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ITMO

ECGAuthNet: A Segment-Adaptive CNN Architecture for Variable-Length ECG Biometric Authentication

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MOTIVATION

- Convenient alternative to traditional passwords.
- Derived from cardiac electrical activity.
- Unique morphological and temporal patterns.
- Suitable for wearable and healthcare applications.

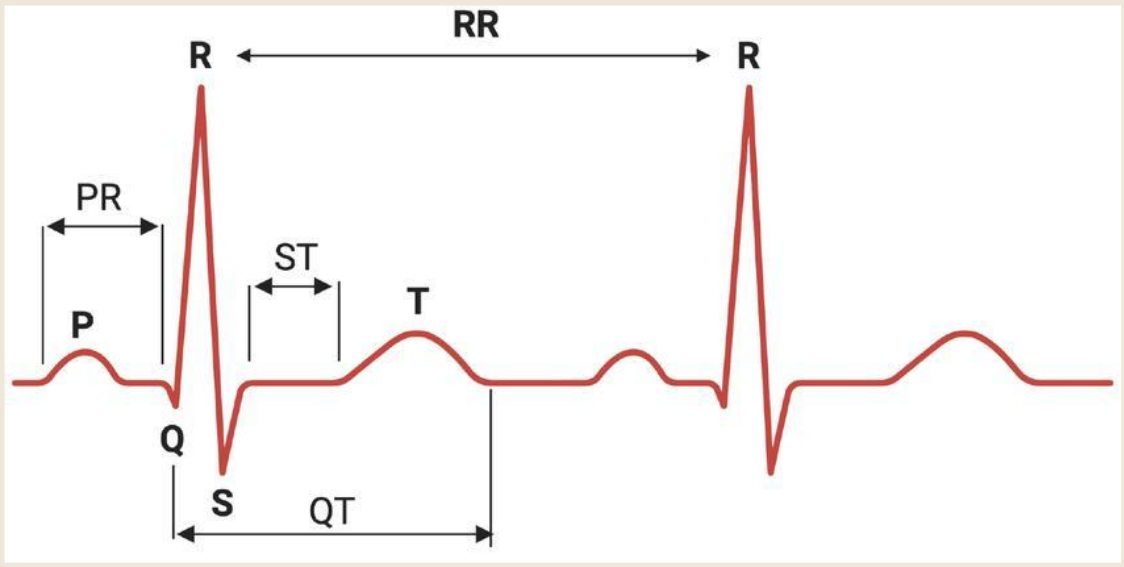


Fig.1. ECG waveform with the P, Q, R, S, and T components

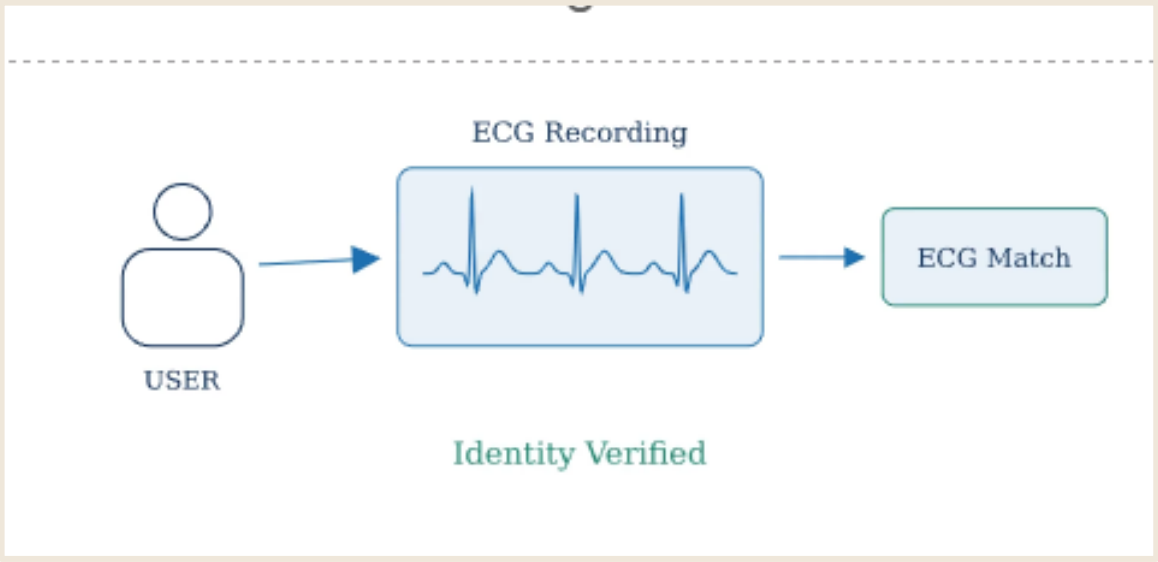


Fig.2. Person authenticated based on ECG

RESEARCH PROBLEM

- Cardiac cycles differ in duration across individuals and over time.
- Conventional CNN pipelines often require standardized ECG segments.
- Cropping, padding, and resampling may remove information or modify temporal characteristics.

