SpacSec 2026

ITMO

Multimodal Biometric Authentication Using Paired ECG and PPG Signals

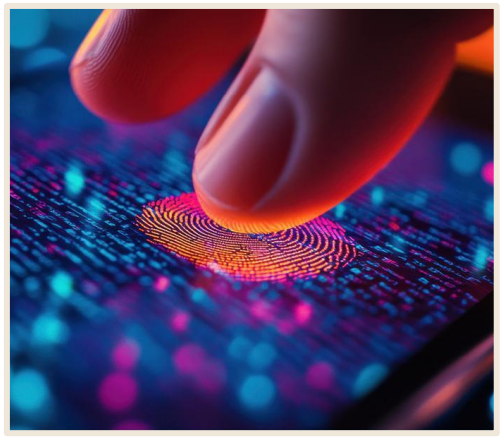
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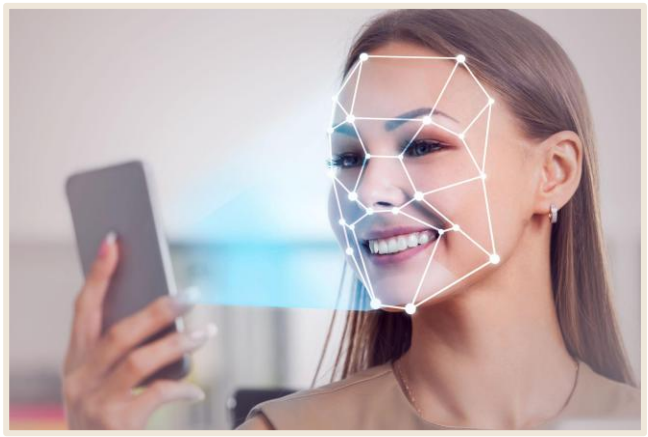
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MOTIVATION

- Biometric authentication is increasingly integrated into personal and connected devices.
- Physiological characteristics offer identity evidence beyond passwords and PINs.
- Wearable sensors enable new opportunities for continuous authentication using cardiac signals such as ECG and PPG.



