Touchless muscle activity monitoring for Hand gesture recognition

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Existing hand gesture recognition systems

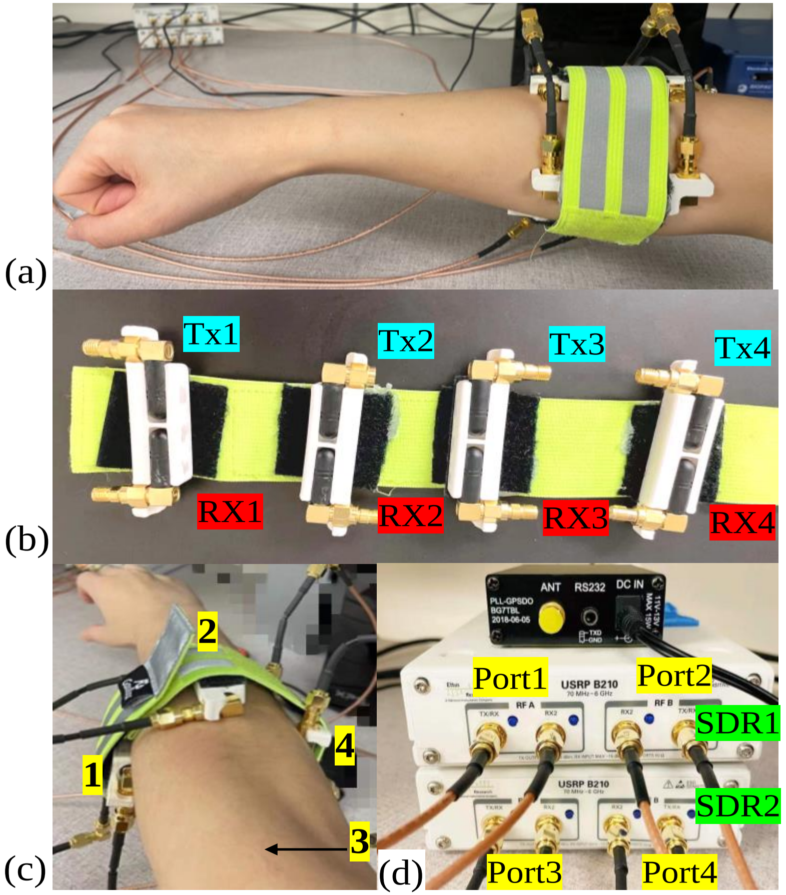
Camera-based?
Occlusion
Complex
Privacy
Latency

Motion-based?
Bulky on finger and hand
Only surface motion

sEMG-based?
Direct skin contact
Ambiguity
Numerous electrodes

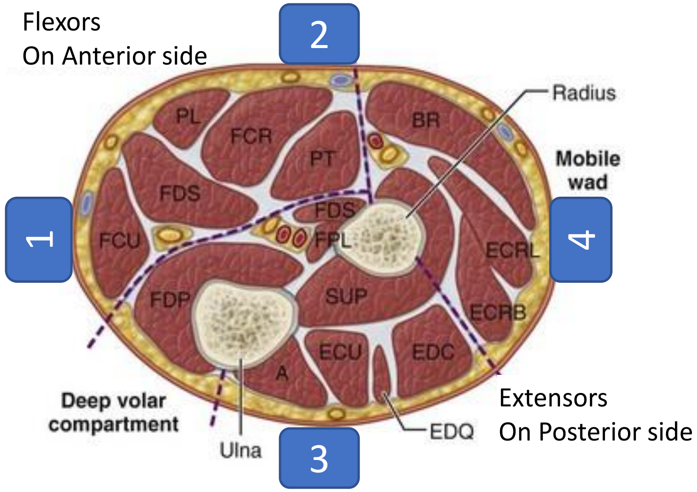
Gloved-based?
Hinder hand motion
Inconvenient
Uncomfortable