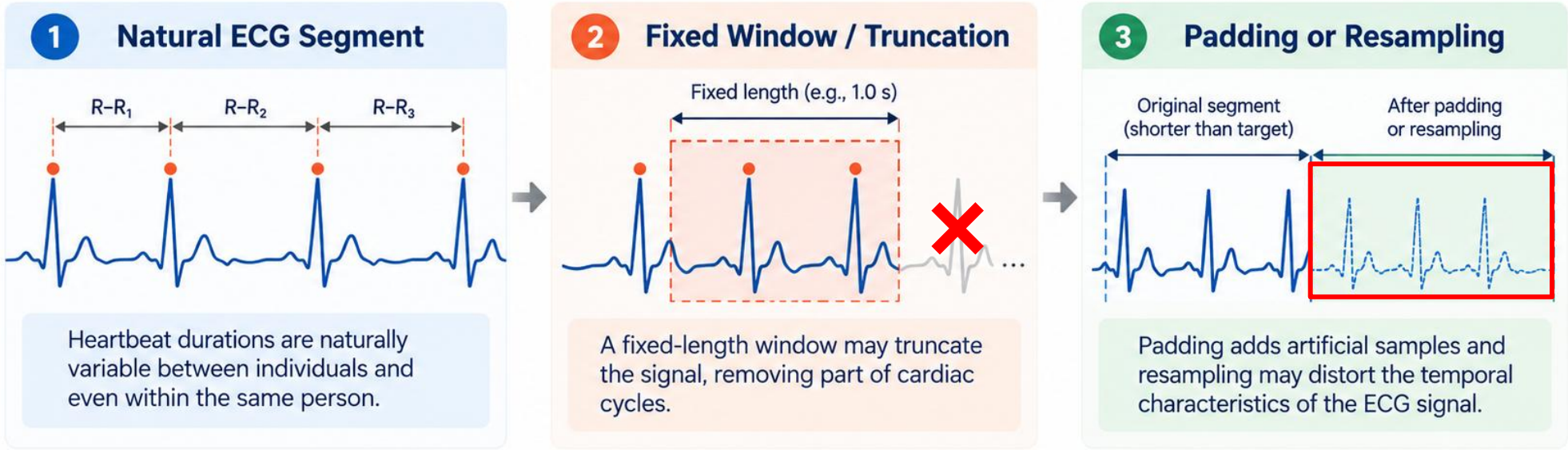


Fig.3. Limitations of conventional fixed-length ECG preprocessing

RESEARCH GOAL

Goal

- Develop an ECG biometric identification framework that processes variable-length cardiac segments without fixed-duration normalization.

Objectives

- Preserve naturally varying heartbeat durations.
- Combine CNN-based learning with adaptive SMP.
- Assess identification accuracy and verification performance.
- Evaluate fixed-length baselines and robustness across two ECG datasets.

PROPOSED METHODOLOGY

- The proposed system combines ECG preprocessing, adaptive R-peak segmentation, CNN feature extraction, and Segment-based Adaptive Max Pooling (SMP) for variable-length ECG biometric identification.