Fingerprint



Facial Recognition



Wearable Devices

Fig.1. Examples of Biometric Authentication Technologies

CARDIAC BIOMETRICS

ECG vs PPG

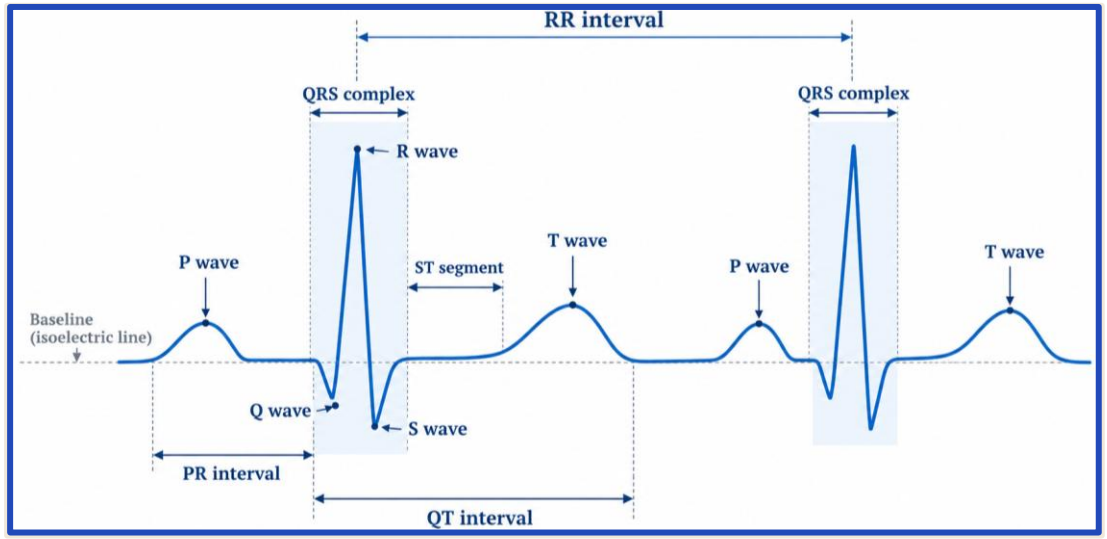


Fig.2. ECG

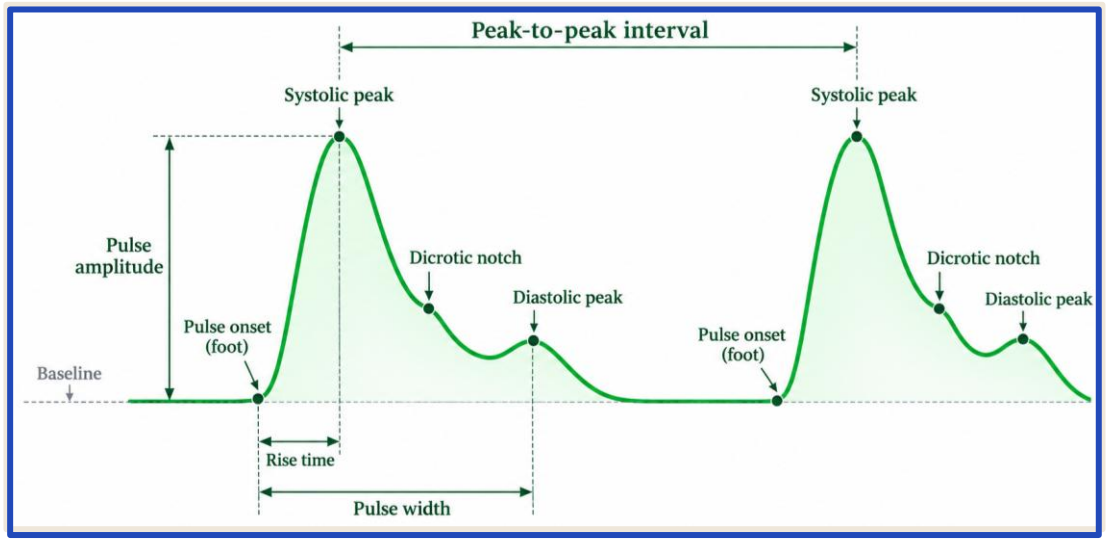


Fig.3. PPG

- Measures the heart's electrical activity.
- Individual differences in P–QRS–T morphology provide biometric features

- Measures blood volume changes using optical sensors.
- Pulse shape, amplitude, and timing provide biometric features.

RESEARCH PROBLEM

- ECG or PPG alone may be affected by modality-specific noise and artifacts.
- Physiological changes affect heartbeat consistency.
- Conventional aggregation methods may assign equal weights to reliable and noisy heartbeats.

