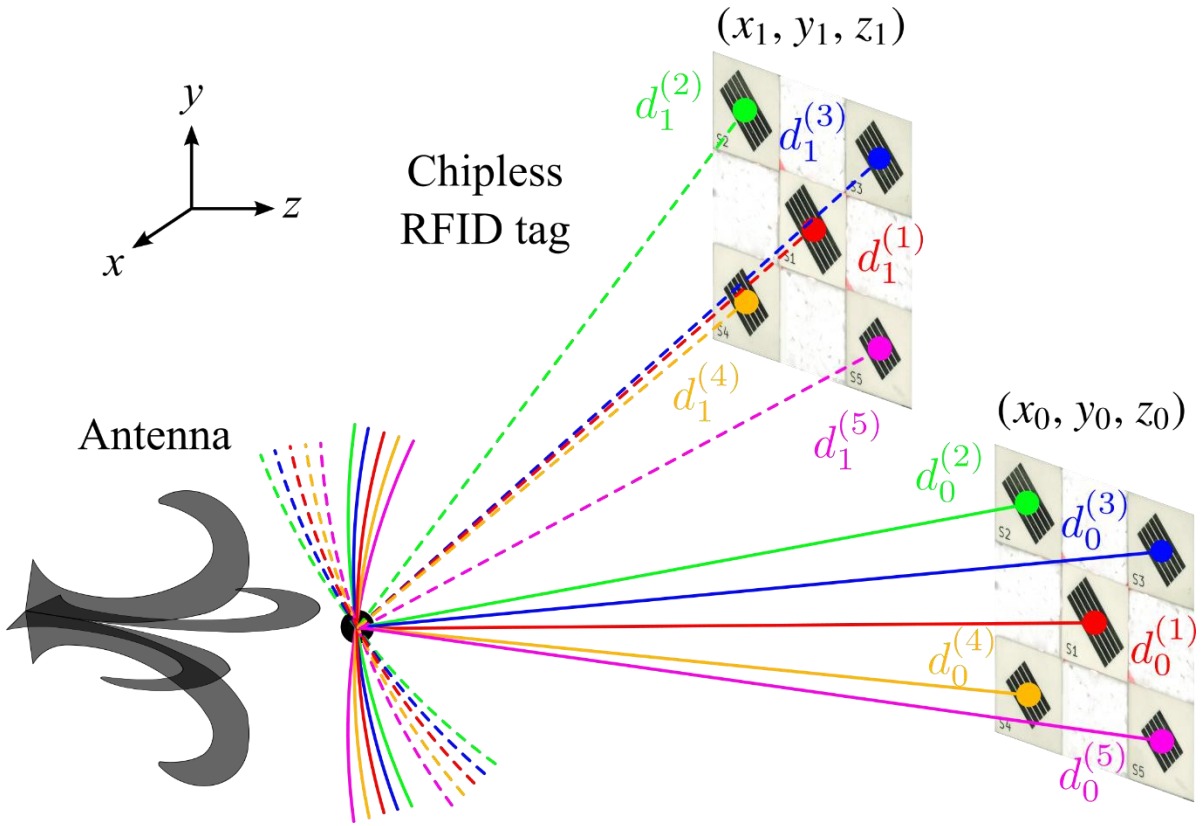
Principle of Operation

Chipless RFID tag



L_1 = 24.8 mm, L_2 = 21.8 mm, L_3 = 19 mm, L_4 = 16.8 mm, L_5 = 15 mm, w = 2 mm, g = 0.5 mm, and r = 4.24 cm.

Multilateration

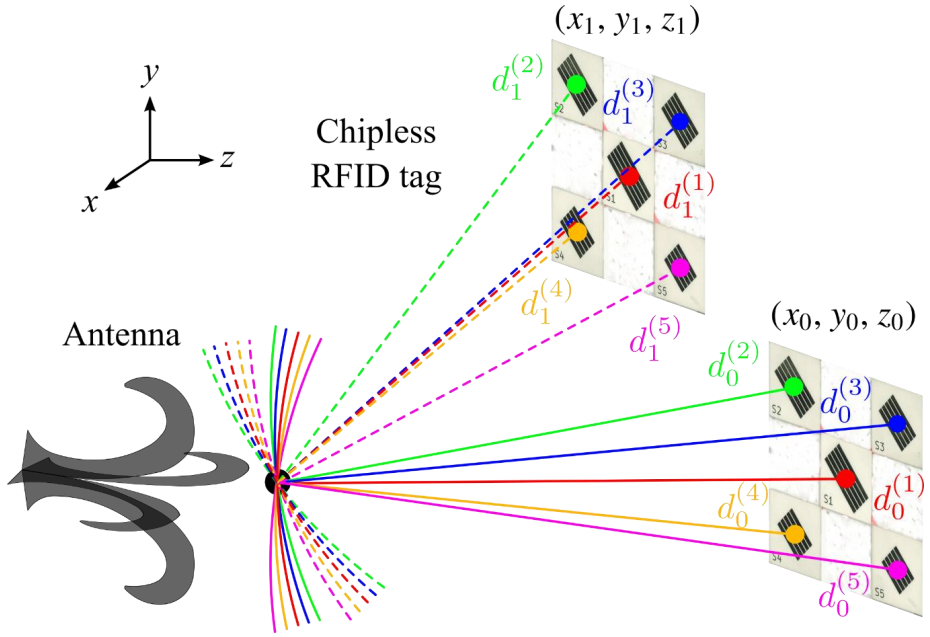


Principle of Operation

Multilateration

$$\begin{cases} \hat{d}_1 = \sqrt{(x + x_{s1} + x_A)^2 + (y + y_{s1} + y_A)^2 + (z + z_{s1} + z_A)^2} \\ \hat{d}_2 = \sqrt{(x + x_{s2} + x_A)^2 + (y + y_{s2} + y_A)^2 + (z + z_{s2} + z_A)^2} \\ \vdots \\ \hat{d}_8 = \sqrt{(x + x_{s8} + x_A)^2 + (y + y_{s8} + y_A)^2 + (z + z_{s8} + z_A)^2} \end{cases}, \quad (2)$$

$$< \hat{x}, \hat{y}, \hat{z} > \quad = \arg\min \sum_{i=1}^{5} (\hat{d}_i - d_{ci})^2, \quad (3)$$