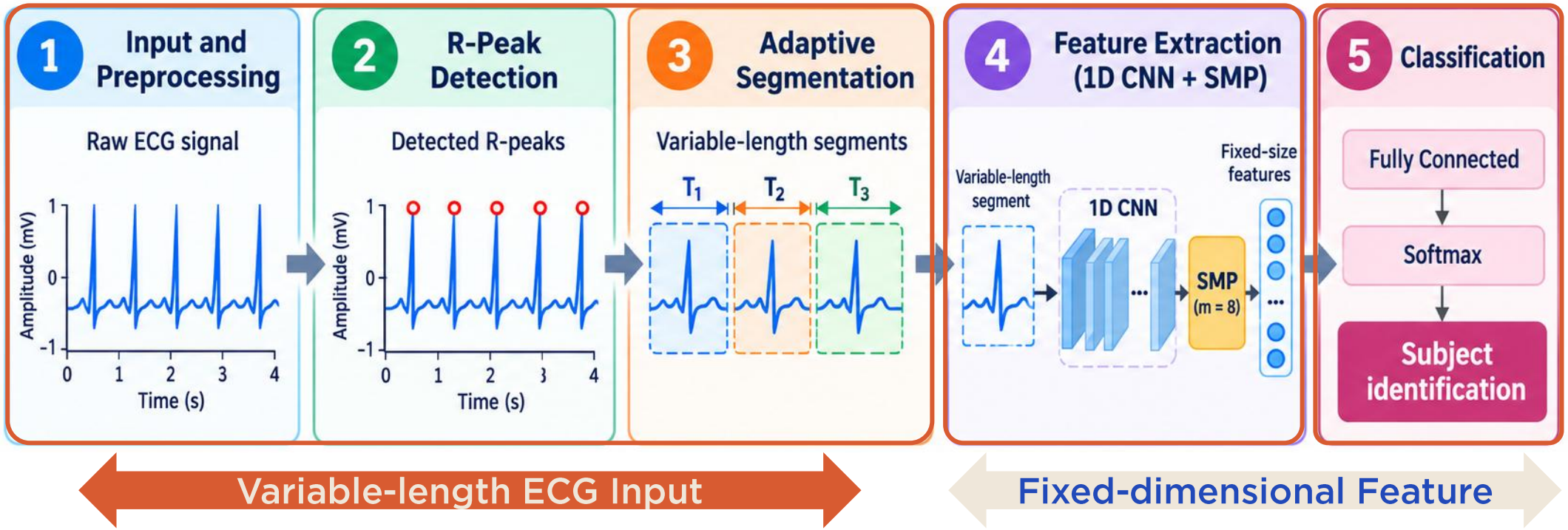


Fig.4. Overall processing workflow of the ECGAuthNet-based biometric

ADAPTIVE ECG SEGMENTATION

- Adaptive ECG segmentation uses neighboring R-peaks to determine heartbeat boundaries, producing naturally variable-length ECG segments.

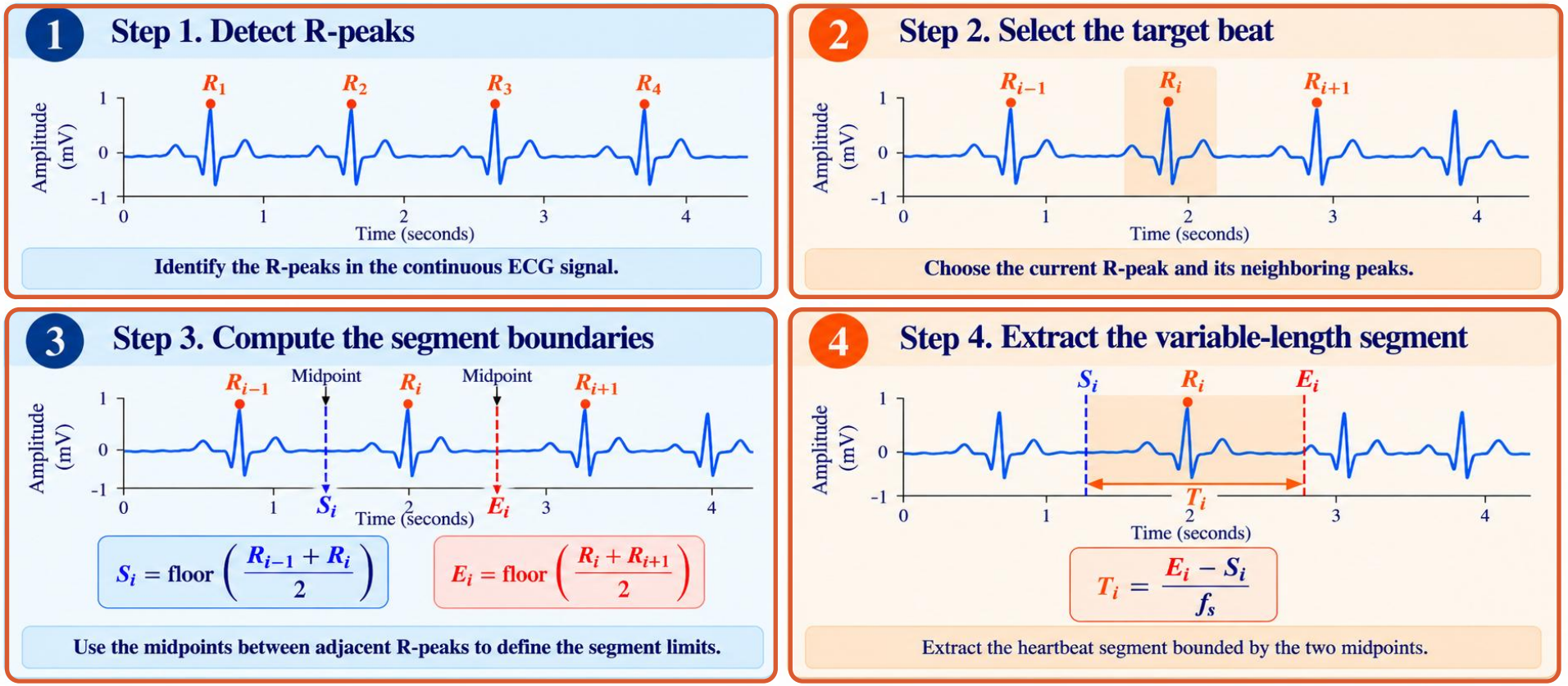


Fig.5. Adaptive ECG segmentation

PROPOSED CNN + SMP ARCHITECTURE

- ECGAuthNet uses 1D CNN and adaptive SMP to convert variable-length ECG signals into fixed-size features for identification.