RMG (radio-myography) for muscle activity sensing

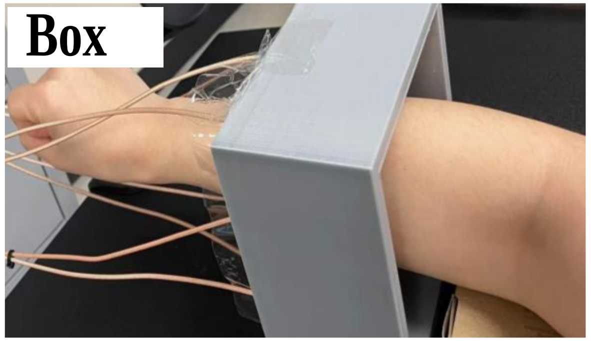


Multiple-input multiple-output (MIMO)
near-field coherent sensing (NCS) radio sensor

continuous muscle actuation sensing that can be wearable and touchless, capturing both superficial and deep muscle groups.



Touchless

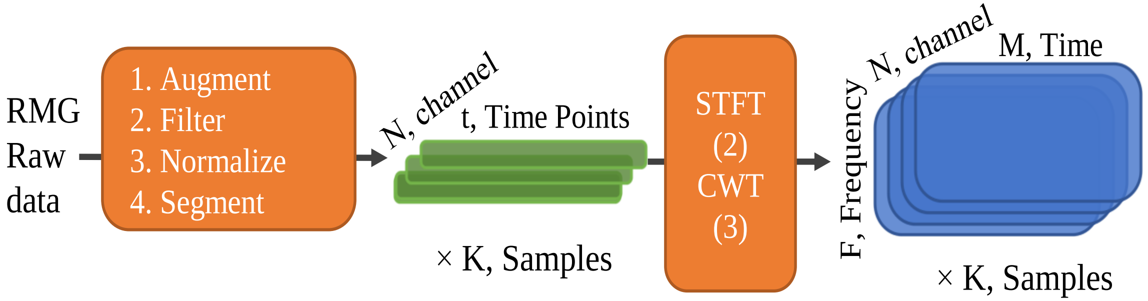


Study protocol and data processing

	Point Thumb	Point Index	Point Ind. +Mid.	Point 4 Finger	Grasp	Wrist Up	Wrist Down	Fist	Rest
Basic Gesture									
Quick	P1	P2	P23	P4	G	U	D		
Quick Double	P1×2	P2×2	P23×2	P4×2	G×2	U×2	D×2		
Slow	sP1	sP2	sP23	sP4	sG	sU	sD	sF	R

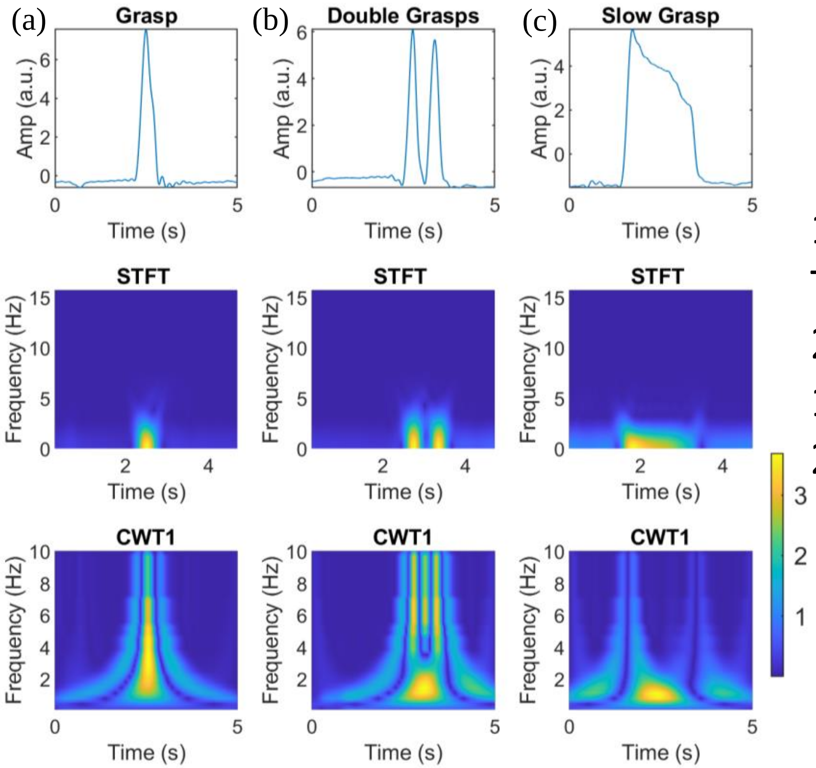
23 hand gestures used in the study protocol