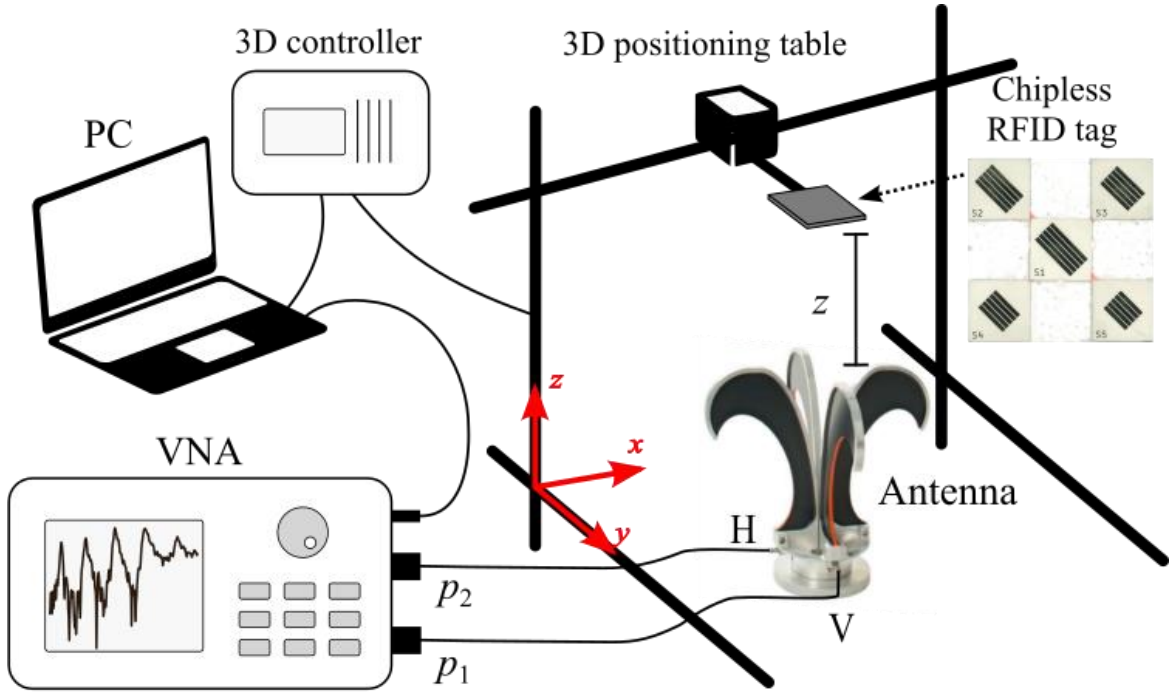
Principle of Operation

Algorithm 1: 3D localization.

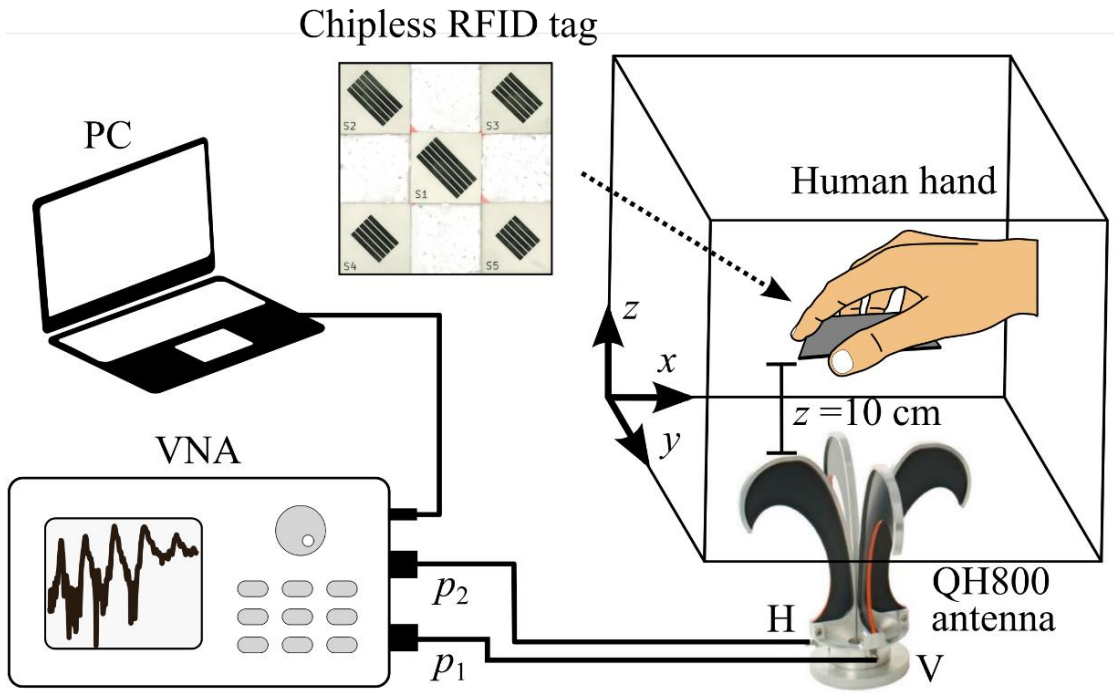
Initialization: phase correction $\phi_c^i = 0$ at (x_0, y_0, z_0)
Acquisition of signals: $S_{vh}^{d_0^{(i)}}(f_i)$, and $I_{vh}(f_i)$
while $j = 1$ **to** $acquisition = True$ **do**
    Acquisition of signal: $S_{vh}^{d_j^{(i)}}(f_i)$
    for $i = 1$ **to** $i = 5$ **do**
        Extraction of $\phi_j^{(i)}$ using (1)
        $\Delta\phi^{(i)} = \phi_j^{(i)} - \phi_{j-1}^{(i)}$
        if $\Delta\phi^{(i)} > \pi$ **then**
            $\phi_c^{(i)} = \phi_c^{(i)} - 2\pi$
        else if $\Delta\phi^{(i)} < \pi$ **then**
            $\phi_c^{(i)} = \phi_c^{(i)} + 2\pi$
        $\phi_j^{(i)} \leftarrow \phi_j^{(i)} + \phi_c^{(i)}$
    Calculation of $\Delta d_j^{(i)}$ from (1)
    Multilateration by solving (2)
    Estimation of (x_j, y_j, z_j) by (3)

