AcousAF: Acoustic Sensing-Based Atrial Fibrillation Detection System for Mobile Phones

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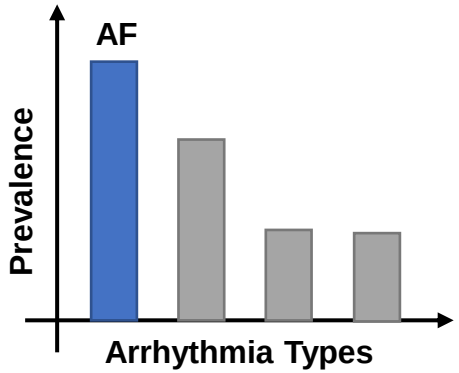
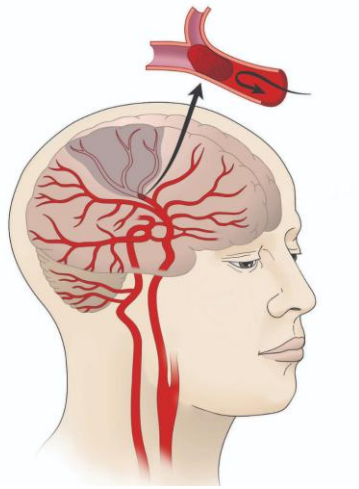
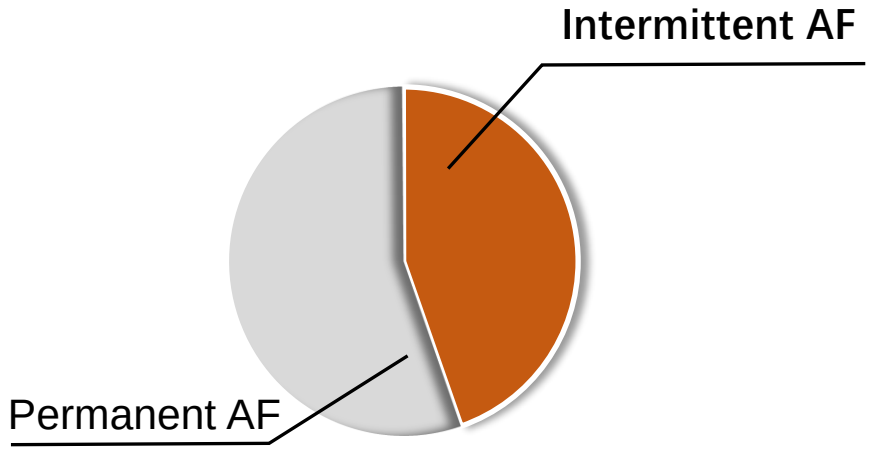
Background of Atrial Fibrillation

Atrial Fibrillation (AF) is:







- The most prevalent arrhythmia[1]
- Highly associated with ischemic stroke[2]
- Intermittent AF accounts for about 40%

[1] Lippi G, et al. Global epidemiology of atrial fibrillation: An increasing epidemic and public health challenge. International Journal of Stroke. 2021;16(2):217-221.
[2] Marini, C., et al. (2005). Contribution of atrial fibrillation to incidence and outcome of ischemic stroke: results from a population-based study. *Stroke*, *36*(6), 1115-1119.

Existing Examination Methods

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Clinical Examination

Routine ECG

✘ Hardly work for Intermittent AF

ECG Holter

✘ Uncomfortable

Personal Examination

Smartwatches

✘ Additional Sensor

Personal ECG Devices

✘ High Cost

AcousAF: Detecting AF with Mobile Phones

User feel uncomfortable

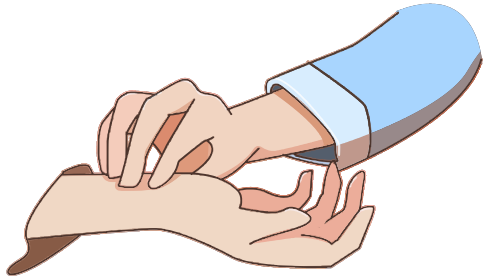
Self detection

Instant results

No need for additional sensors!

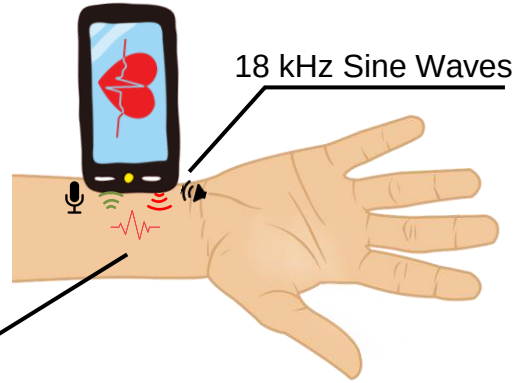
* Pictures designed by Freepik

Challenge 1: How to Probe Minute Pulse Wave?