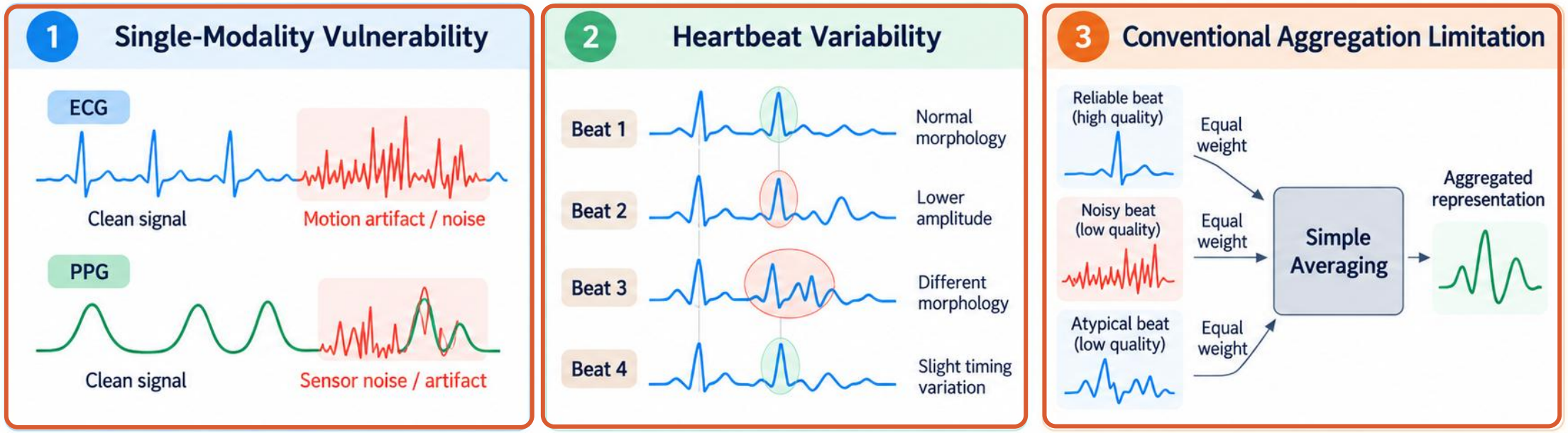


Fig.4. Key Challenges in ECG–PPG Biometric Authentication

RESEARCH GOAL

Goal

- Develop a robust multimodal biometric authentication framework that combines ECG and PPG signals using quality-aware Multiple Beat Aggregation (MBA) to improve authentication accuracy and reliability.

Objectives

- Combine synchronized ECG and PPG biometric features.
- Design a quality-aware Multiple Beat Aggregation algorithm.
- Enhance authentication reliability by reducing noisy-beat influence.
- Assess accuracy, error rates, and computational efficiency against baselines.

PROPOSED METHODOLOGY

- The proposed framework integrates synchronized ECG–PPG signals with quality-aware heartbeat aggregation for reliable biometric authentication.

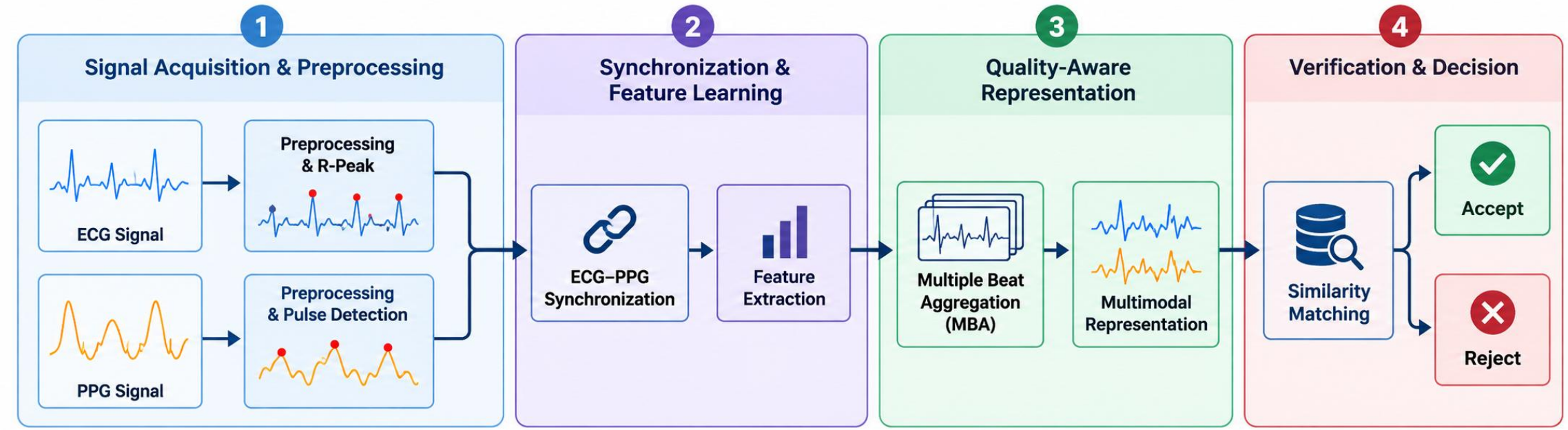


Fig.5. Multimodal ECG–PPG Authentication Framework

MULTIPLE BEAT AGGREGATION (MBA)

- MBA assigns greater importance to reliable heartbeats, reducing noisy-beat influence during multimodal feature aggregation.