Measurement Setups

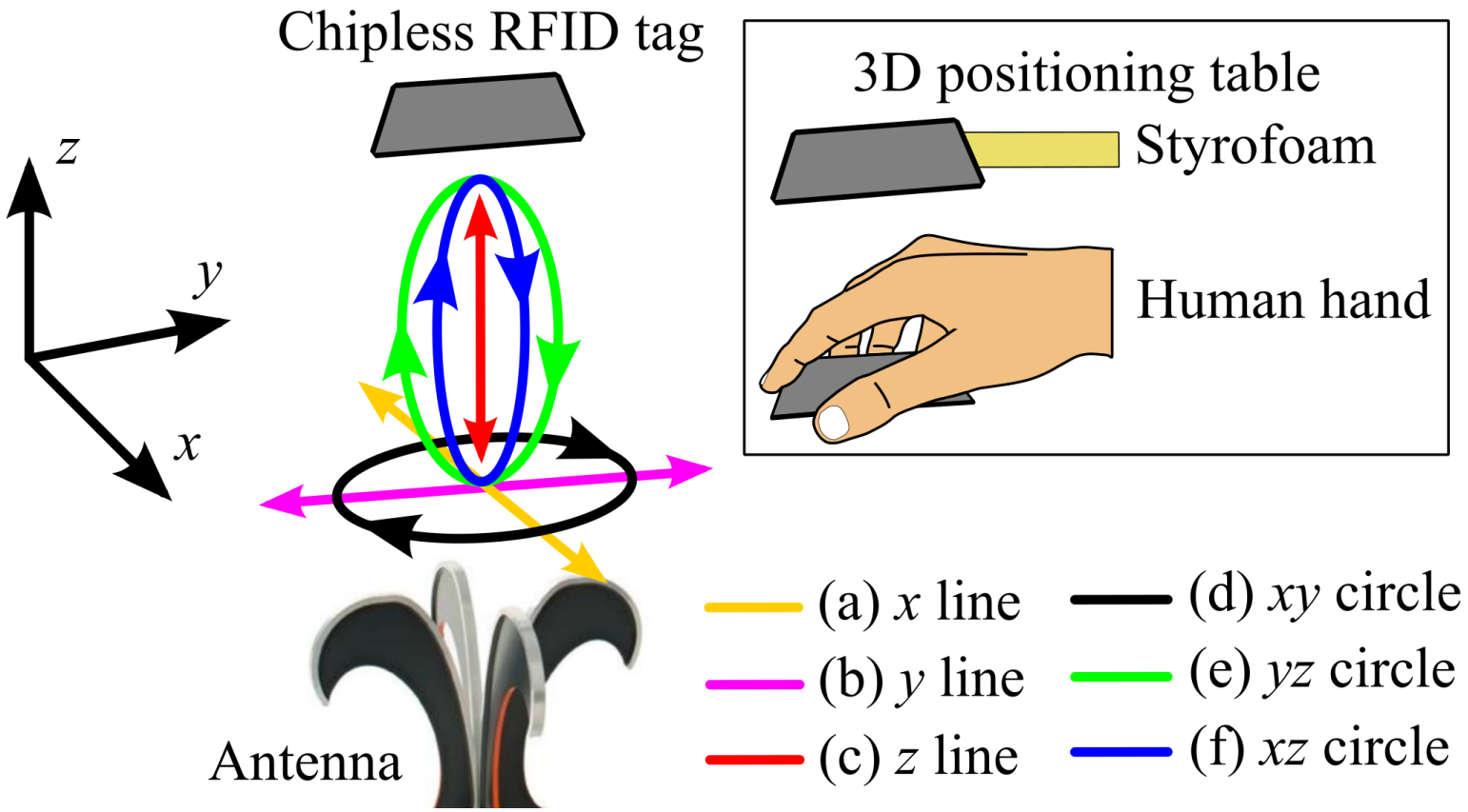
3D positioning table



Human hand



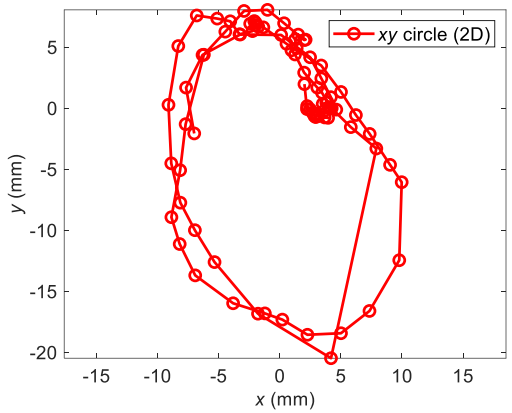
Ideal Gestures Trajectories



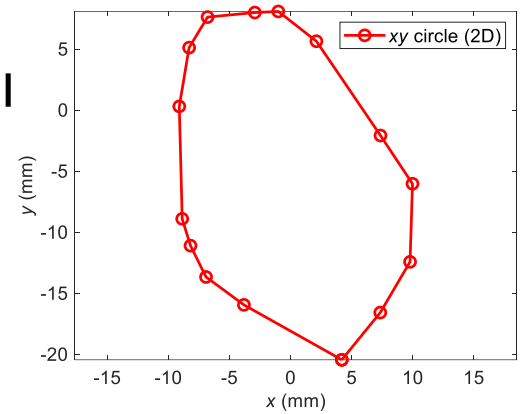
Similarity Metric

- Convex hull

Measured trajectory



Convex hull



Turning distance = 0

- Turning distance
  - Compares polygons
  - Regardless of rotation or scaling

$$d_p = \left(\min_{\theta \in \mathbb{R}} \int_{t \in [0,1]}^{1} \int_{0} |\Theta_A(s+t) - \Theta_B(s) + \theta|^p ds \right)^{\frac{1}{p}}, \qquad (4)$$