8 participants
5,847 samples
23 gestures

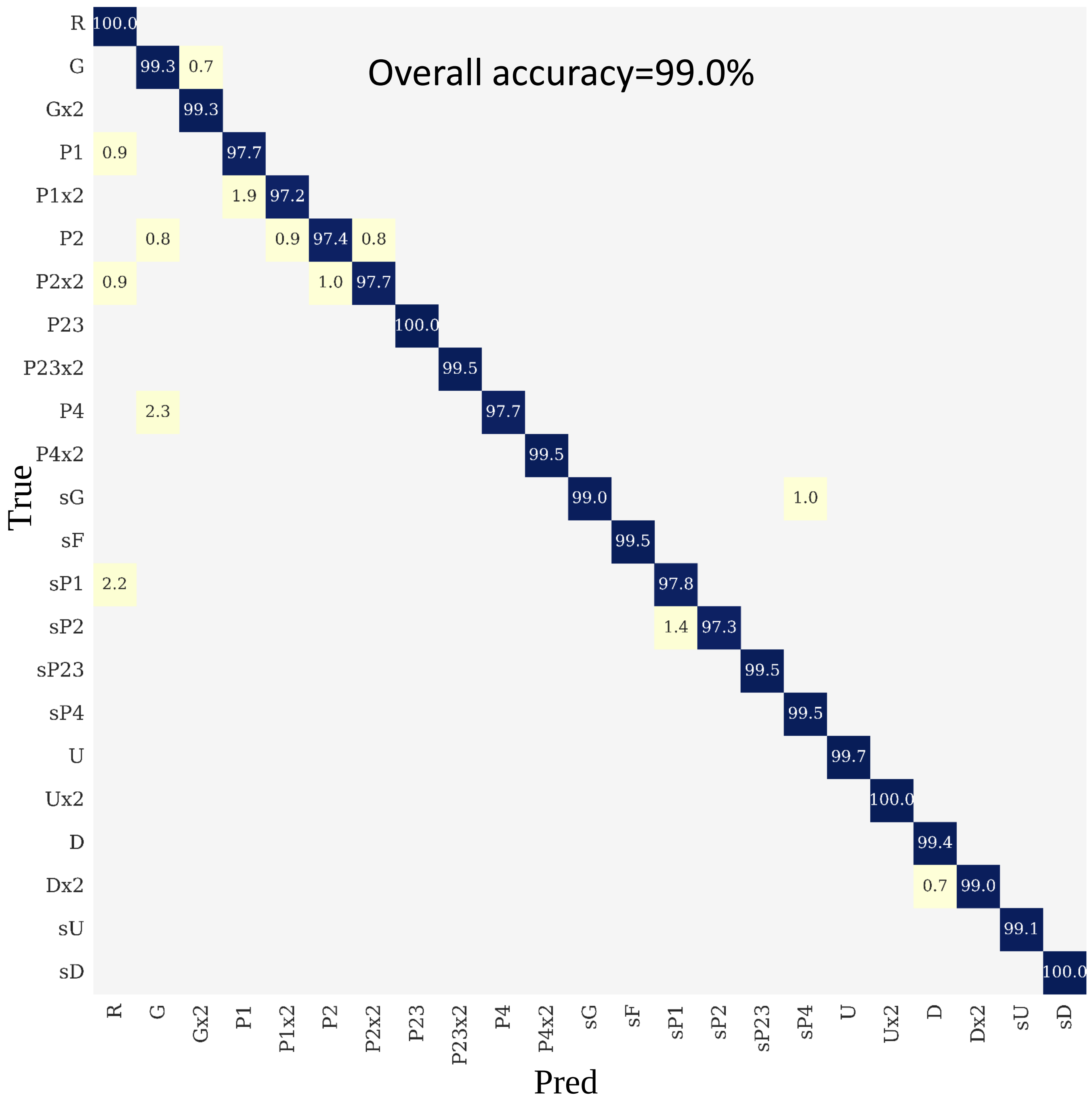


data pre-processing

Each gesture is segmented into 5s time window



1D time series
To
2D spectrogram
1. STFT
2. CWT

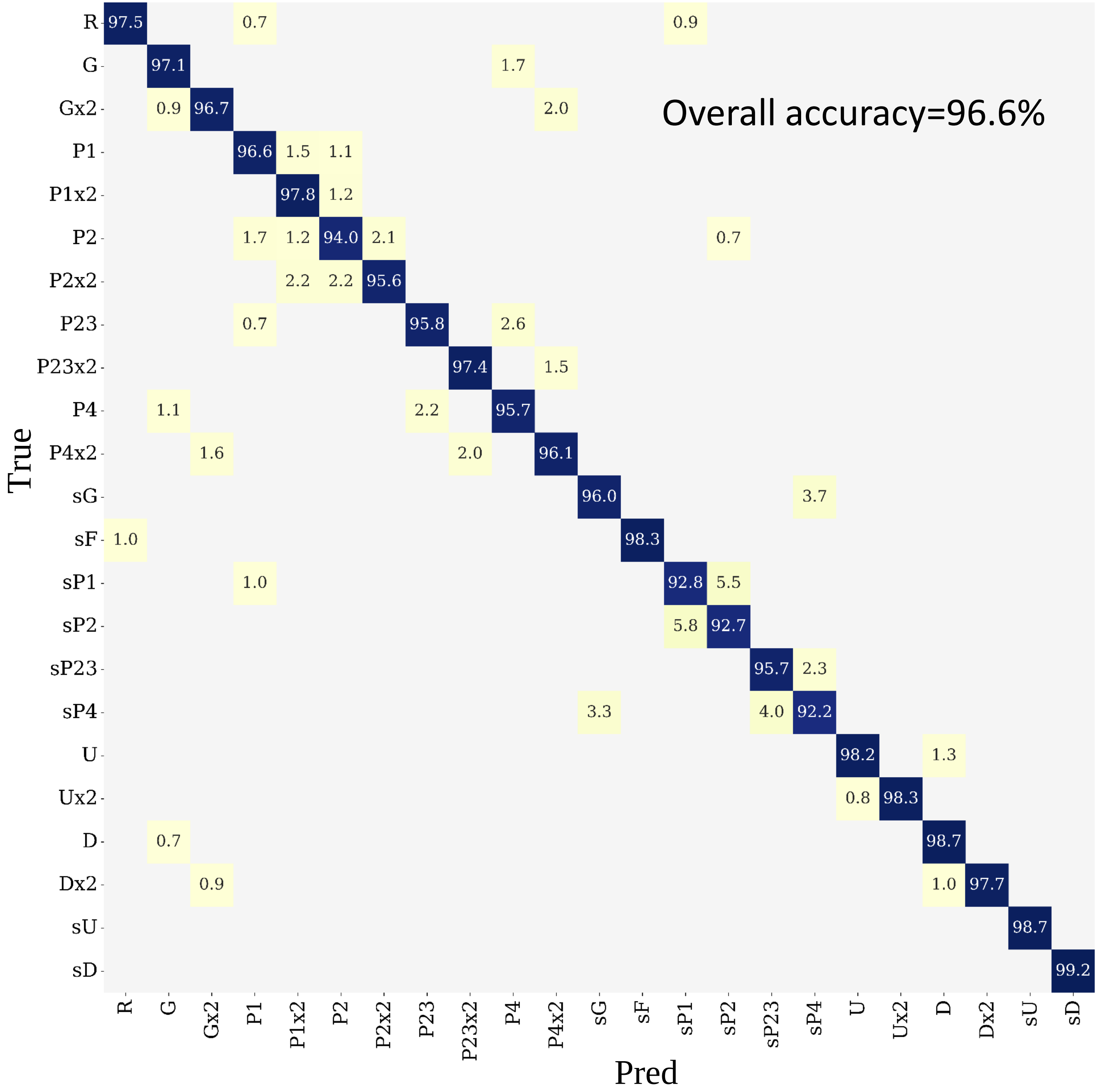


Classification results using deep learning

personal training model

Model:
Vision transformer

7-fold CV



Classification results using deep learning

Transfer learning on the unseen participant by 1/5 of new data.