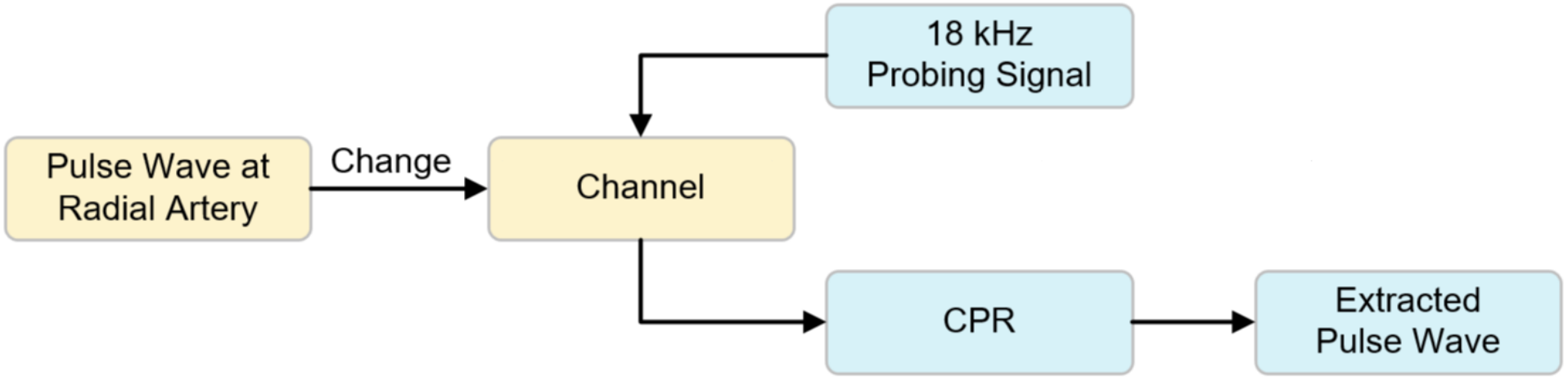
Pulse Wave at Radial Artery

Can we use smartphone to probe it?

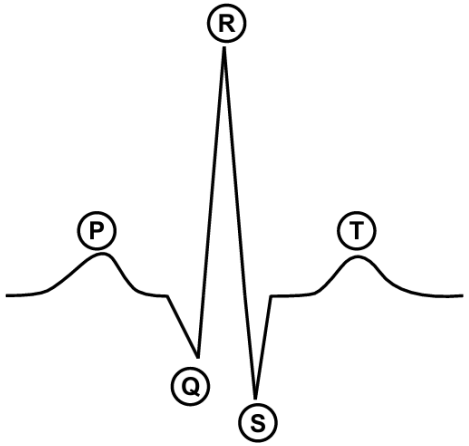


Yes!

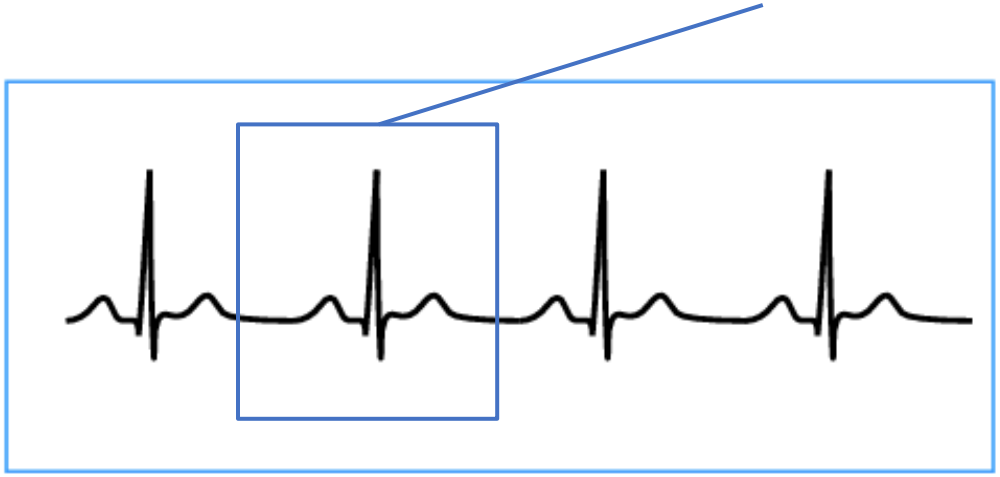
Channel Phase Response (CPR)-based Pulse Wave Extraction:



Challenge 2: How to Classify AF?