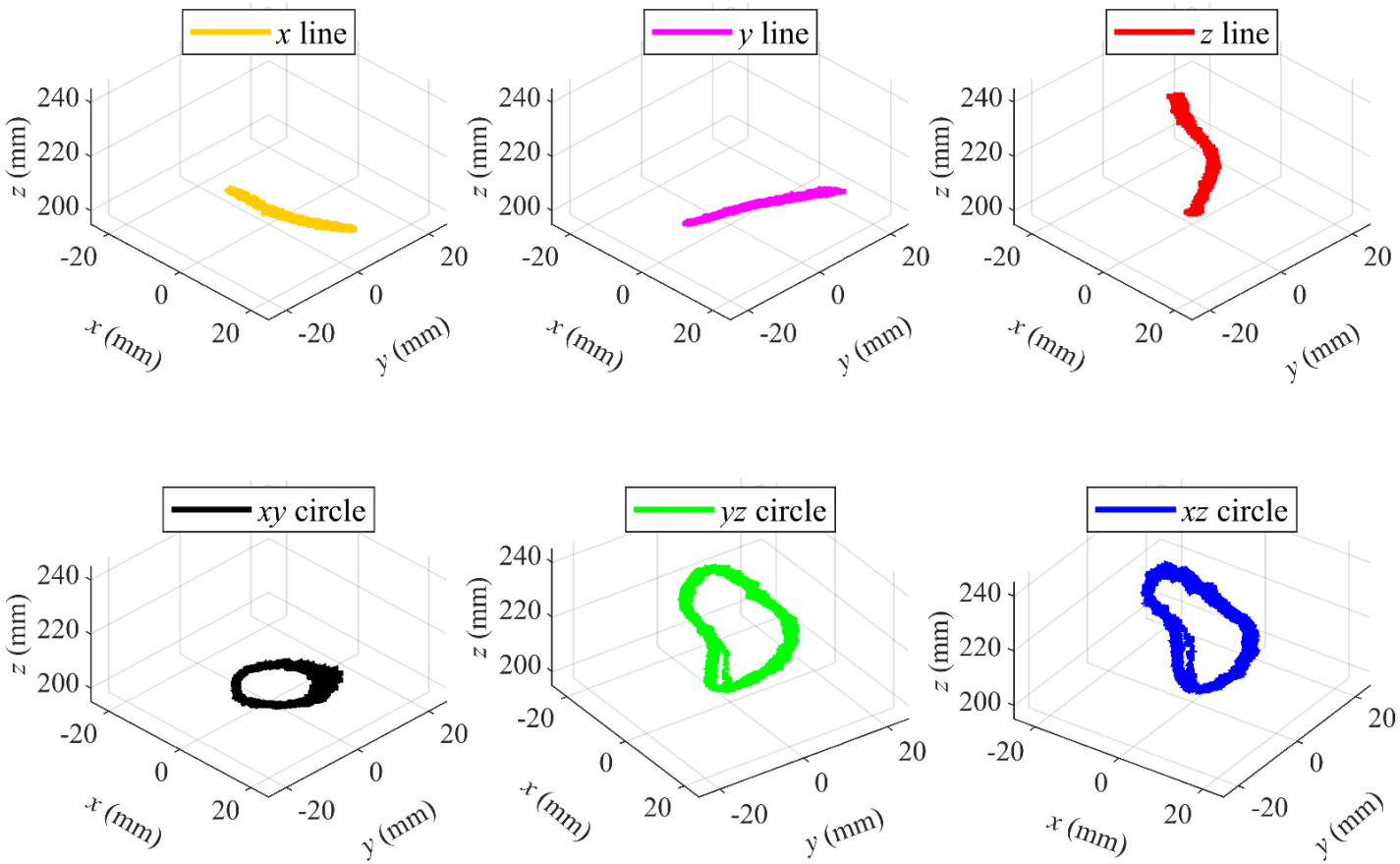
Ideal geometry

Circle

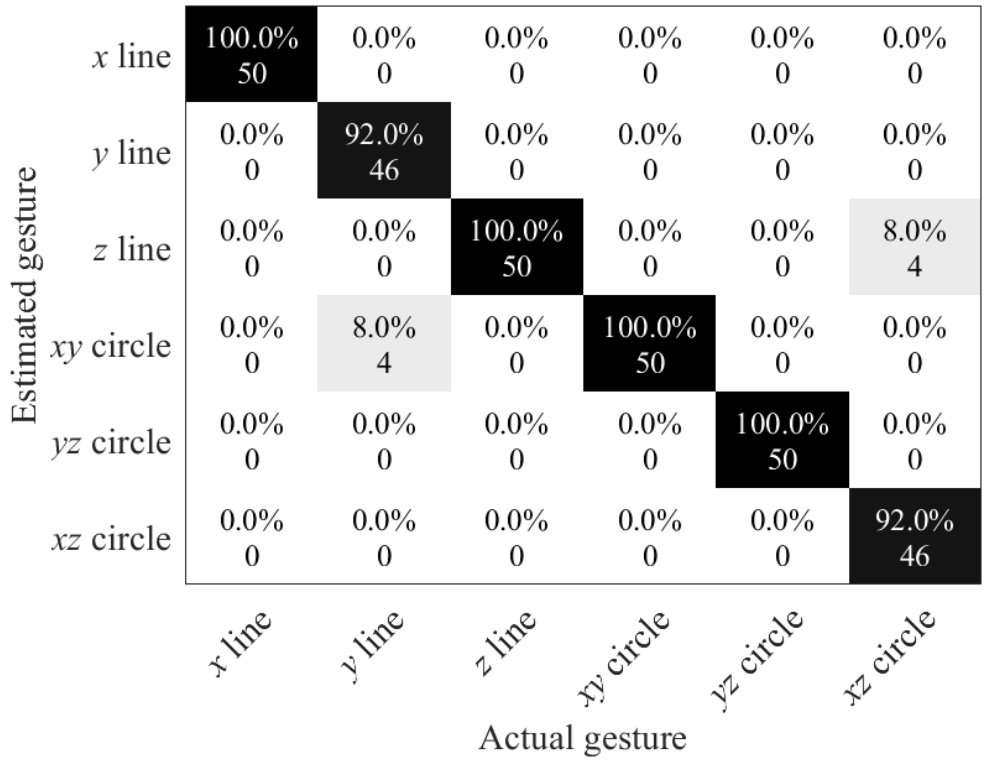
E. Arkin, L. Chew, D. Huttenlocher, K. Kedem, and J. Mitchell, “An efficiently computable metric for comparing polygonal shapes,” IEEE Trans. Pattern Anal. Mach. Intell., vol. 13, no. 3, pp. 209–216, 1991.

Measurements (3D Table)