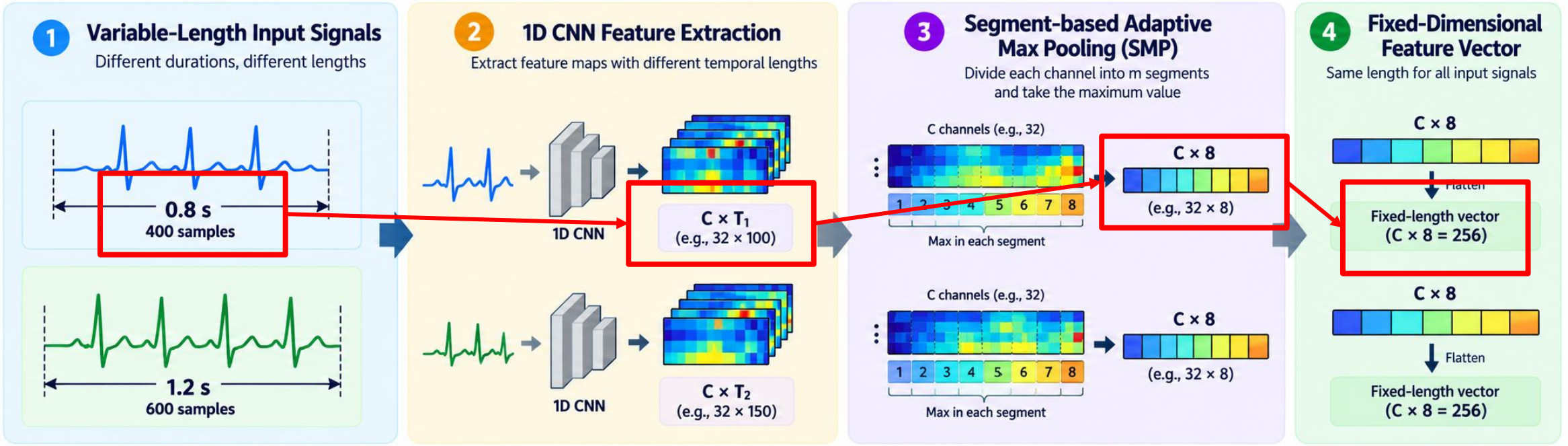


Fig.6. ECGAuthNet Working Principle

DATASETS

ECG Databases

- Two publicly available ECG datasets, ECG-ID and MIT-BIH, were used for experimental evaluation.

	ECG-ID	MIT-BIH
Subjects	90	47
Recordings	310	48
Sampling frequency	500 Hz	360 Hz
Average segment duration	1.21 s	1.42 s

- The datasets provide different sampling frequencies and physiological characteristics for evaluating ECGAuthNet.

[1] https://physionet.org/

EXPERIMENTAL SETUP

- ECGAuthNet was trained independently on both datasets using a 70/15/15 data split and evaluated for identification accuracy and biometric verification.

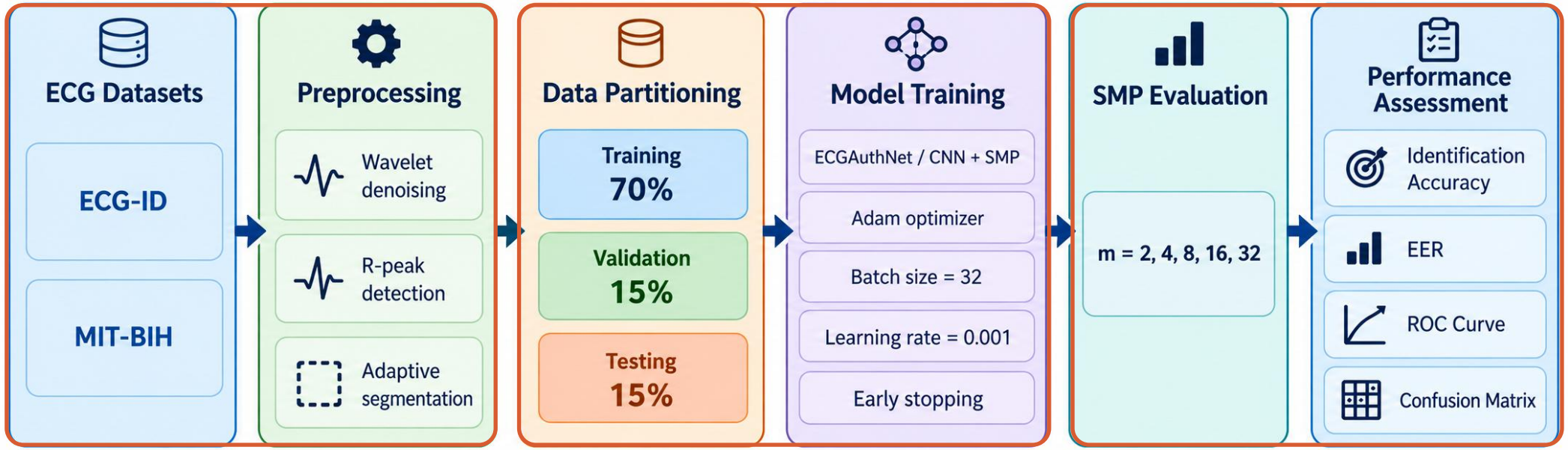


Fig.7. Experimental setup

SMP ABLATION STUDY

- Among five evaluated SMP configurations, m=8 achieved the highest identification accuracy on both ECG-ID (97.6%) and MIT-BIH (95.4%).