Fig.6. MBA Algorithm

DATASETS

ECG–PPG Databases

- Two public datasets containing synchronized ECG and PPG recordings were used for evaluation.

	BIDMC	CapnoBase
Subjects	53	42
Sampling rate	125 Hz	300 Hz
Recording length	20 min	8 min

- After signal quality screening, 62 subjects were retained for multimodal biometric authentication evaluation.

EXPERIMENTAL SETUP

- The framework was evaluated using Leave-One-Subject-Out (LOSO) cross-validation across subjects from BIDMC and CapnoBase.
- Enrollment and verification were performed to assess authentication accuracy, error rates, and latency

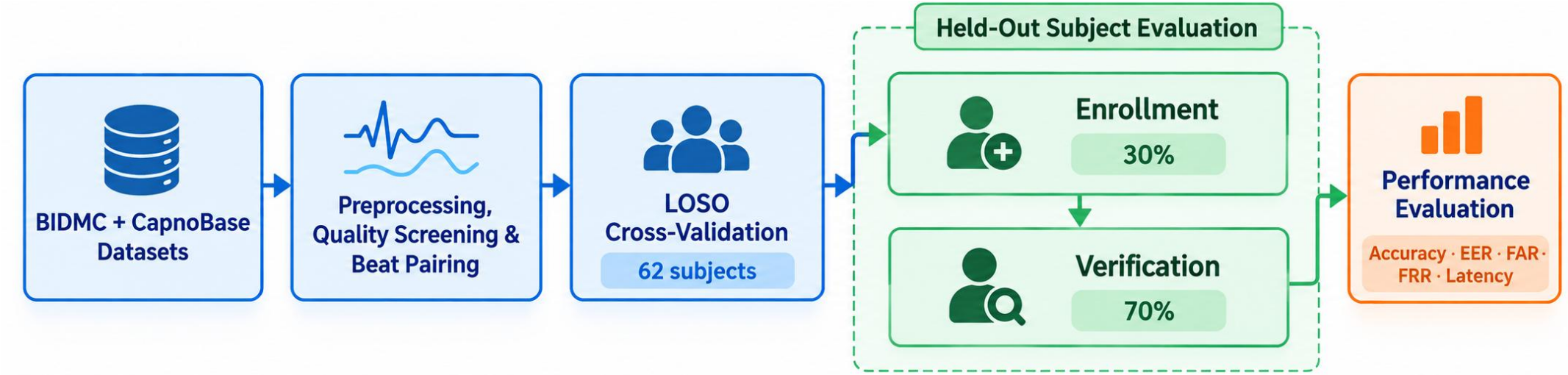


Fig.7. Experimental setup

AUTHENTICATION PERFORMANCE

- Multimodal MBA achieves 98.14% authentication accuracy and 2.31% EER, outperforming single-modality and conventional fusion approaches.