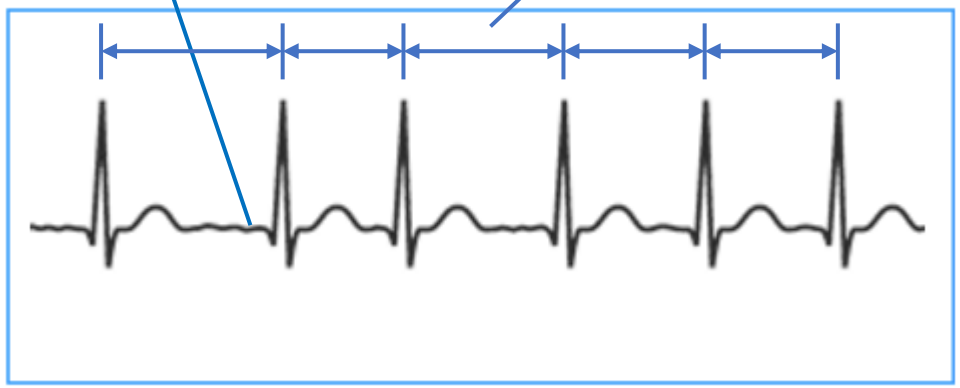
Standard ECG Waveform



ECG of Normal Sinus Rhythm

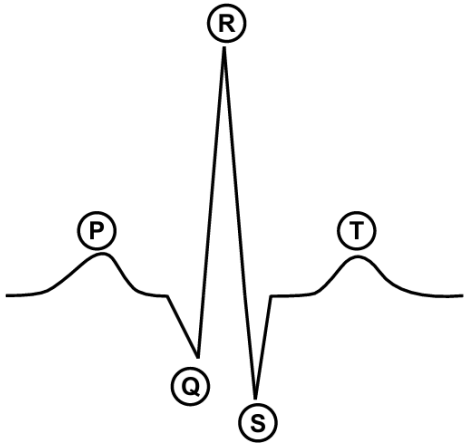
Feature 2: Irregular RR Intervals

Feature 1: Missing P Wave

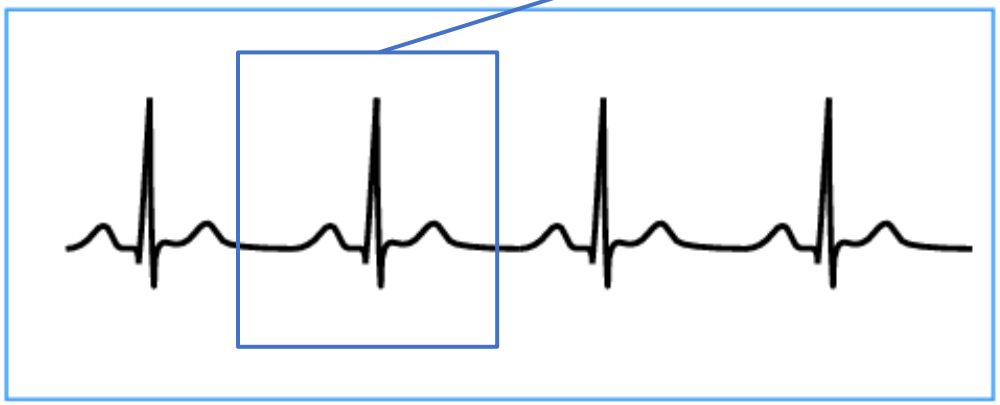


ECG of AF

Challenge 2: How to Classify AF?