50 measured trajectories



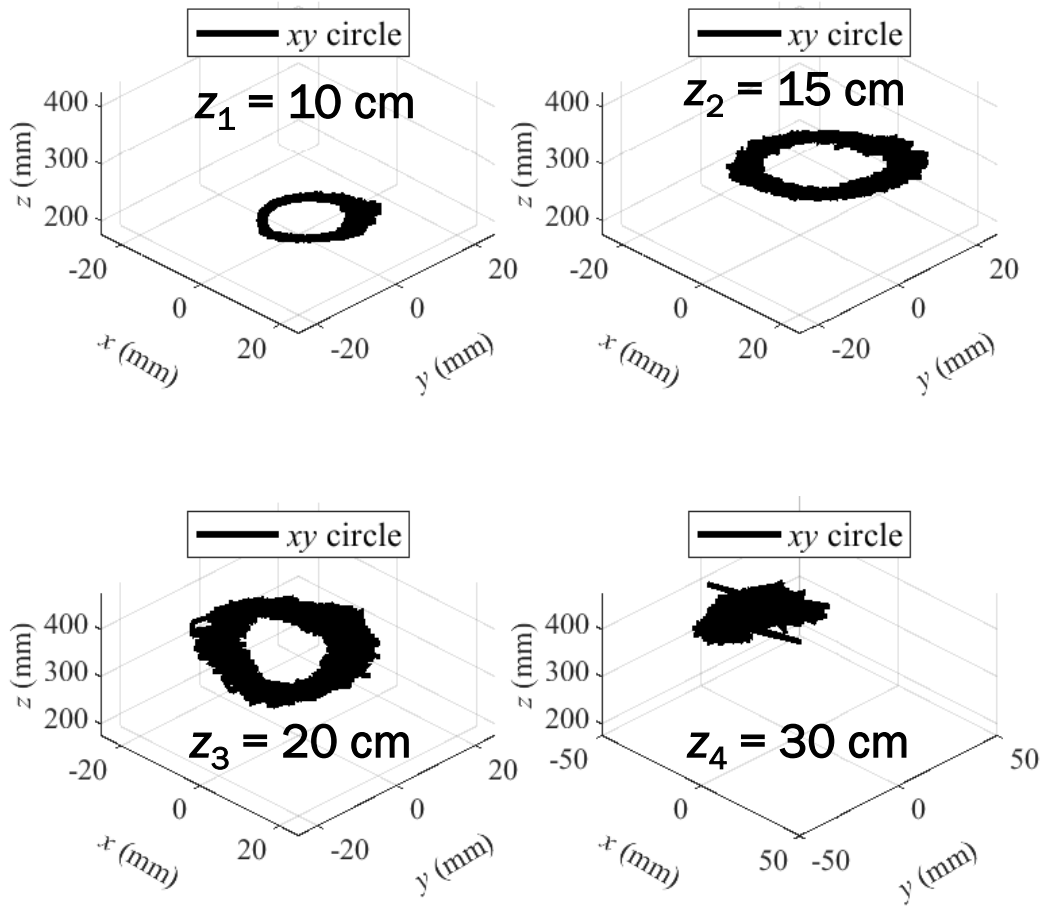
Confusion matrix



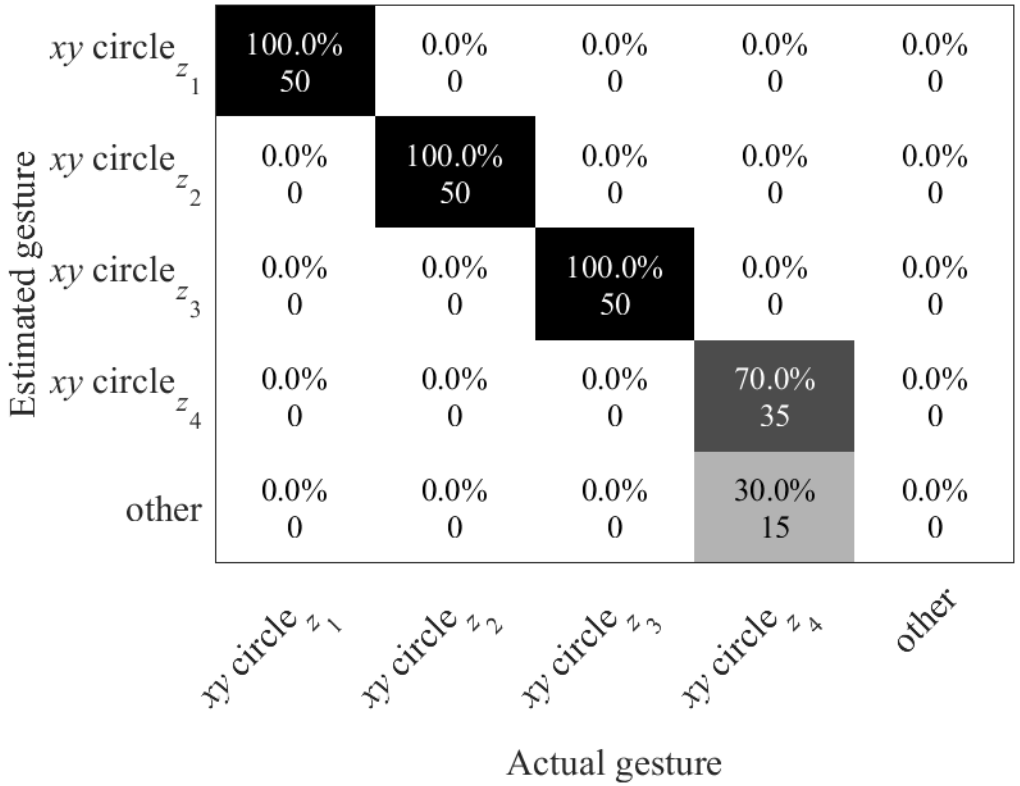
Overall accuracy = 97.33%

Measurements (3D Table)

50 measured trajectories



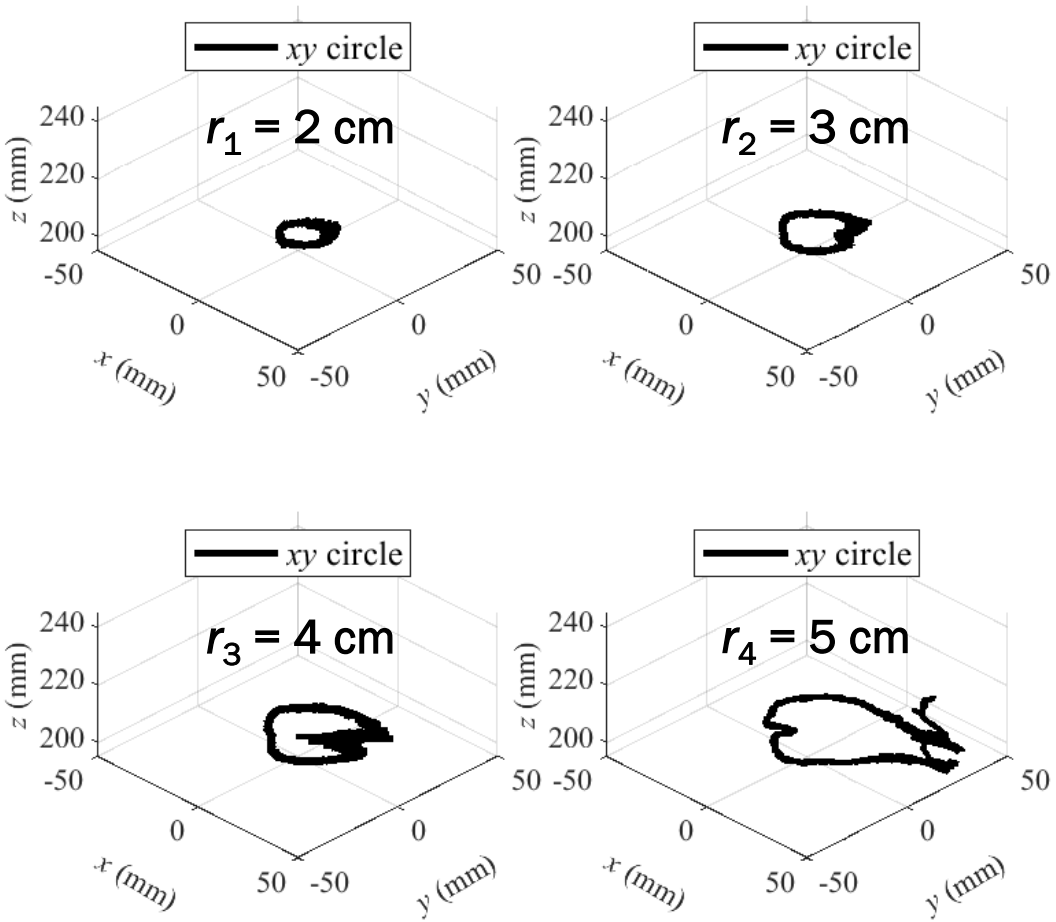
Confusion matrix



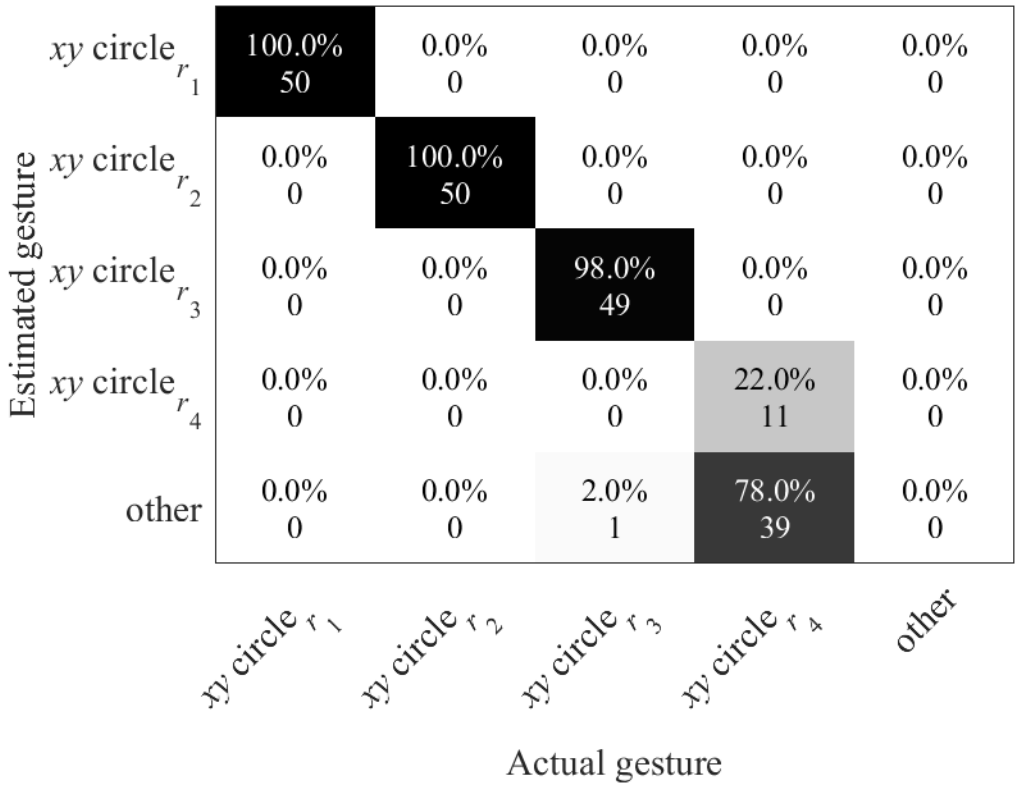
Overall accuracy = 92.50%

Measurements (3D Table)