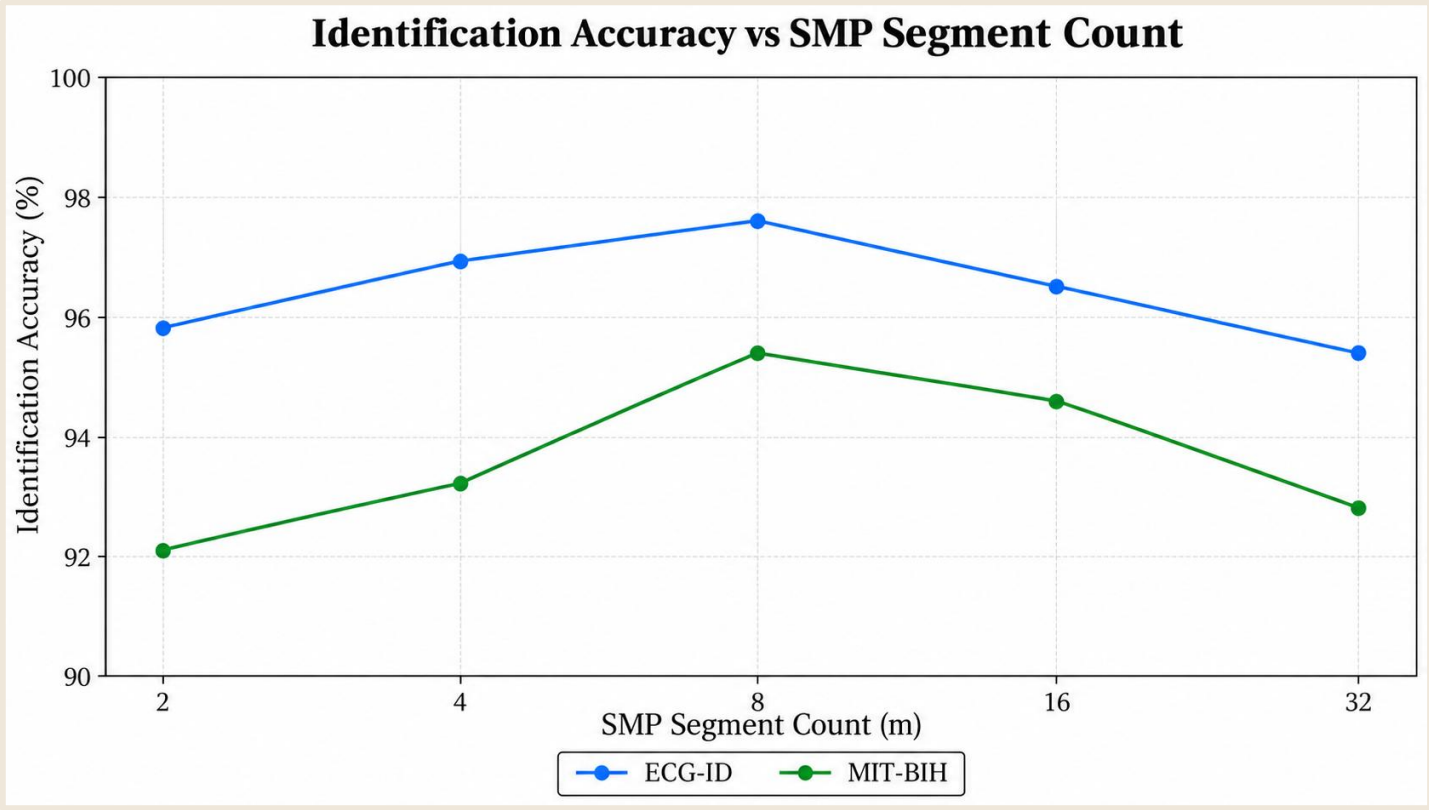


Fig.8. Effect of SMP segment count on identification accuracy

Results

SMP (m)	ECG-ID (%)	MIT-BIH (%)
2	95.8	92.1
4	96.9	93.2
8	97.6	95.4
16	96.5	94.6
32	95.4	92.8

IDENTIFICATION ACCURACY

- ECGAuthNet maintains high identification accuracy across different cardiac-cycle durations without requiring fixed-length input normalization.

