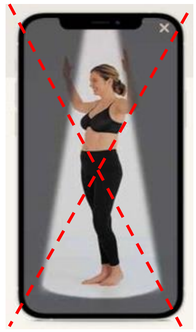
3D geometry recognition by RFID-Box based on deep learning

Cornell University

Zijing Zhang*(zz587@cornell.edu), Guoyi Xu, and Edwin C. Kan

3D geometry recognition for garment telemarketing

- **Limitation in camera-based virtual fitting :**
  - **High cost** of geometry reconstruction in terms of merging the camera images from multiple angles.
  - **Privacy** concern when the user has to be in front of multiple cameras without clothing or with snug-fit thin fabrics.
- **3D geometry recognition using RFID box or closet:**
  - **Cost-effective**.
  - Maintenance-free **passive** tags.
  - Convenient deployment and easily portable.
  - **No privacy concern** not only because no camera is used, but also because the user can be in their daily garment for the body shape.



3D geometry recognition for gesture identification

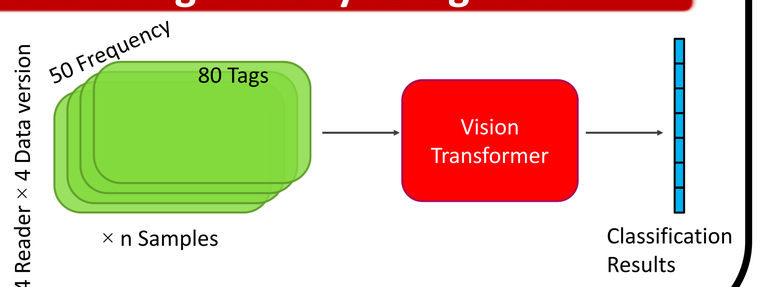
- Convenient setup for accurate static hand gesture recognition.
- Facilitate Human Computer Interaction (HCI) applications including 3D virtual reality control and sign-language detection.

Passive UHF RFID tags for spatial diversity in RFID-Box

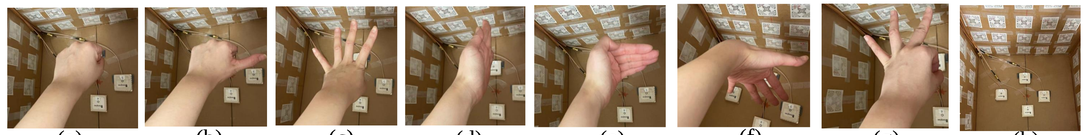
- **80** commercial passive RFID tags were lined inside the four peripheral sides of a cubic cardboard box of 45 cm.
- Four reader antennas were placed at the bottom driven from the Impinj reader running EPC Gen 2.
- 50 carrier frequencies in the range of 902-928 MHz were used. Reader antennas employed time division multiplexing (TDM).
- The reader Rx retrieved the tag ID, RSSI, phase, carrier frequency, and reader antenna port after 1 minute data collecting.

Deep learning model for geometry recognition

- The reader outputs were pre-processed by 2D image-like spectrogram and then fed into the Vision Transformer (ViT) as the deep learning model for geometry classification.



Static hand gesture recognition in RFID-Box



(a) (b) (c) (d) (e) (f) (g) (h)

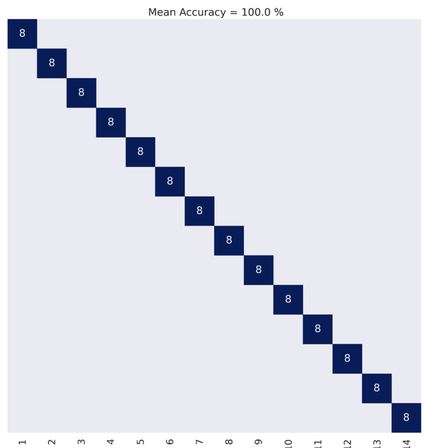
Testing accuracy for **8** hand gesture categories

Participants	P1	P2	P3	P1 (with glove)	P1+ P2
Sample size	80	49	52	43	129
Accuracy (%)	100	100	100	95.3	99.2

- K-fold (k = 6) cross validation was performed to estimate the mean accuracy.
- Built the personal training model for static gesture geometry recognition, and tested on 3 participants to demonstrate the ready generalization to gestures across different persons.
- For evaluation of the capability to distinguish individual participants, the system achieved 100% accuracy on distinguishing the participant from P1 and P2.

Geometry recognition in RFID-Box

Confusion matrix for **14** shape recognition



- Tested on objects wrapped in aluminum foils.
- 14 shapes consist of Lego blocks (4”×4”×2”) with additional thin layers (3”×3”×0.5”), imitating shoe size fitting.
- **Spatial resolution**: around 0.25” until recognition accuracy starts to degrade.

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Future improvement

- Our equivalent spatial resolution is high, and the 3D geometry is more complex than conventional RFID-based fingerprinting.
- The study can be applied to **garment** and **shoe fitting** setups with larger data sets of human study.
- Even **higher spatial resolution** of geometry recognition can be potentially achieved by adapting the system to mmID with higher carrier frequency.