

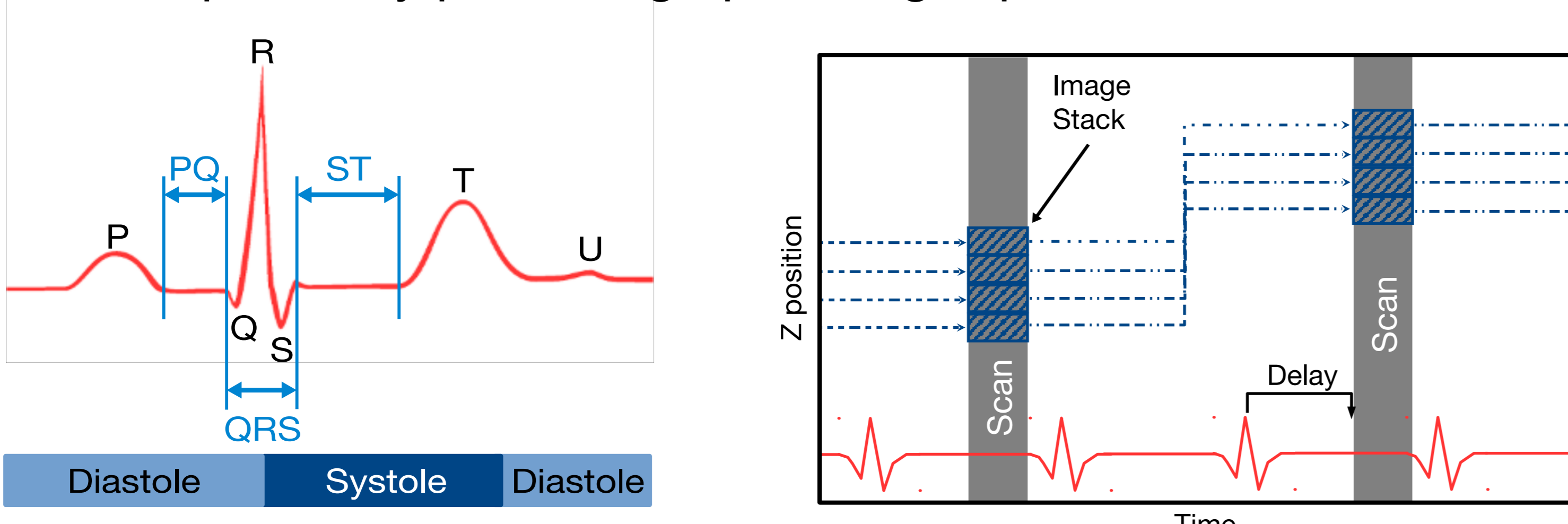


Automatic Detection of Non-Biological Artifacts in ECGs Acquired During Cardiac Computed Tomography