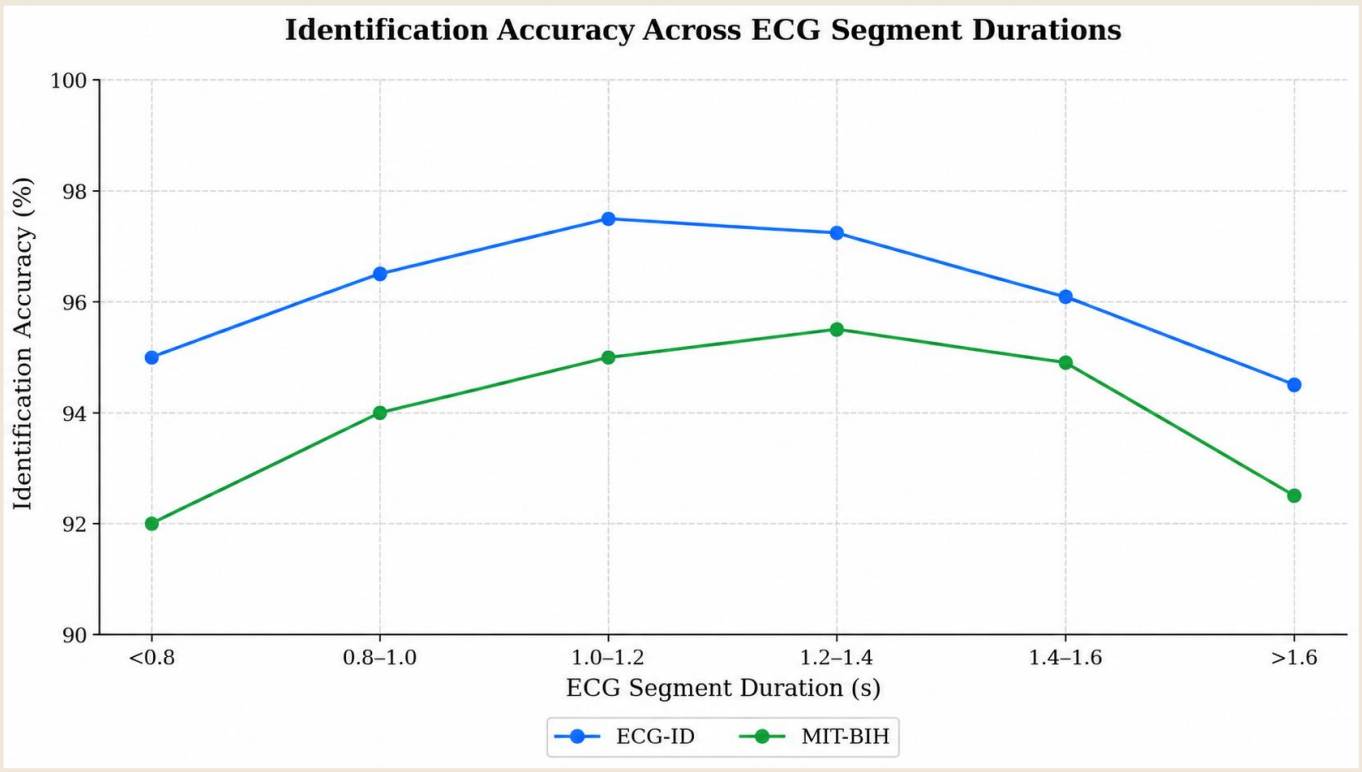


Fig.9. Identification Accuracy Across ECG Segment Durations

Accuracy by Segment Duration

Duration	ECG-ID (%)	MIT-BIH (%)
Below 0.8 s	95.0	92.0
0.8–1.0 s	96.5	94.0
1.0–1.2 s	97.6	95.0
1.2–1.4 s	97.3	95.4
1.4–1.6 s	96.1	94.9
Above 1.6 s	94.5	92.5

IDENTIFICATION ACCURACY

- ECGAuthNet improves identification accuracy on both datasets while using the natural average segment duration.

