GestSpoof: Gesture Based Spatio-Temporal Representation Learning For Robust Fingerprint Presentation Attack Detection

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Download GestSpoof Dataset
buffalo.edu/cubs/research/datasets/gestspoofdataset.html

Motivation:

- Fingerprint spoof attacks are highly common and pose a significant threat to biometric security systems.

- Existing methods primarily focus on image classification, ignoring the potential benefits of temporal learning.

- The differences in the elastic properties of real versus fake fingerprints can be better detected through motion-induced gestures.

- Widely used datasets lack temporal information, prompting the creation of a new dataset to explore distortion-based spoof detection.
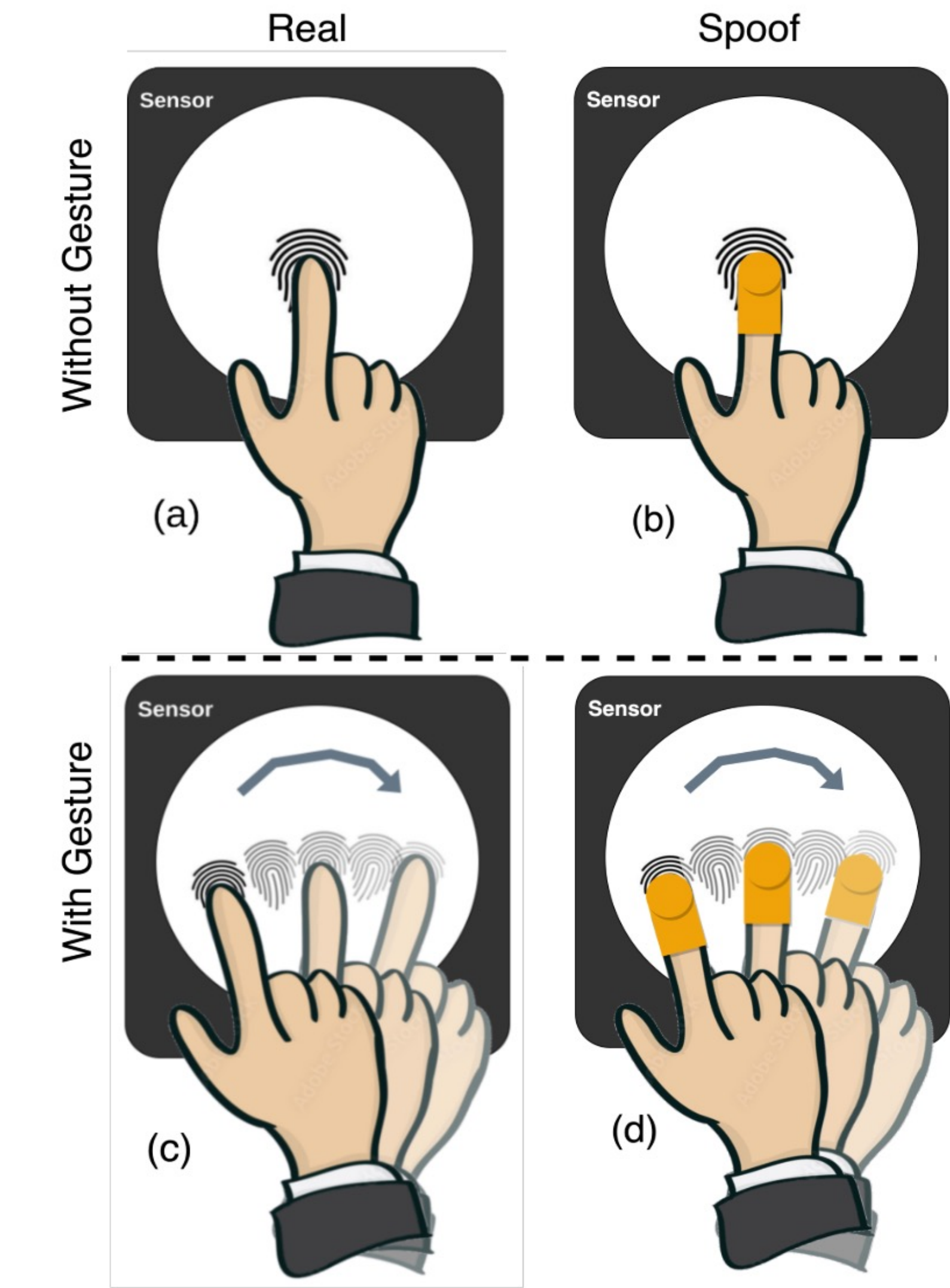