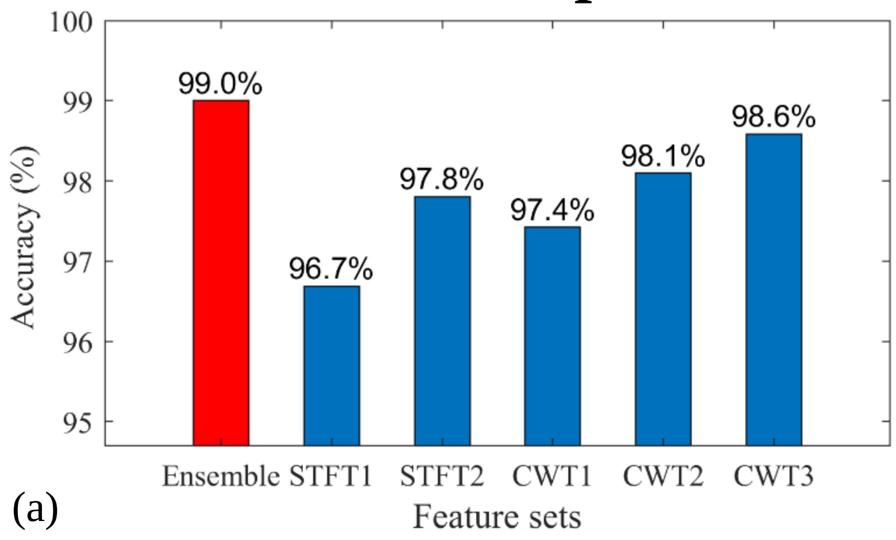
Pre-train on general model

Fine-tune by few cases of new participant

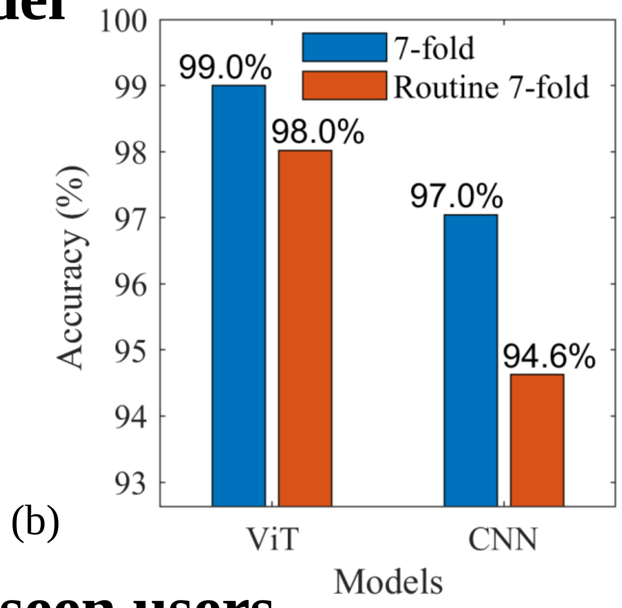
Model:
Vision transformer

Analysis on classification results

personal training model

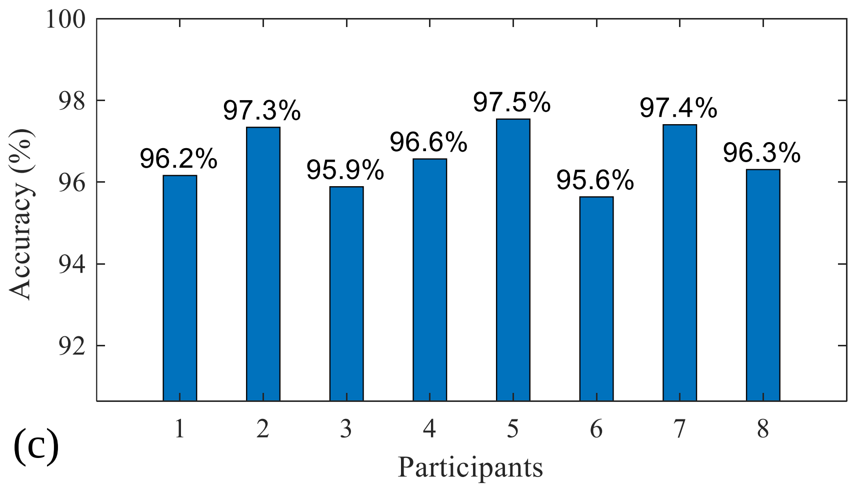


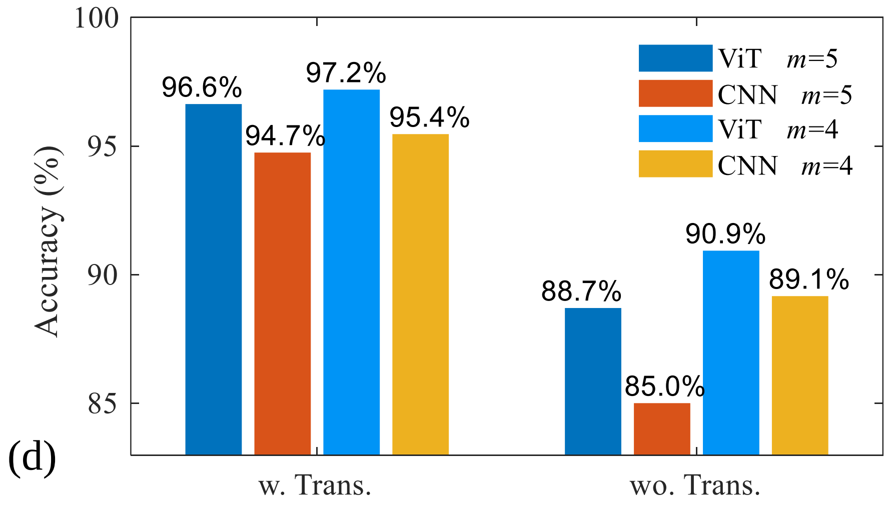
Ensemble boosts accuracy



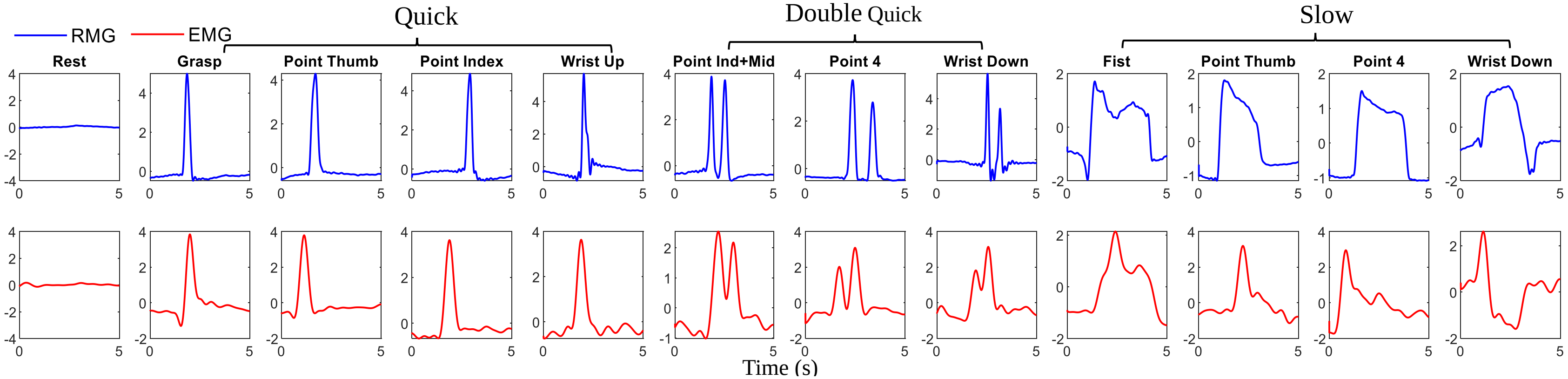
Vision Transformer outperformed CNN