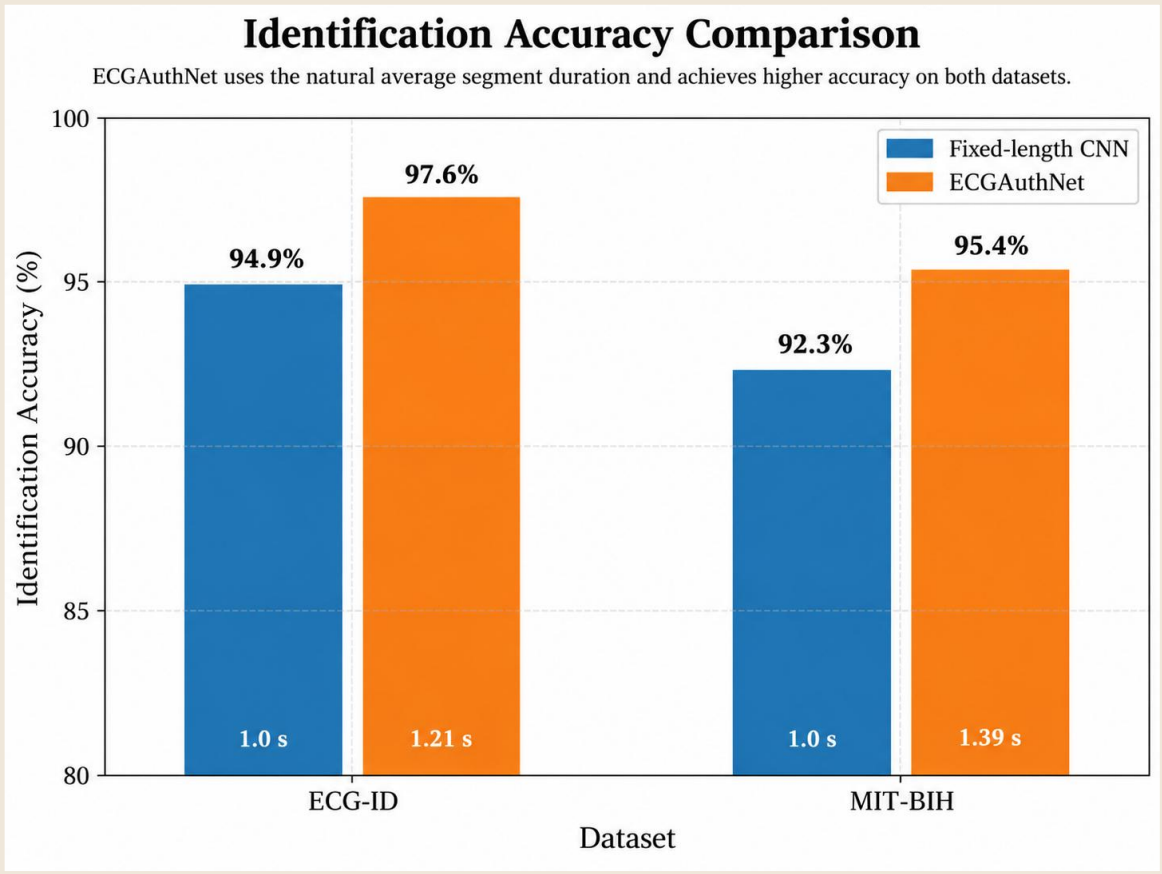


Fig.10. Identification Accuracy Comparison

Identification Accuracy Comparison

Method	Dataset	Duration	Accuracy (%)
Fixed-length CNN	ECG-ID	1.0 s	94.9
ECGAuthNet	ECG-ID	1.21 s	97.6
Fixed-length CNN	MIT-BIH	1.0 s	92.3
ECGAuthNet	MIT-BIH	1.39 s	95.4

NOISE ROBUSTNESS EVALUATION

- ECGAuthNet maintains high identification accuracy under moderate signal noise, although performance decreases as noise intensity increases.