Gesture Based Spoof Detection:
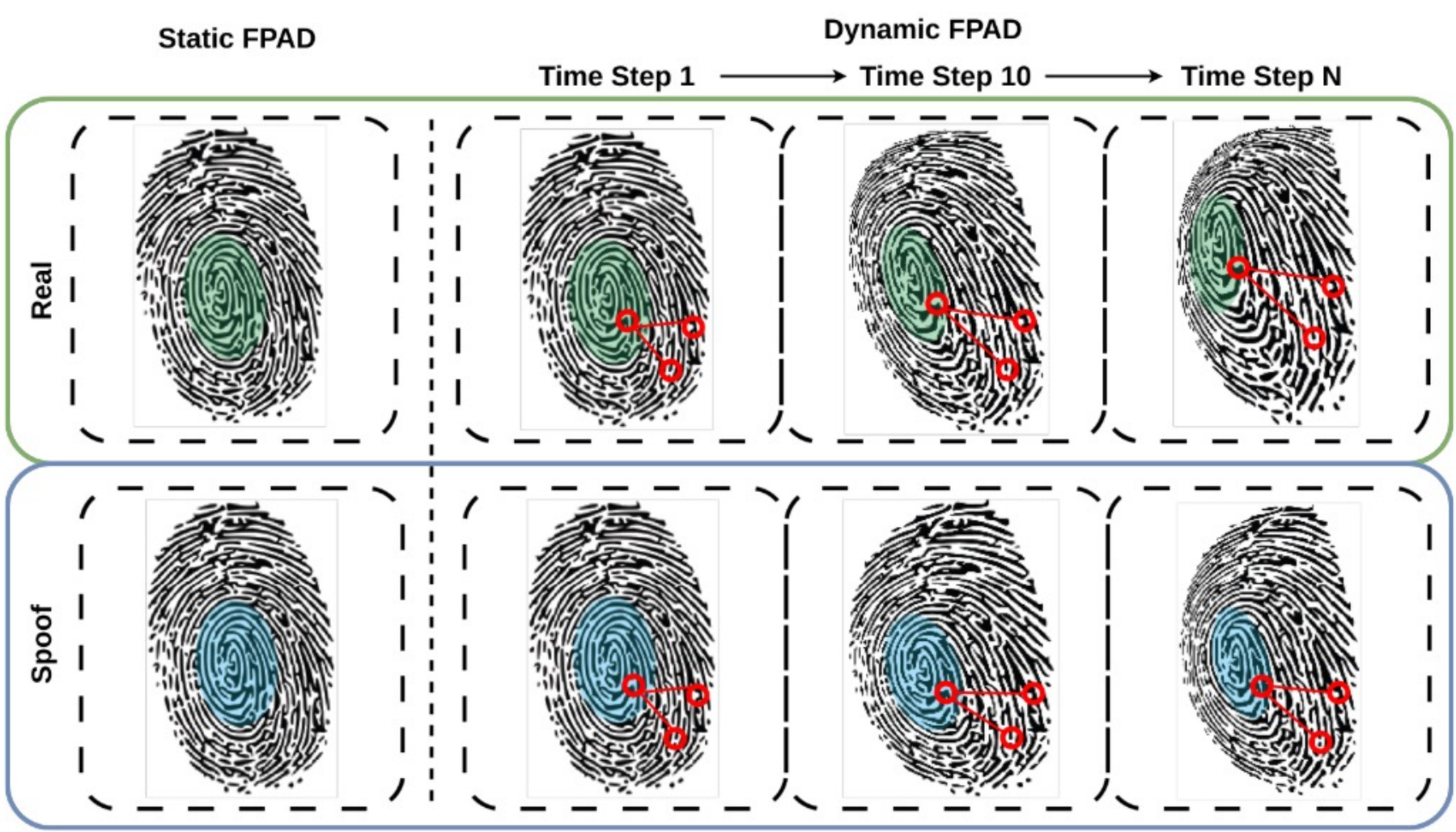
Intentional motion amplifies elastic properties, highlighting differences in fingerprint distortion between real and spoof due to friction, with green and blue regions indicating relative displacement and red showing minutia position changes.
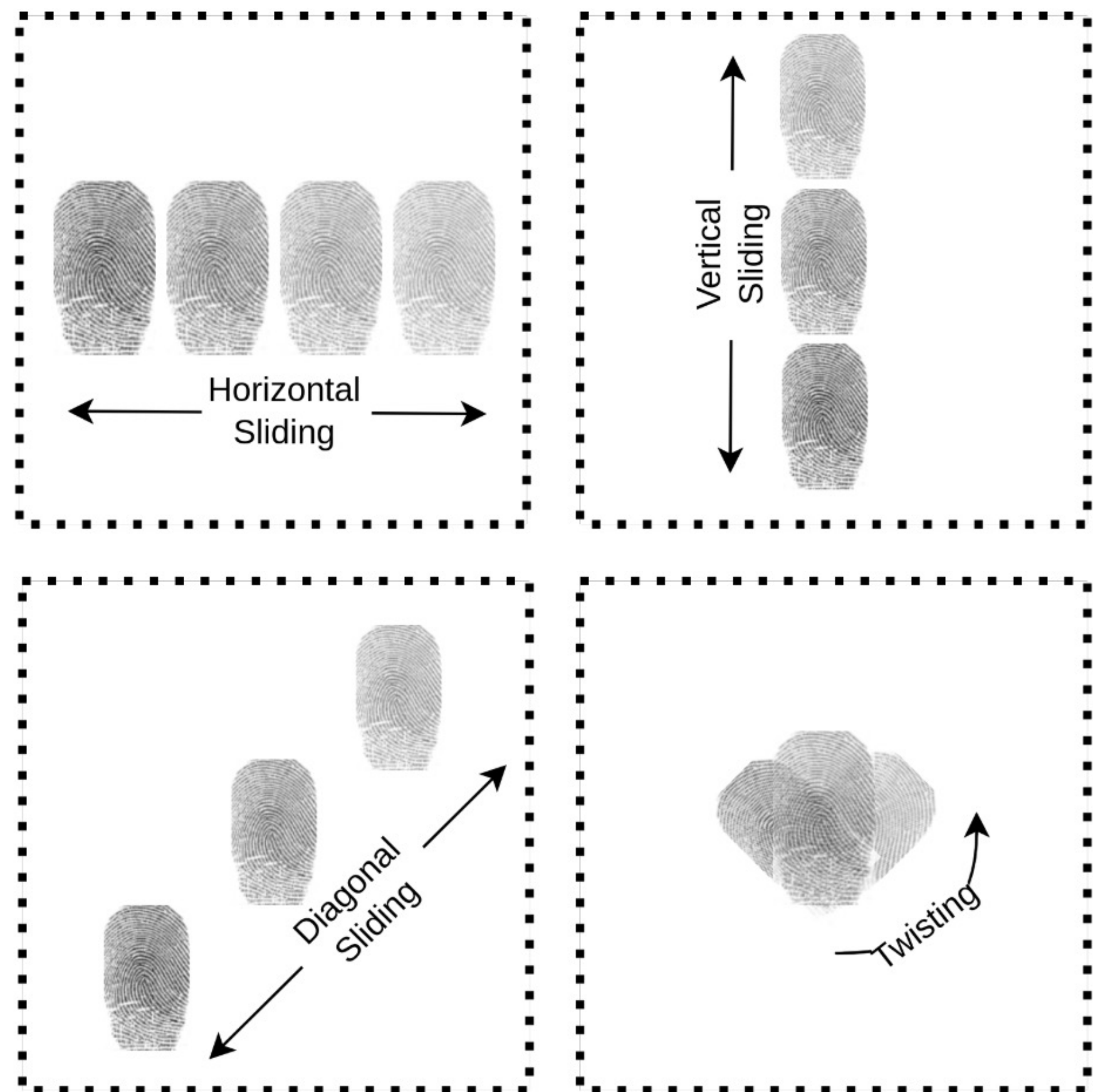
Different types of gestures incorporated in GestSpoof