Transfer learning for unseen users

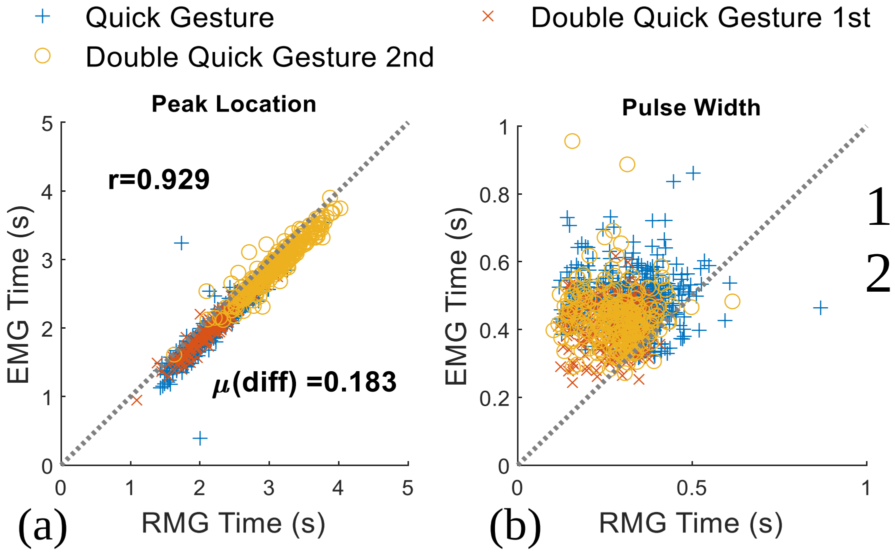




Benchmark with sEMG



RMG and sEMG waveforms for various gestures by DTW averaging on all samples

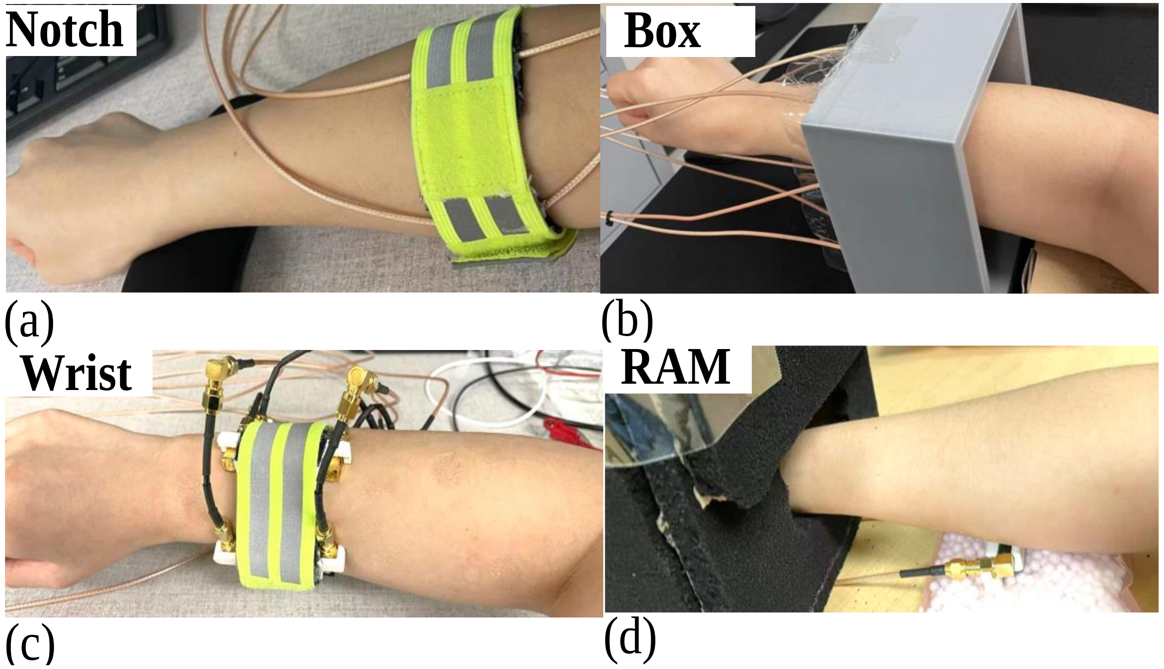


1. High temporal correlation
2. Consistent time lag

Accuracy comparison of RMG vs. sEMG

Exp:	1	2	3	μ
RMG	99.0 %	98.5 %	98.7 %	98.7 %
sEMG	68.2 %	70.8 %	66.7 %	68.6 %

Variation in experimental design



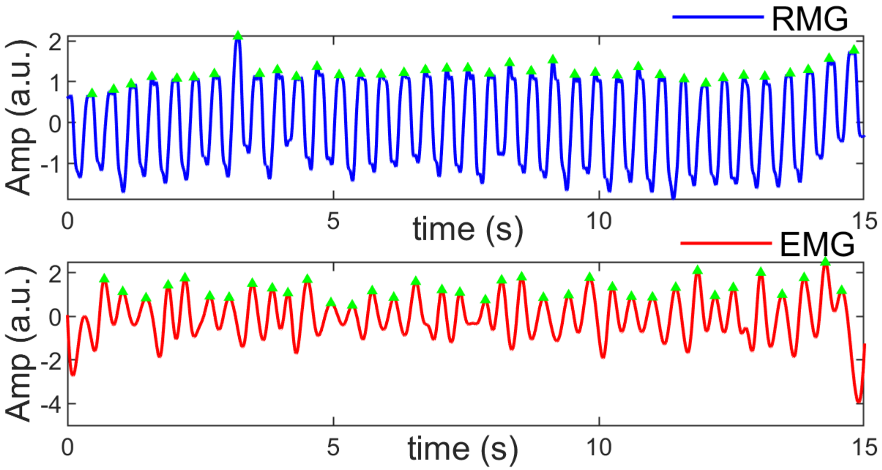