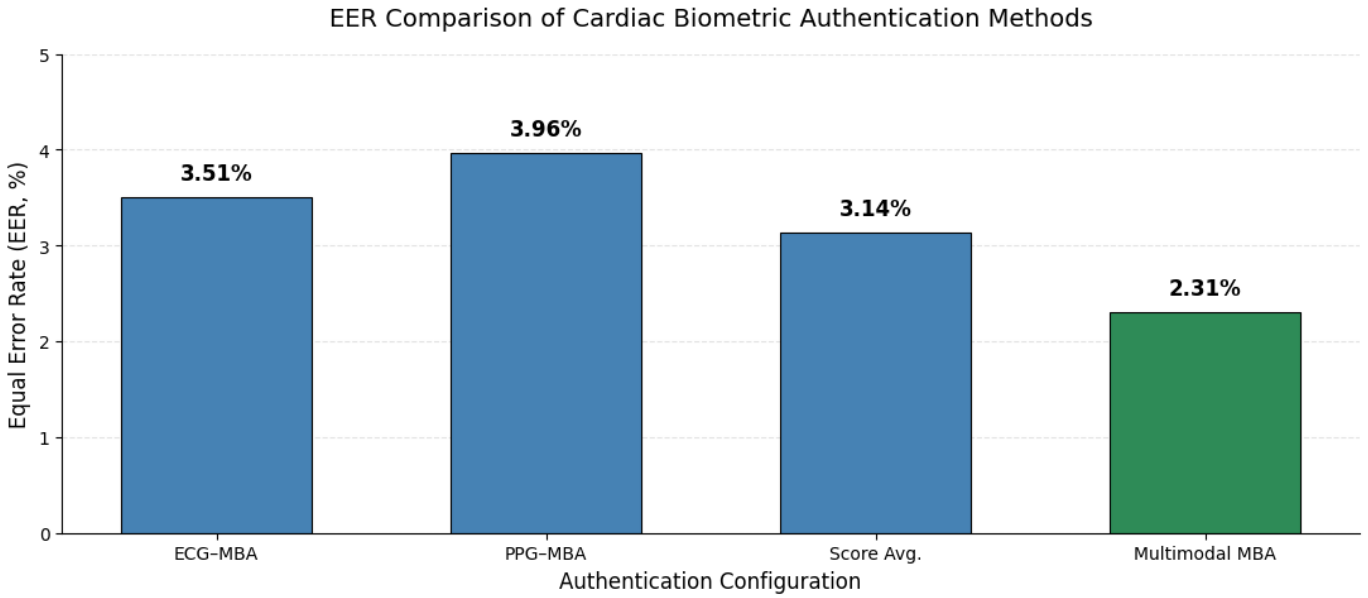


Fig.7. EER Comparison of Cardiac Biometric Authentication Methods

Results from Table 3 of the article

Configuration	EER (%)	Accuracy (%)
ECG-only MBA	3.51	96.49
PPG-only MBA	3.96	96.04
Multimodal score averaging	3.14	96.86
Proposed Multimodal MBA	2.31	98.14

IMPACT OF BEAT AGGREGATION WINDOW SIZE

- A seven-beat window provides the best practical trade-off, achieving 2.31% EER with 1.84 s authentication latency.