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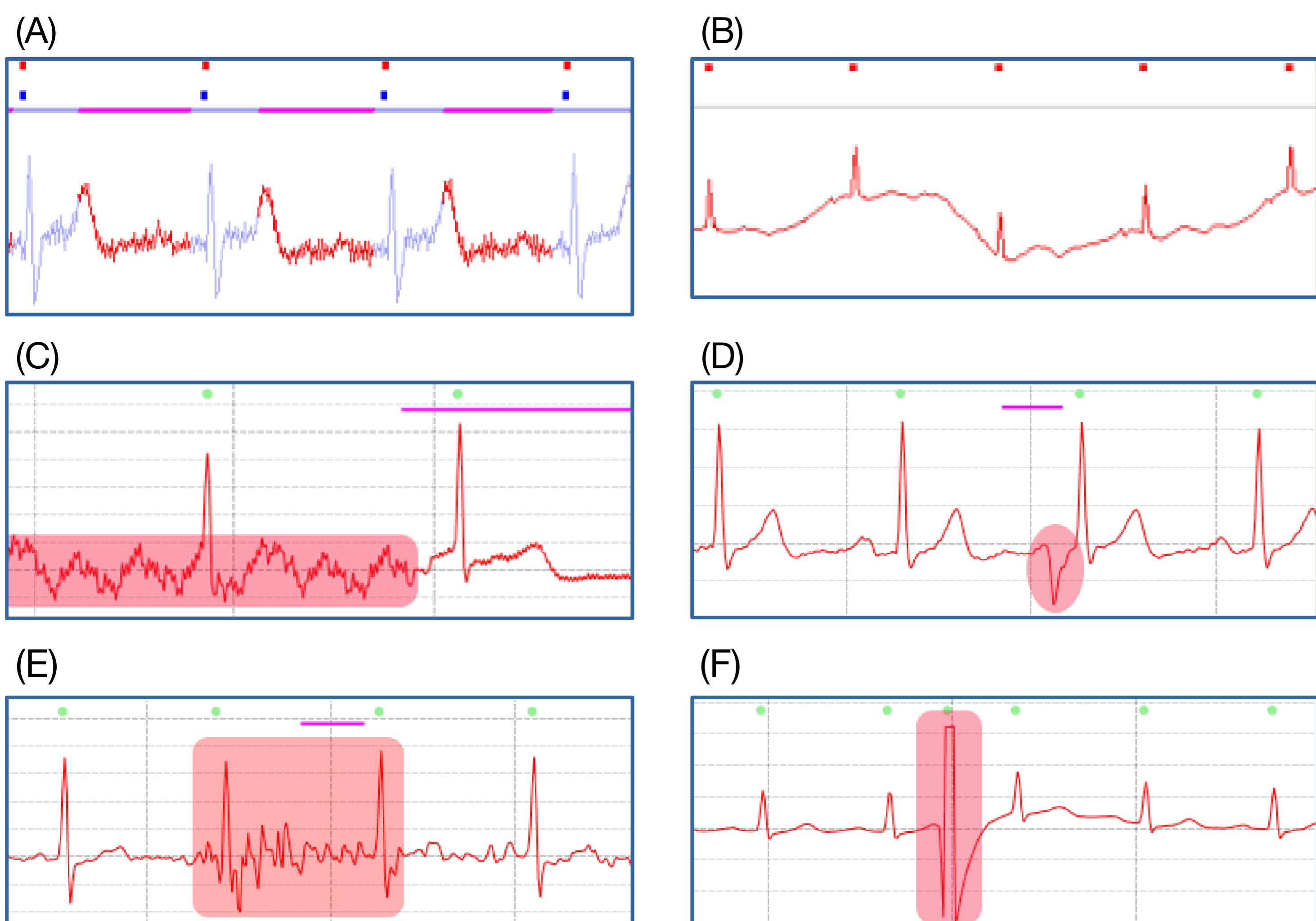
Overview

- **Cardiac computed tomography (CT)** is a non-invasive technique to image the beating heart, which is particularly challenging due to the constant motion of the heart.
 - **Prospective ECG gating** reduces the total radiation dose imposed on the patient by only imaging the heart in the target cardiac phase by predicting upcoming R peaks.¹
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- **Noise or non-biological artifacts in the ECG signal** may result in false positive R peaks, which in turn may desynchronize the whole workflow and result in a low quality image and the need for a repeat scan.
 - By proactively identifying CT scanners producing a high amount of anomalous ECG traces, we mitigate the aforementioned health care concerns and improve customer experience.

Artifacts In ECG

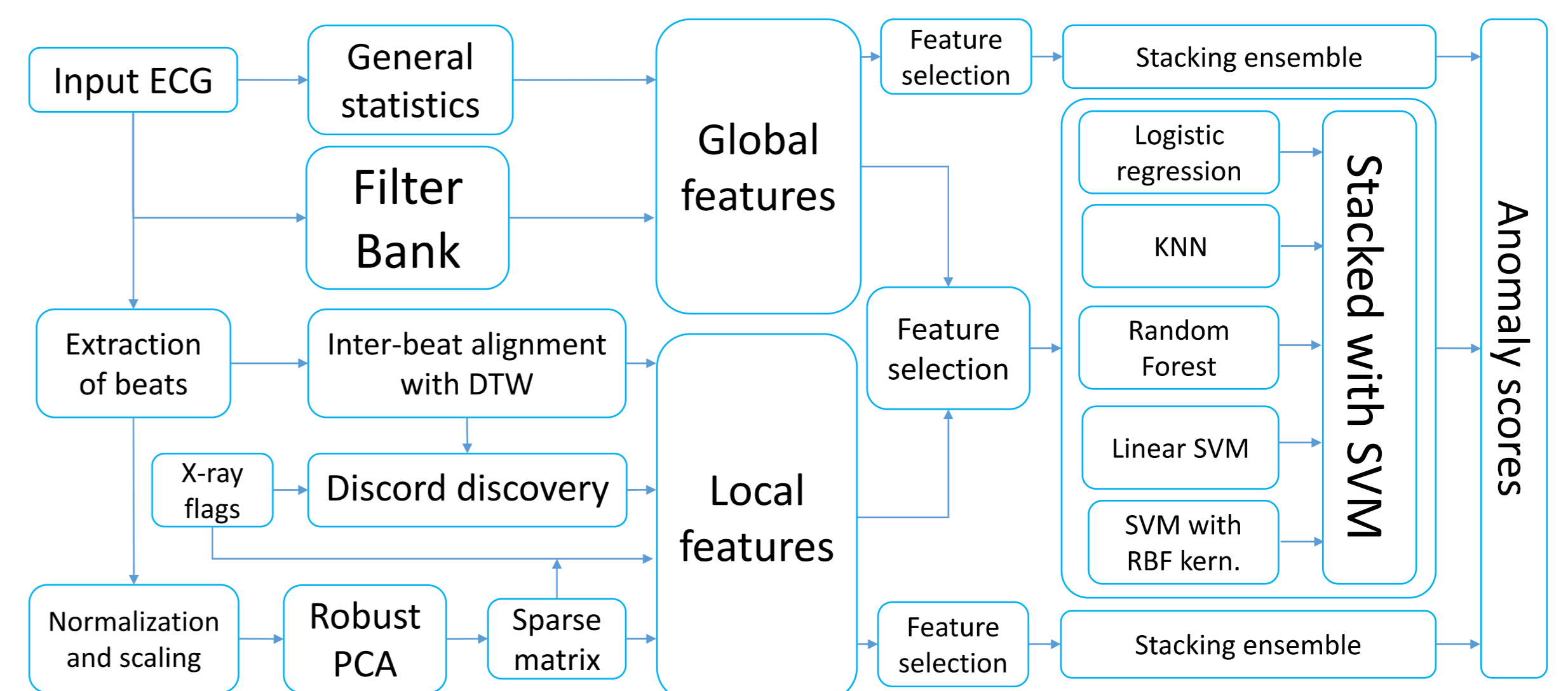
ECG signals are highly heterogeneous: different equipment used, institutions, standards among countries, and medical conditions.