(a) (b) (c) (d)

	Notch (a)	Box (b)	Wrist (c)
Accuracy (%)	99.0	97.4	95.8

Timing and latency

Sampling rate:

Camera: 60 fps RMG: 1M sps



	Timing Test	
	150 beats/minute	
	μ	σ
RMG	0.40 s	38 ms
sEMG	0.40 s	55 ms

Comparison of RMG to previous HGR works.

	Li 2019 [11]	Liao 2021 [19]	Ma 2019 [20]	Zhang 2016 [17]	Savur 2016 [4]	Qi 2020 [25]	Côté-Allard 2019 [40]	Moin 2021 [23]	**This work**
Class	8	9	6	8	27	9	7/18	13/21	**23**
Subject	5	8	-	4	1	-	17/10	2	**8**
Sensor setup	Camera	Visible light	Solar light	FMCW Radar	sEMG	sEMG	sEMG	sEMG	**RMG**
Algorithm	CNN	kNN	kNN	CNN	Ensemble	GRNN	ConvNet	Neural	**ViT**
Accuracy	98.5%	96.1%	96.0%	96.0%	79.4%	95.3%	98.3% (7) 69.0% (18)	97.1% (13) 92.9% (21)	**99.0%**

Applications in Human Machine Interface

Hand gesture recognition system

virtual reality gesture control

Smart device control

Virtual object manipulation