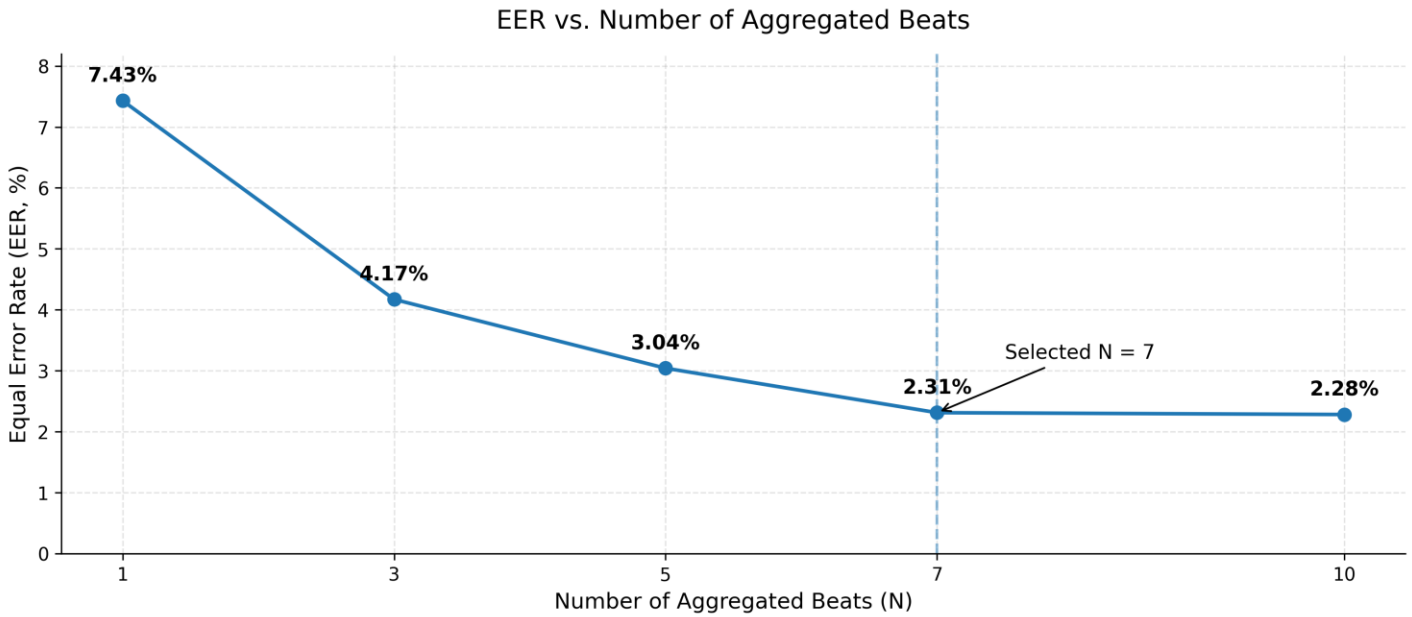


Fig.8. Effect of Beat Aggregation Window Size on Authentication EER

Results from Table 4 of article

N	EER (%)	Accuracy (%)	Latency (s)
1	7.43	92.57	0.26
3	4.17	95.83	0.78
5	3.04	96.96	1.28
7	2.31	98.14	1.84
10	2.28	98.19	2.61

ROC CURVE

- Multimodal MBA achieves the highest ROC-AUC of 0.9931, demonstrating improved discrimination between genuine users and impostors.