50 measured trajectories

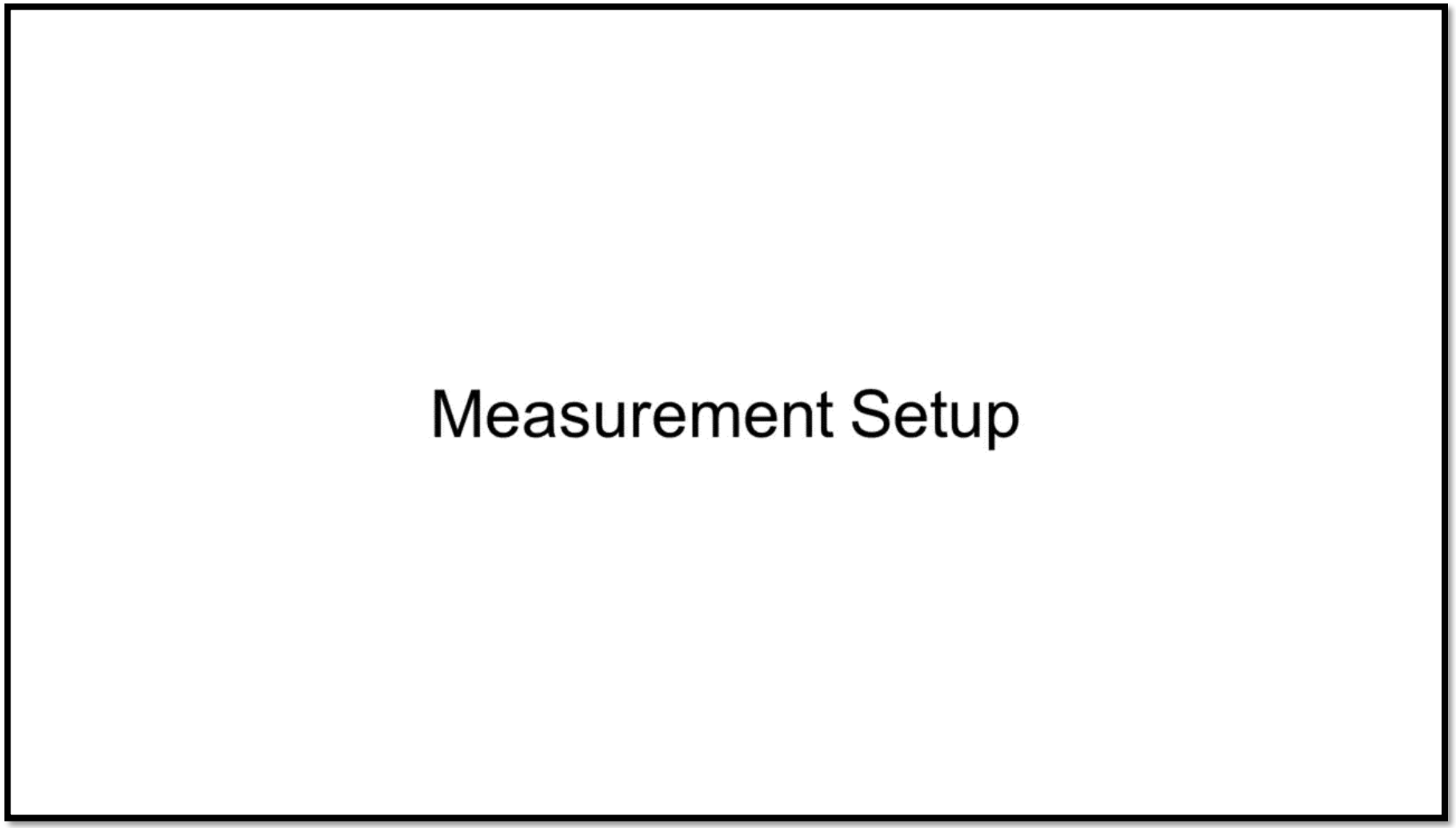


Confusion matrix



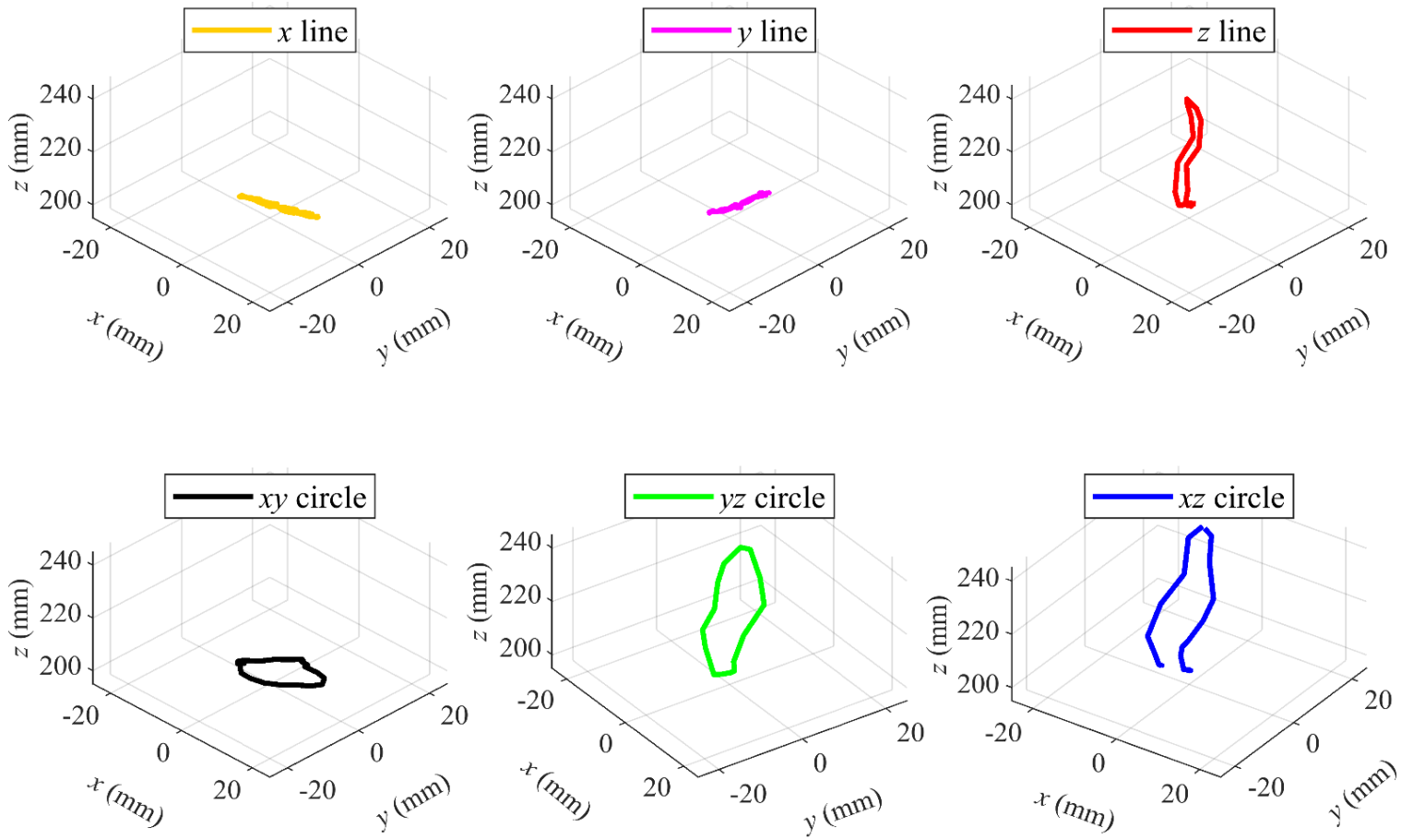
Overall accuracy = 80%

Video Demonstration (3D Table)