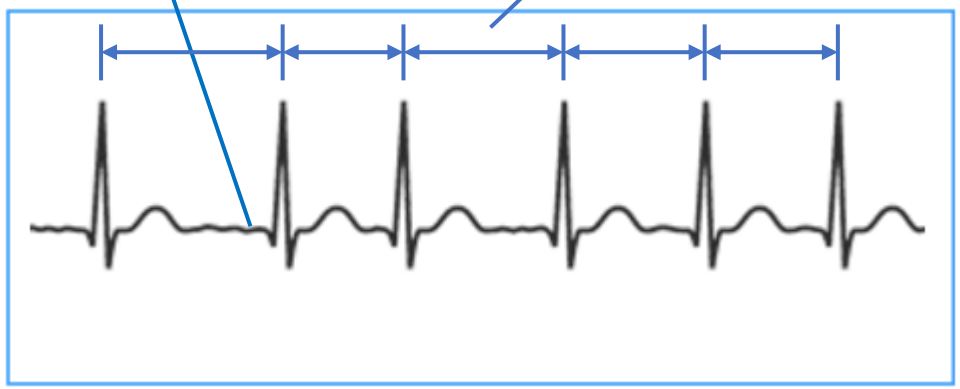


Standard ECG Waveform



Feature 2: Irregular RR Intervals

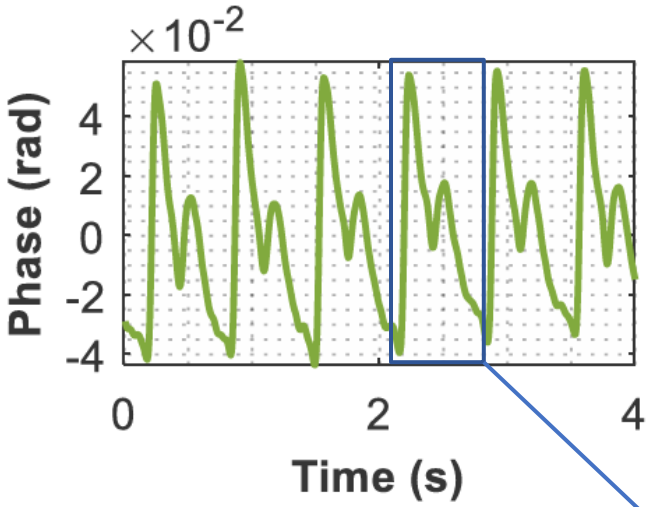
Feature 1: Missing P Wave



How about AcousAF?

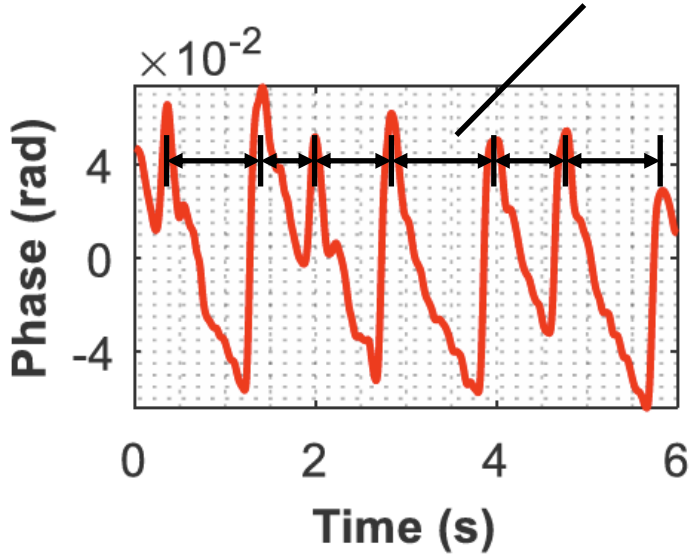
Challenge 2: How to Classify AF?