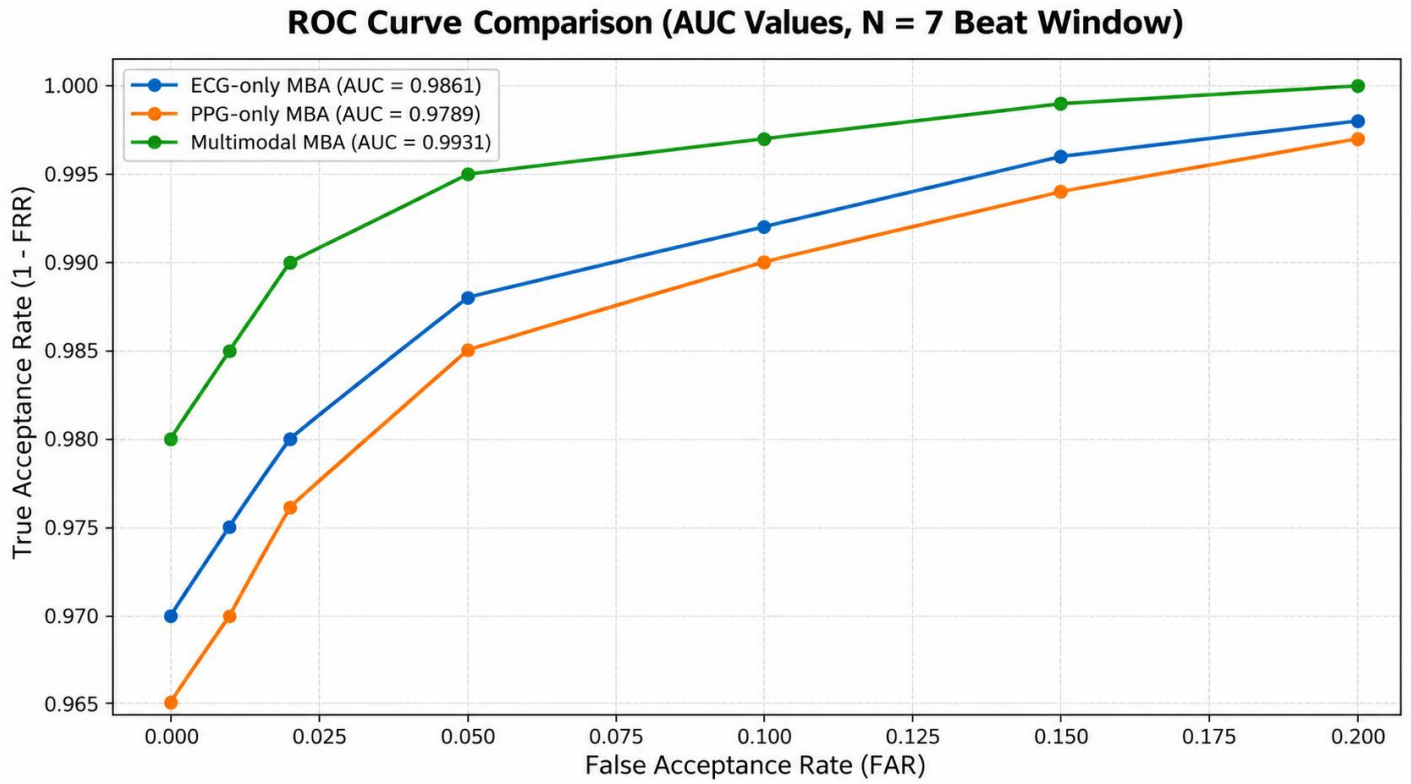


Fig.9. ROC Curve Comparison of ECG-only, PPG-only, and Multimodal MBA

ROC-AUC Results from Fig. 2

Method	ROC-AUC
ECG-only MBA	0.9861
PPG-only MBA	0.9789
Multimodal MBA	0.9931

COMPARISON WITH EXISTING METHODS

- The proposed ECG–PPG MBA framework achieves a competitive EER of 2.31%, demonstrating promising authentication performance with moderate computational requirements.