(a) and (b) show existing fingerprint spoof detection using static image classification, while (c) and (d) show our proposed approach using **gesture-induced distortions** to amplify elastic differences.

GestSpoof Dataset:

| Dataset	# Fingers	# Real	# Fake	Temporal	Gesture	Materials Used
LivDet 2009 [25]	254	5500	5500	✗	✗	Gelatine, Silicone and Play-Doh
LivDet 2011 [30]	200	3000	3000	✗	✗	Gelatine, Silgum, Ecoflex ...
LivDet 2013 [13]	225	8000	8000	✗	✗	Gelatine, Modasil, Ecoflex ...
LivDet 2015 [26]	100	4500	5948	✗	✗	Body Double, EcoFlex, Wood Glue ...
LivDet 2017 [27]	150	8099	9685	✗	✗	Body Double, Liquid Ecoflex , Body Double ...
LivDet 2019 [28]	-	6029	6936	✗	✗	Gelatine, Wood Glue, Latex ...
LivDet 2021 [5]	66	10700	11740	✗	✗	GLS20, Body Double, Mix 1 ...
PB Spoof-Kit [7]	-	1000	900	✗	✗	Crayola, Wood glue, 2D print ...
MSU-FPAD [7]	-	9000	10500	✗	✗	2D Print-Matte Paper, 2D Print (Transparency) ...
ATVS-FFp [12]	68	816	816	✗	✗	Silicone, Play-Doh
Tsinghua [18]	60	300	470	✓	✗	Silicone
BSL [2]	90	900	400	✓	✗	Silicone, gelatin, latex, wood glue
T. Chugh et.al [8]	685	26650	32910	✓	✗	Ecoflex, Crayola Model Magic, Dragon Skin ...
GestSpoof	184	920 (videos) 132466 (frames)	2760 (videos) 478194 (frames)	✓	✓	Body Double, EcoFlex, Gelatine

Comparison against existing datasets

Sample frames from GestSpoof dataset for different types of spoof materials

Property	Count
Number of Subjects	23
Number of Unique Fingers	184
Number of Videos Real	920
Number of Videos Fake	2760
Number of Spoof Materials	3
Number of Intentional Motions	5
Number of Frames	610660

Summary of GestSpoof dataset statistics.

Spatial-Temporal Representation Learning:
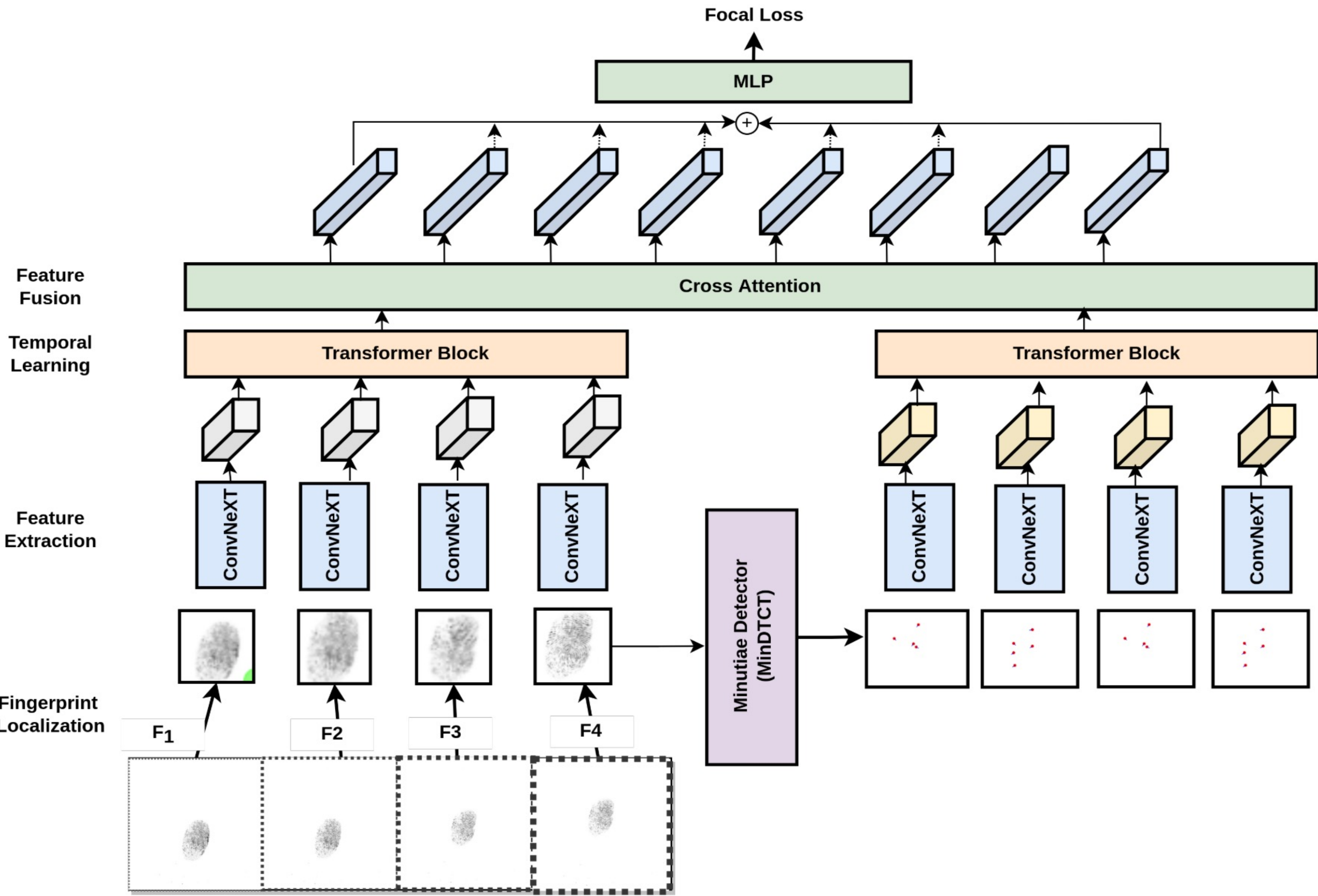
Performance and Results:

Method	F1 Score	TAR@FAR=1%	APCER@BPCER=1%
Static Image Based Approaches (10 Frame)			
Hold out spoof - Bodydouble			
ResNet 50 [14]	66.24%	49.93%	86.25%
ViT Base [10]	73.68%	42.99%	73.75%
Hold out spoof - Ecoflex			
ResNet 50 [14]	65.22%	50.21%	77.50%
ViT Base [10]	61.63%	46.88%	56.67%
Hold out spoof - Gelatin			
ResNet 50 [14]	64.88%	49.79%	88.75%
ViT Base [10]	67.94%	46.19%	70.83%
Static Image Based Approaches (1 Frame)			
Hold out spoof - Bodydouble			
ResNet 50 [14]	71.93%	47.57%	90.83%
ViT Base [10]	73.19%	25.24%	96.67%
Hold out spoof - Ecoflex			
ResNet 50 [14]	70.50%	46.88%	97.50%
ViT Base [10]	66.07%	43.34%	79.17%
Hold out spoof - Gelatin			
ResNet 50 [14]	71.18%	47.16%	86.67%
ViT Base [10]	73.17%	43.41%	86.67%
Dynamic Video Based Approaches			
Hold out spoof - Bodydouble			
VideoModel	**79.23%**	**54.29%**	**61.50%**
Hold out spoof - Ecoflex			
VideoModel	**74.67%**	**51.46%**	71.23%
Hold out spoof - Gelatin			
VideoModel	**78.85%**	**52.78%**	**67.11%**

Hold out Performance - The performance of the models on unseen (unknown) spoof types, where the model is trained on two spoof types and evaluated on all three.

Ablation Study:

Ablation Setting		F1 Score	TAR@FAR	APCER@BPCER
Ridge	Min			
✓		79.34%	49.76%	72.80%
✓	✓	83.34%	50.83%	61.48%

Conclusion:

Proposed a novel fingerprint spoof detection approach using gesture-induced elastic distortions and released the first motion-based fingerprint spoof dataset "**GestSpoof.**"

Presented baseline results for static image and dynamic video-based spoof detection, and introduced a **novel spatio-temporal** approach combining ridge and minutiae features.

Future works can use **GestSpoof** to benchmark new methods and that this gesture-augmented approach can be integrated into existing smartphones to enhance security without hardware changes.

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