AcousAF Pulse Waves

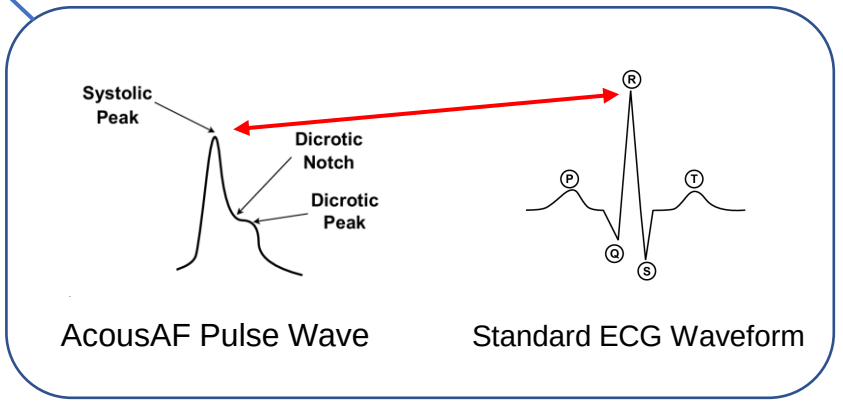


Normal Sinus Rhythm

Feature: Irregular RR Intervals



AF



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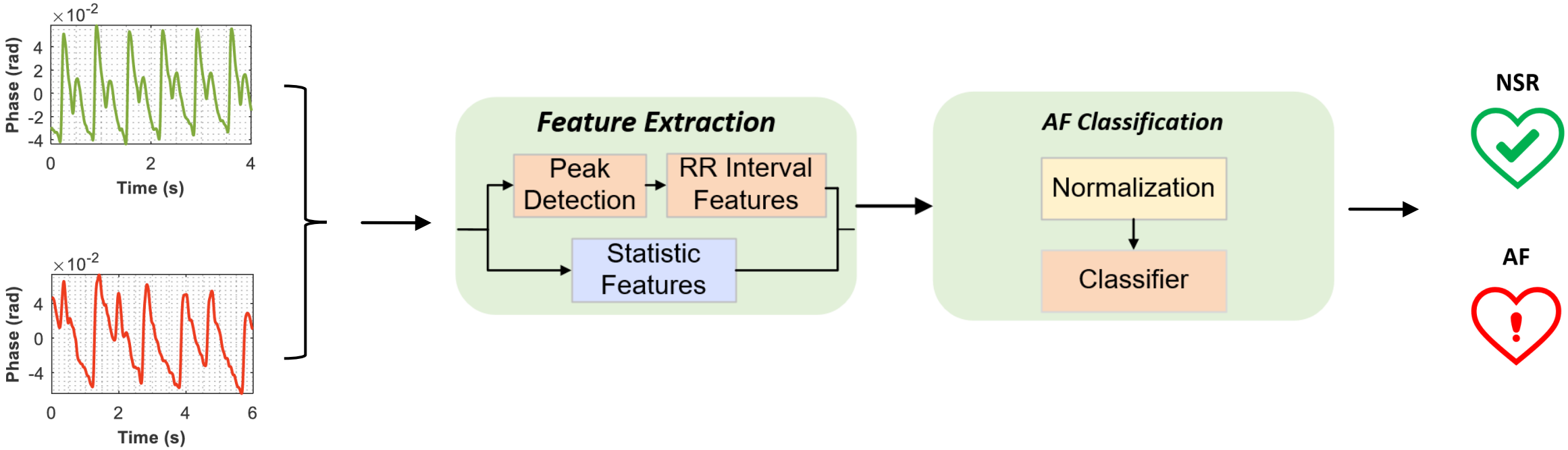
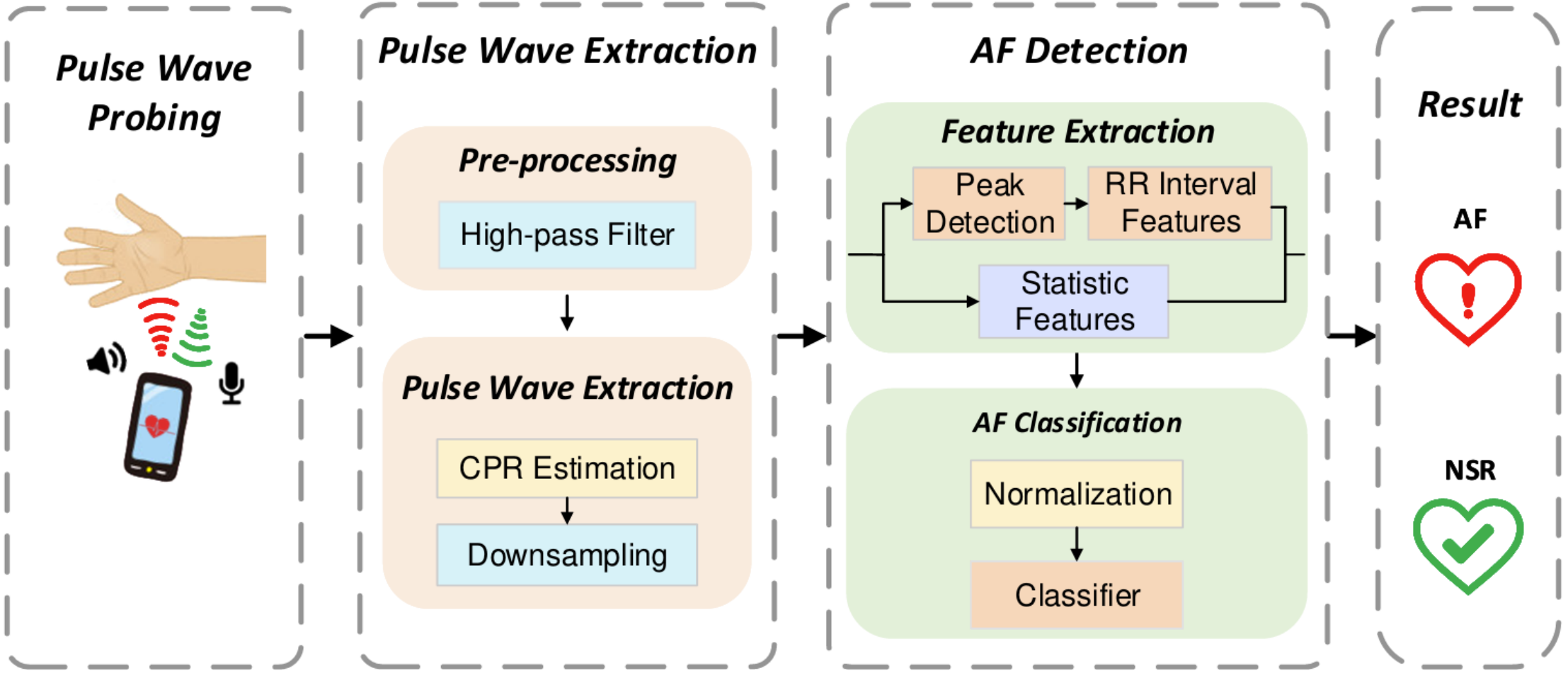