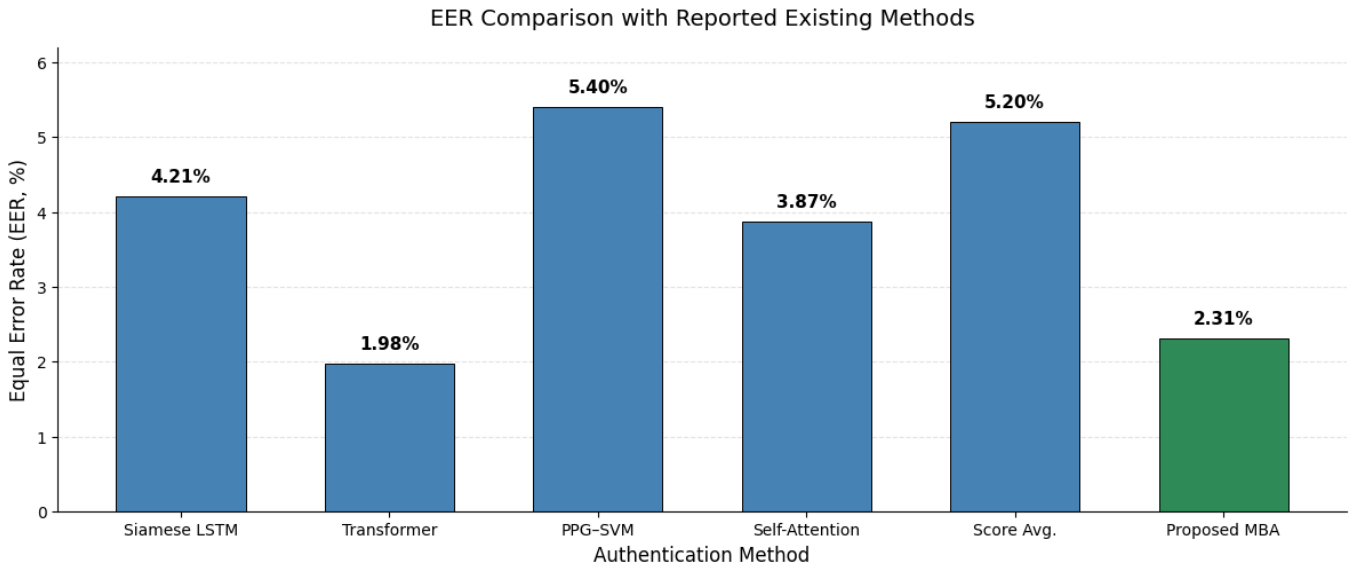


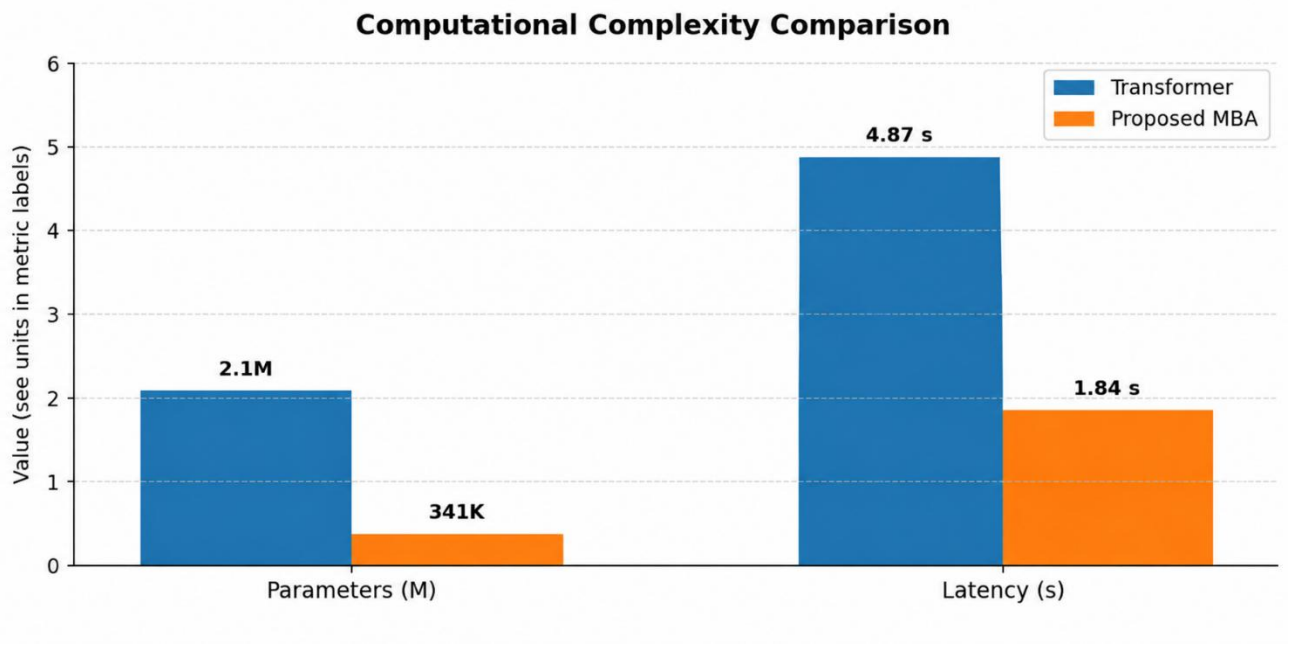
Fig.10. EER Comparison with Existing Cardiac Biometric Authentication Methods

Results from Table 5 of article

Method	Modality	EER (%)
Siamese LSTM	ECG	4.21
Transformer	ECG	1.98
SVM	PPG	5.40
Self-Attention	ECG	3.87
Score Averaging	ECG + PPG	5.20
Proposed MBA	ECG + PPG	2.31

COMPUTATIONAL EFFICIENCY

- The proposed Multimodal MBA framework achieves competitive authentication performance with moderate model and memory requirements.



Results from Table 6 of article

Metric	Transformer	Proposed
Parameters	2.1 million	341 thousand
Latency	4.87 s	1.84 s

Fig.11. Computational complexity comparison between the Transformer baseline and the proposed MBA

CONCLUSION & FUTURE WORK

Conclusions

- Successfully combined ECG and PPG signals to exploit complementary cardiac biometric information.
- Developed an MBA algorithm that prioritizes reliable heartbeats and reduces the influence of noisy signals.
- Achieved 98.14% authentication accuracy and 2.31% EER using a seven-beat aggregation window

Future Work

- Extend the framework to continuous, real-time identity verification.
- Evaluate performance across different wearable sensors and sessions.
- Investigate privacy-preserving model training across distributed devices.

THANK YOU
FOR YOUR ATTENTION !

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