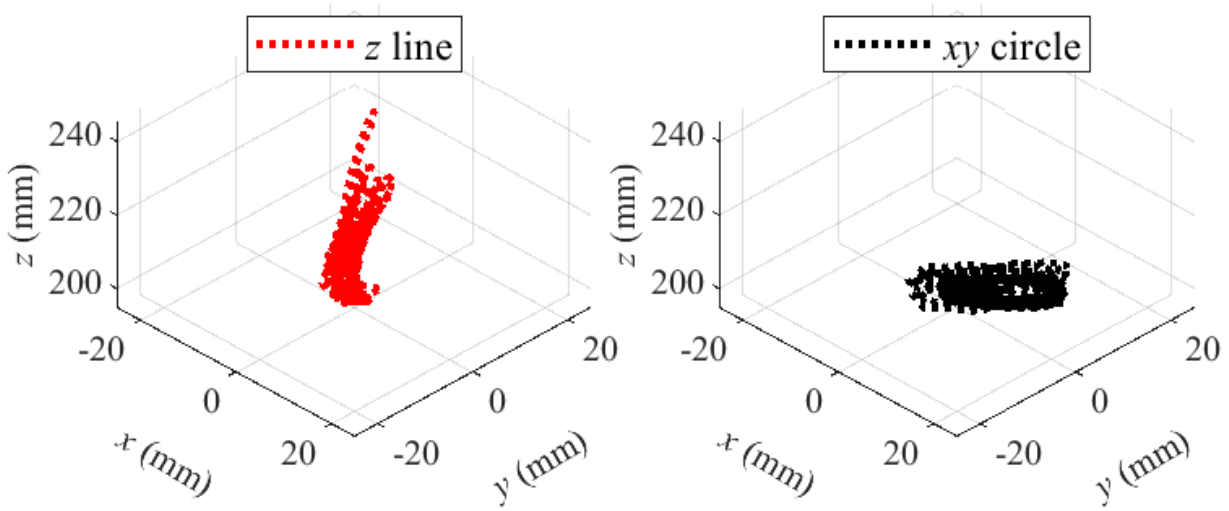
Measurements (Human Hand)

Measured trajectories

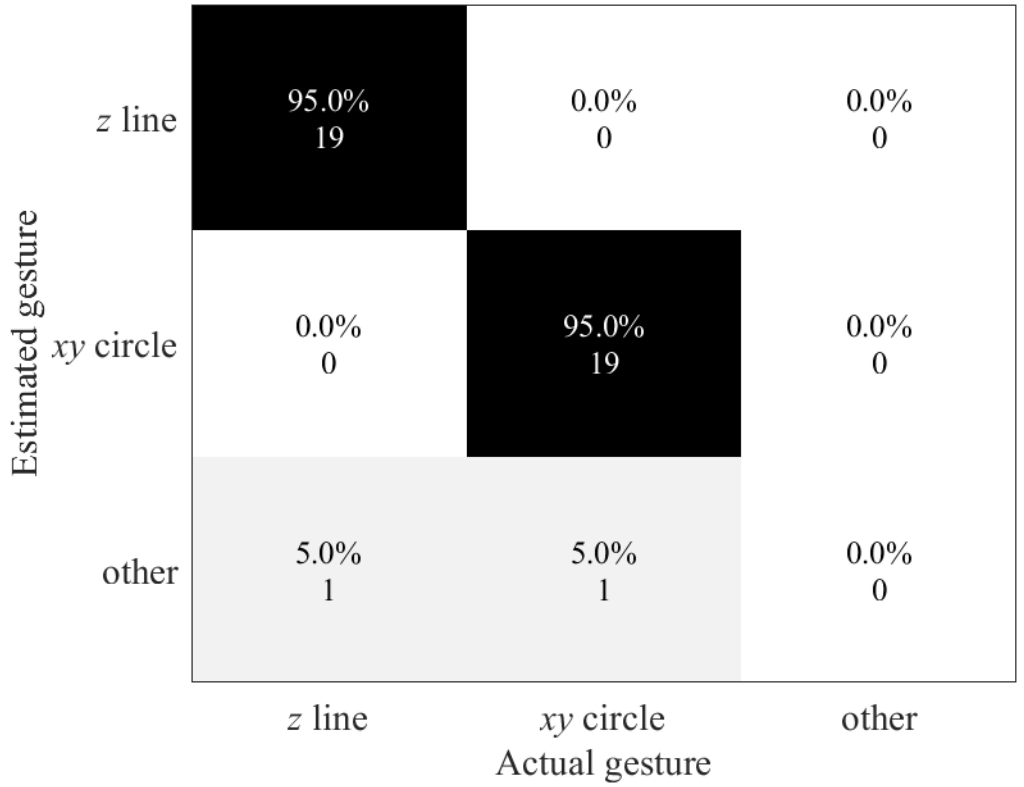


Measurements (Human Hand)