Step1: Calculate the numeric features

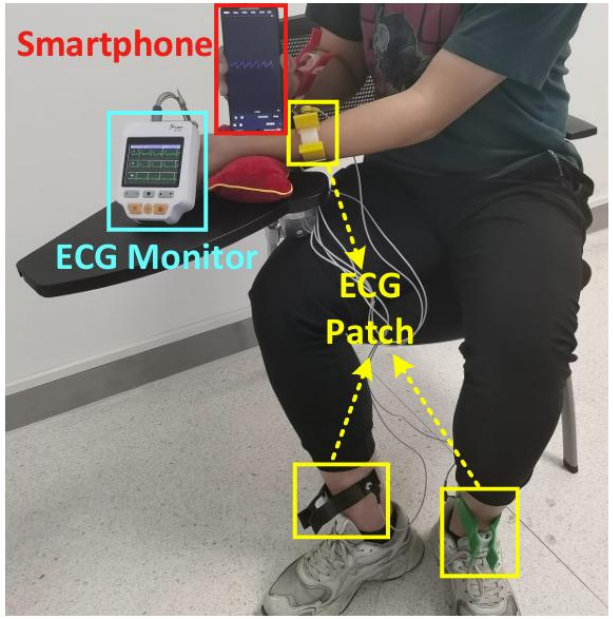
Step2: Feed features into machine learning-based classifier

AcousAF: Put All Together



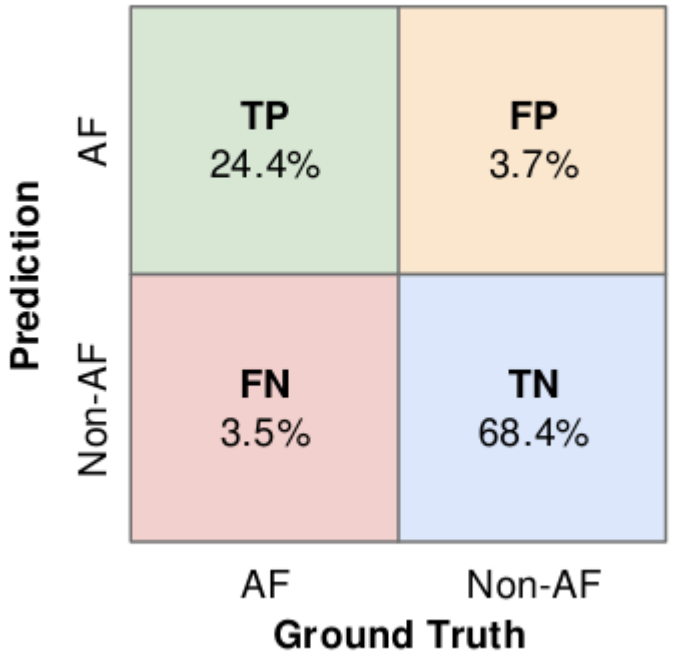
Evaluation Setup

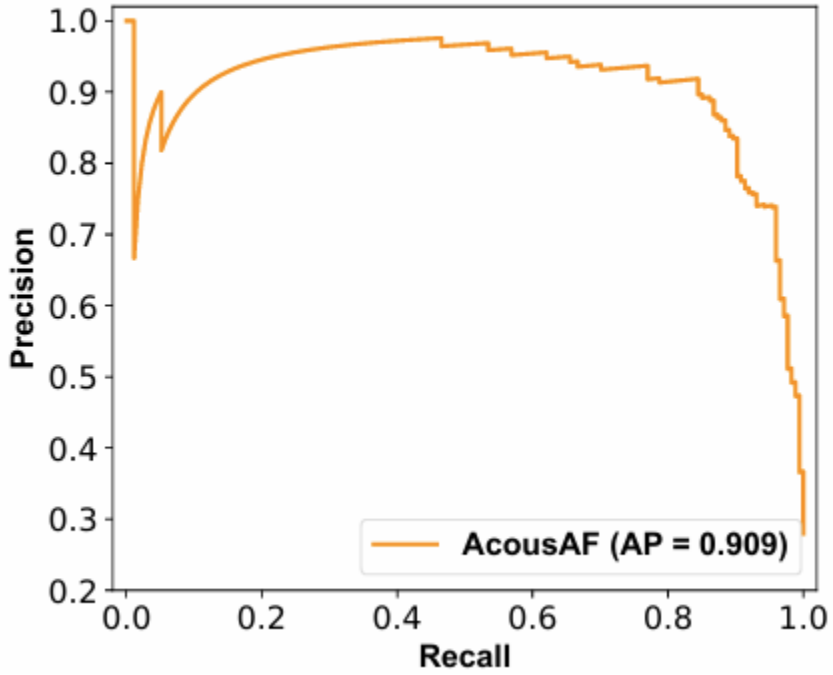
Subjects:	20 subjects aged from 20 to 89 years (including 6 AF patients)
Mobile Phone:	Redmi Note 13
Ground Truth:	Annotated ECG signal collected by LEPU 3-Lead ECG monitor
Duration:	30s per segment, 30 mins per subject
Method:	Leave-one-out cross validation