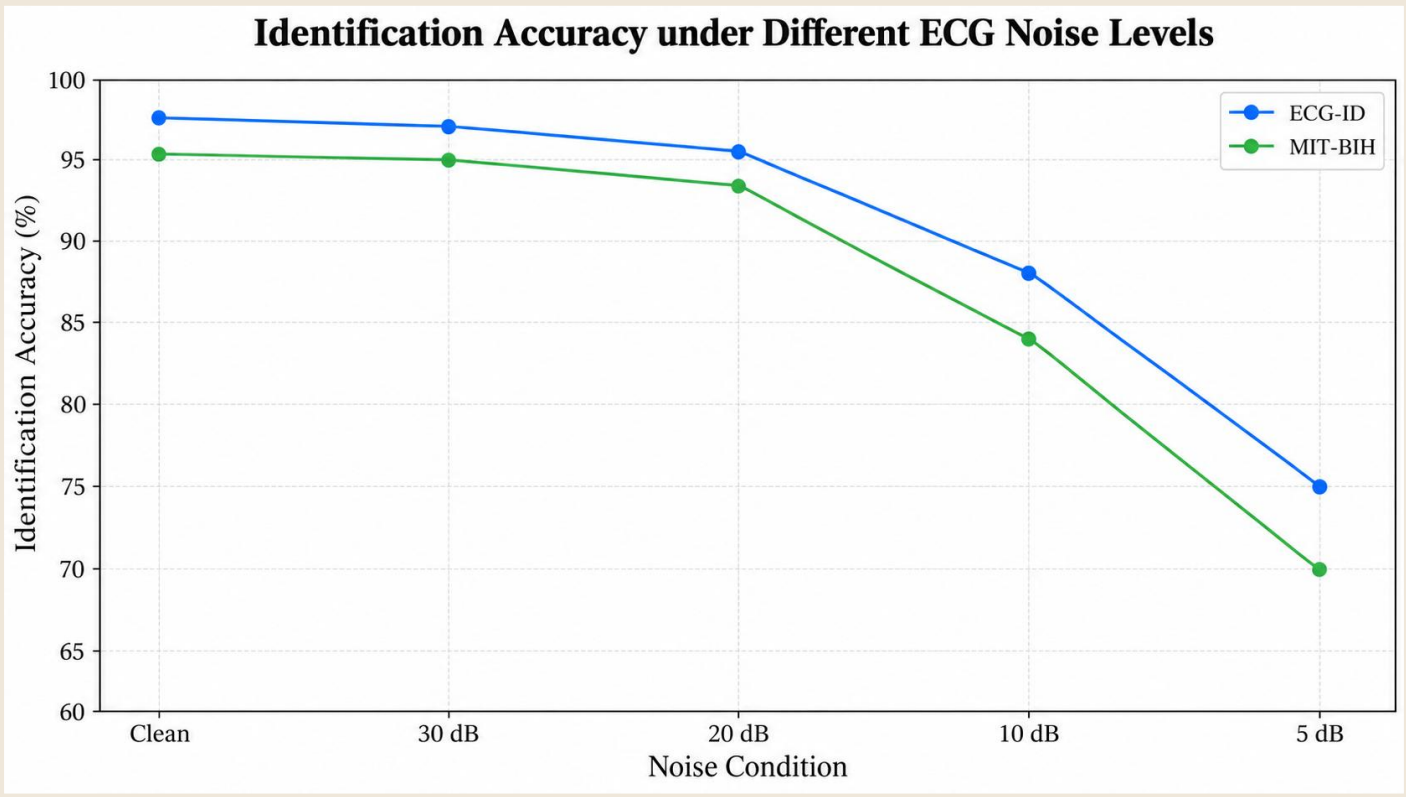


Fig.11. Noise Robustness Evaluation

Noise Robustness Evaluation

Noise	ECG-ID (%)	MIT-BIH (%)
Clean ECG	97.6	95.4
30 dB SNR	97.1	95.0
20 dB SNR	95.5	93.5
10 dB SNR	88.0	84.0
5 dB SNR	75.0	70.0

EER AND ROC ANALYSIS

- ECGAuthNet achieved low Equal Error Rates (EERs) on both datasets using class-specific Softmax scores for enrolled-subject verification.

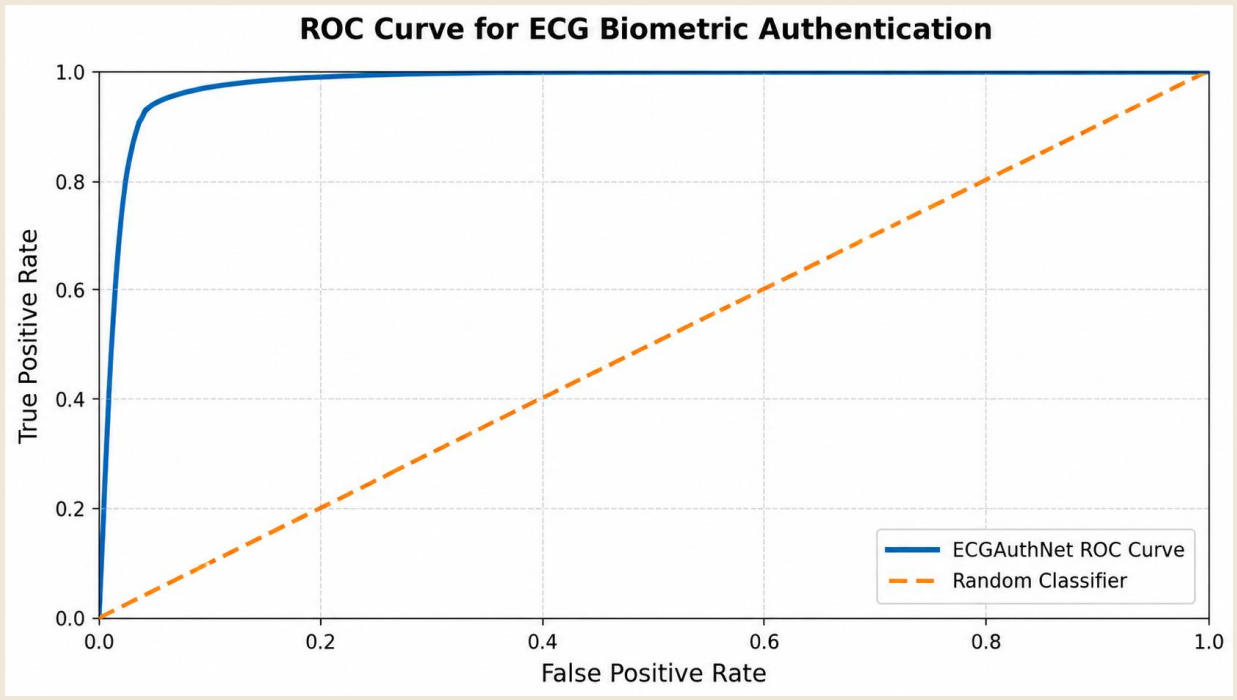


Fig.12. ROC curve of ECGAuthNet on ECG-ID

Results

	Accuracy (%)	EER (%)
Ibtehaz et al.	88.30%	2.29
Behrouzi et al.	92.10%	1.94
Hazratifard et al.	93.60%	1.88
Proposed (MIT-BIH)	95.40%	1.90
Proposed (ECG-ID)	97.60%	1.72

CONCLUSION & FUTURE WORK

Conclusions

- Developed a CNN–SMP framework for variable-length ECG biometric.
- Achieved 97.6% accuracy on ECG-ID and 95.4% on MIT-BIH.
- Identified m = 8 as the best-performing SMP configuration on both datasets.
- Demonstrated effective variable-length processing and tolerance to moderate noise.

Future Work

- Cross-session and cross-dataset generalization.
- Robustness to irregular cardiac rhythms.
- Computational optimization for wearable devices.

THANK YOU
FOR YOUR ATTENTION !

SAINT PETERSBURG, 2026

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