20 measured trajectories

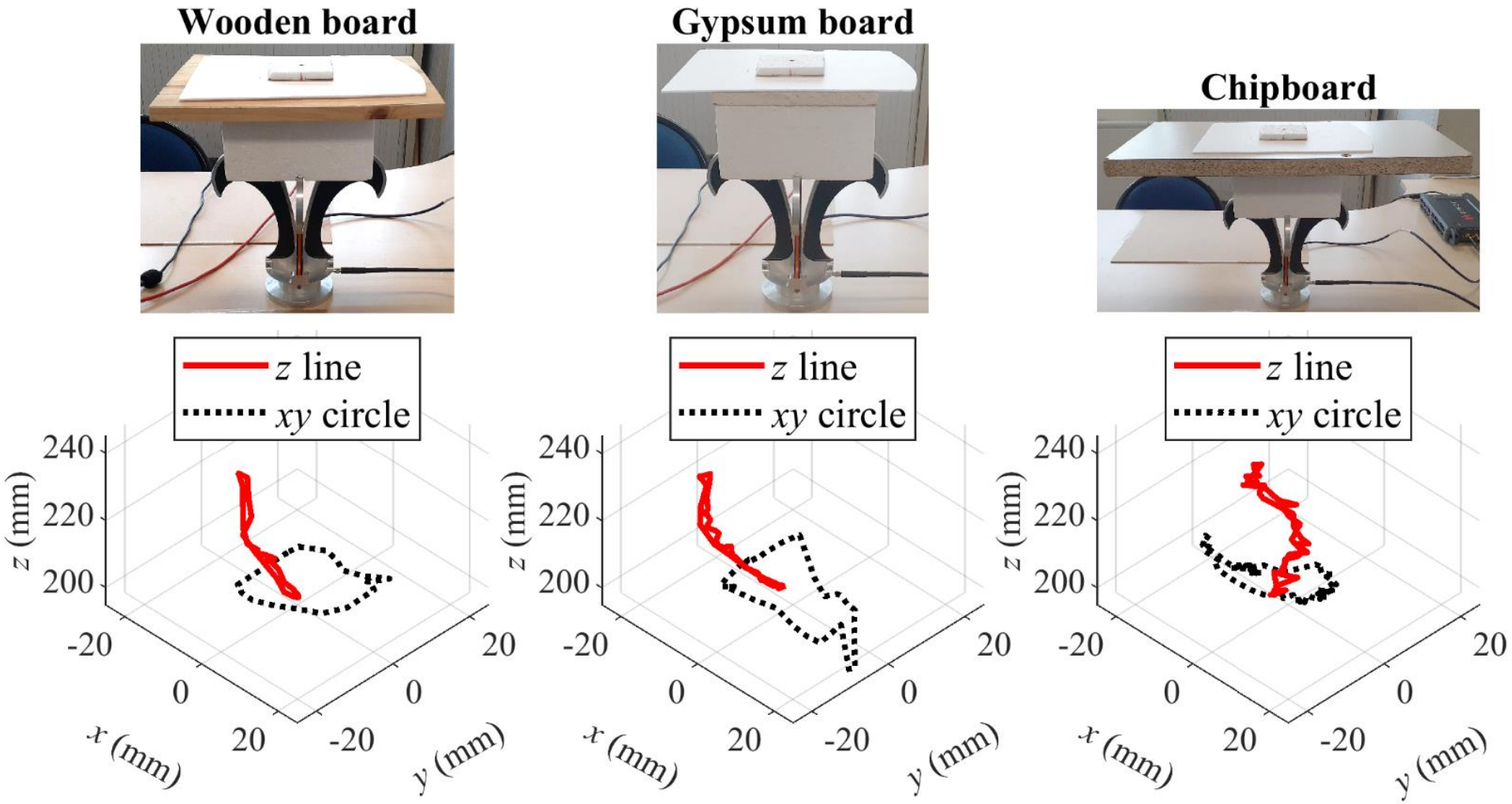


Confusion matrix

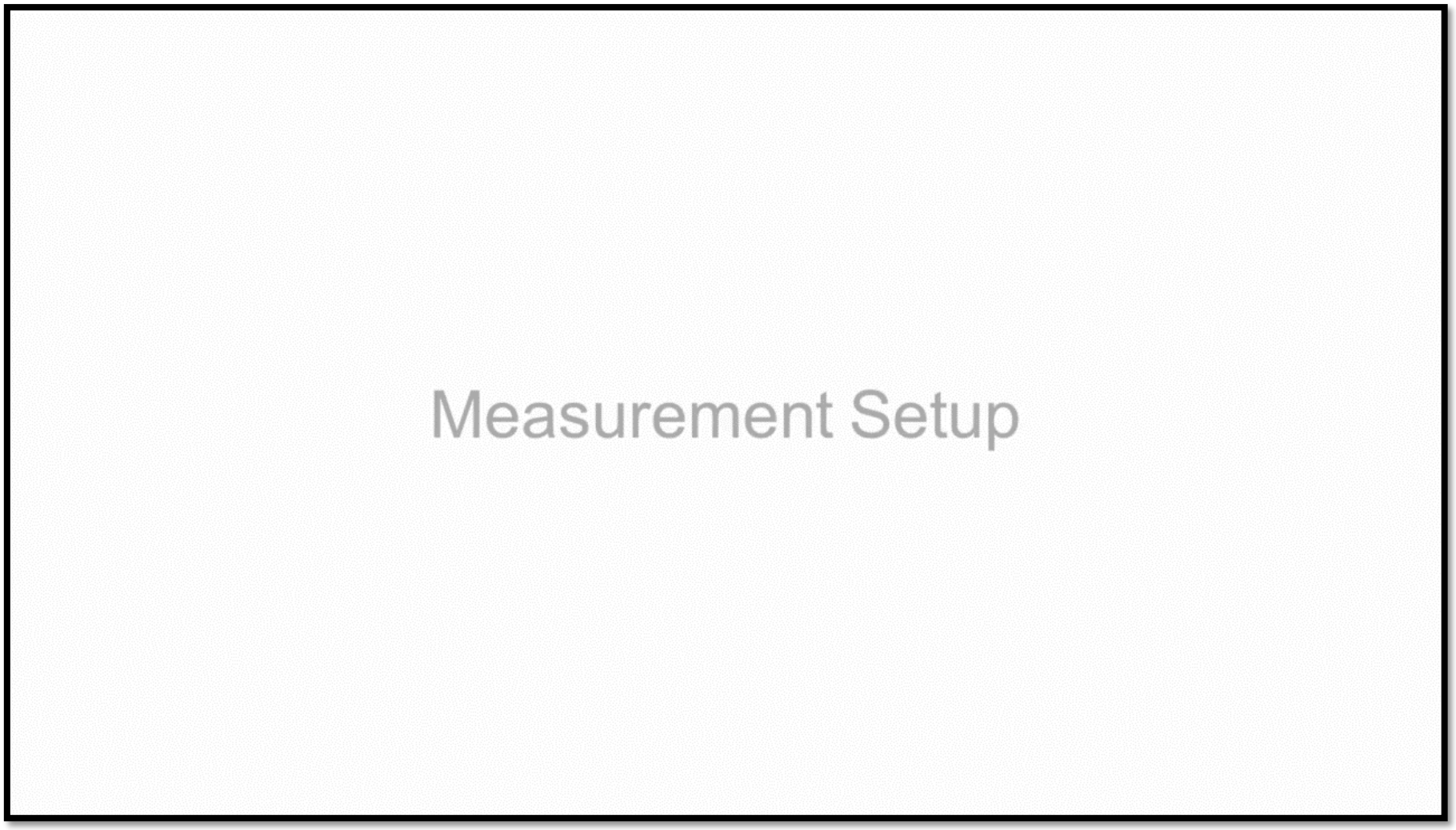


Overall accuracy = 95%

Measurements (Human Hand)



Video Demonstration (Human Hand)



Conclusions

- Proposed gesture recognition
  - Model based
  - Real time
  - Works within a 3D volume of 10 × 10 × 10 cm^3
  - Works under the objects
- Other possible features
  - Chipless RFID functionalities
  - 3D computer mouse

Thank You

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Questions


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QUESTION
PROBLEM
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DOUBT
EXPRESS
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UNCERTAINTY
QUESTION
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