Overall Performance

Accuracy:	92.8%
Precision:	86.9%
Recall:	87.4%
F1 Score:	87.1%





AcousAF can accurately detect AF with relatively high recall and precision simultaneously.

Conclusion

- AcousAF: a novel system for detecting AF using commercial-off-the-shelf mobile phones.
  - No need for additional sensors
  - Providing instant and accurate test result

- Feature Work
  - Detection of multiple types of arrhythmias.
  - Pulse wave purification for better and more robust performance.
  - Eliminating privacy and security risks.

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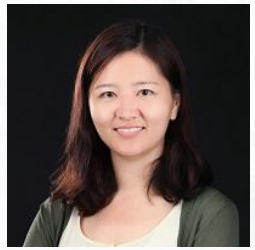
THANK YOU

Authors





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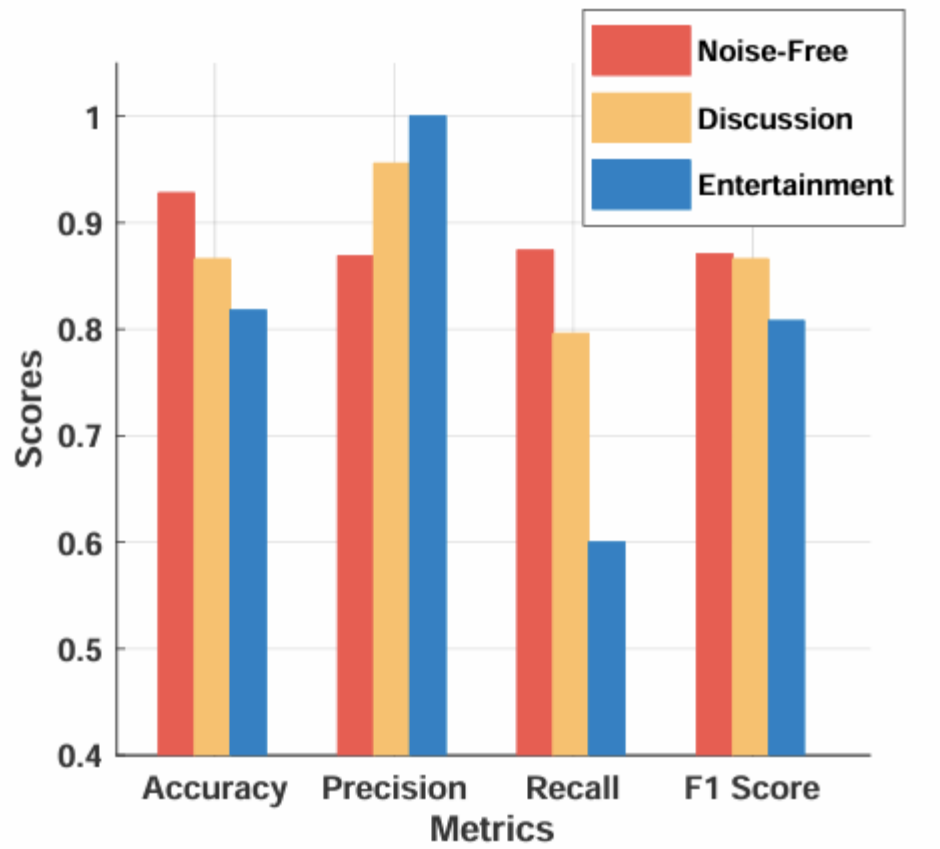
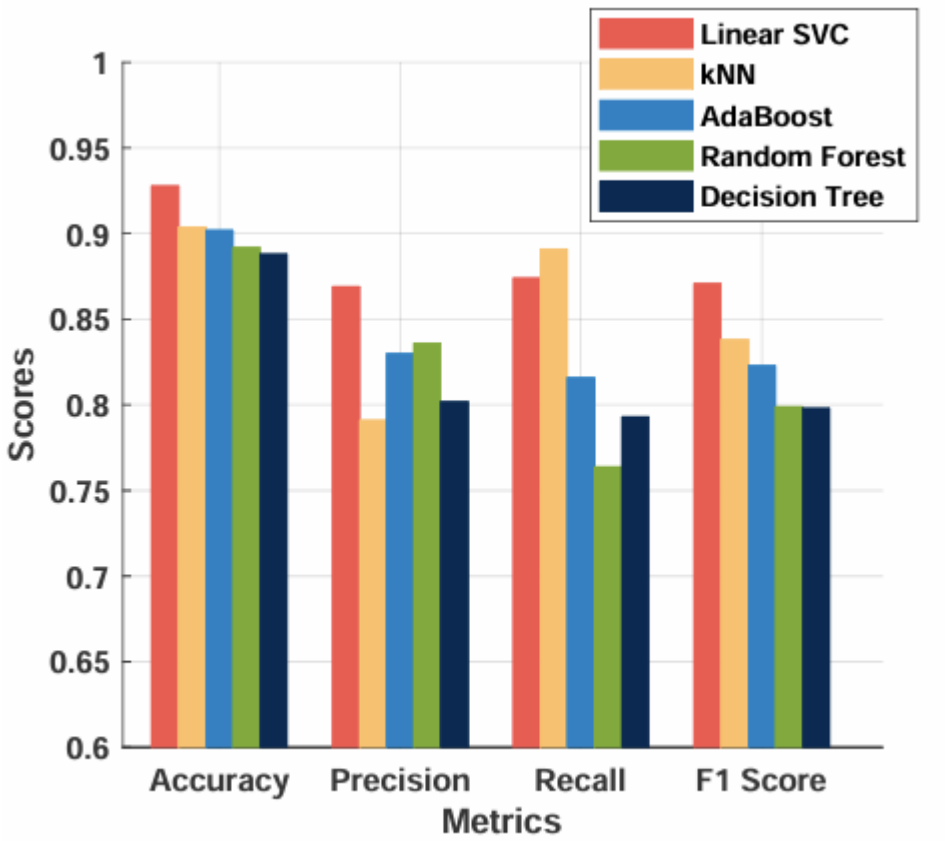
Performance Under Different Scenarios



Our system maintains relatively high performance in terms of accuracy and F1 score despite the background noise.

The system shows extremely high precision and very low recall in noisy scenarios, indicating that the model behaves cautiously under these conditions.

Performance Using Different Classifiers



Linear SVC generally outperforms the other four classifiers.

RR Interval Features

Feature	Description
minRR	Minimum value of all RR intervals.
meanRR	Mean value of all RR intervals.
medianRR	Median value of all RR intervals.
skRR	Skewness of all RR intervals.
SDRR	Standard deviation of the RR intervals.
CVRR	Standard deviation of the RR intervals divided by the mean of the RR intervals.
pNN50	Proportion of RR intervals greater than 50 ms, out of the total number of RR intervals.
RMSSD	Square root of the mean of the squared successive differences between adjacent RR intervals.
SDRMSSD	SDRR / RMSSD, a time-domain equivalent for the low frequency to high frequency ratio.
SDSD	Standard deviation of the successive differences between RR intervals.
CVSD	Root mean square of successive differences (RMSSD) divided by the mean of the RR intervals (meanHR).

[1] Guo, Y, et al. Photoplethysmography-Based Machine Learning Approaches for Atrial Fibrillation Prediction: A Report From the Huawei Heart Study. JACC: Asia. 2021 Dec, 1 (3) 399–408.
[2] Shan, S. M., et al. (2016, October). Reliable PPG-based algorithm in atrial fibrillation detection. In 2016 IEEE Biomedical Circuits and Systems Conference (BioCAS) (pp. 340-343). IEEE.

Statistic Features

Metric	Description
HF	Spectral power of high frequencies (15 Hz to 4 Hz).
HFn	Normalized high frequency, obtained by dividing the high frequency power by the total power.
LnHF	Log-transformed HF.
TP	Total spectral power.
SD1	Standard deviation perpendicular to the line of identity.
SD2	Standard deviation along the identity line. Index of long-term HRV changes.
SD1/SD2	Ratio of SD1 to SD2.
S	Area of ellipse described by SD1 and SD2.
Difference	Ratio of the sum of the differences between successive RR intervals to the sum of the differences between these differences.
Sample Entropy	Sample entropy of the input signal.
Shannon Entropy	Shannon entropy of the input signal.
Approximate Entropy	Approximate entropy of the input signal.
Multiscale Entropy	Multiscale entropy of the input signal.
Turning Point Ratio	Ratio of turning points (points greater or less than their two neighbors) to the total data length.

[1] Guo, Y, et al. Photoplethysmography-Based Machine Learning Approaches for Atrial Fibrillation Prediction: A Report From the Huawei Heart Study. JACC: Asia. 2021 Dec, 1 (3) 399–408.
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