- (A) **Powerline noise:** external power supply causes noise in the 50/60Hz frequency band.
- (B) **Baseline wandering:** respiratory motion, loos electrodes.
- (C) **Rotational noise:** gantry rotation causes electrostatic charges, which are discharged when X-ray is activated.
- (D) **X-ray artifact:** X-ray beam hits a metallic object (electrode, implant).
- (E) **Table motion:** high-frequency disturbances after the table starts moving due to patient movement or improper wiring of electrodes.
- (F) **Other artifacts:** various artifacts of unknown origin.

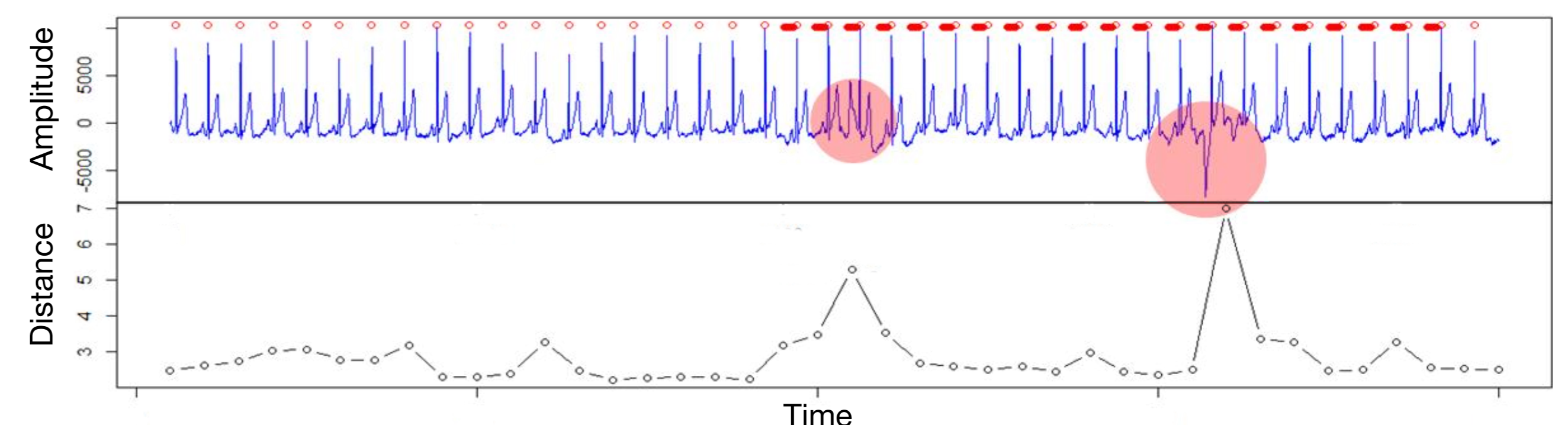


Proposed System

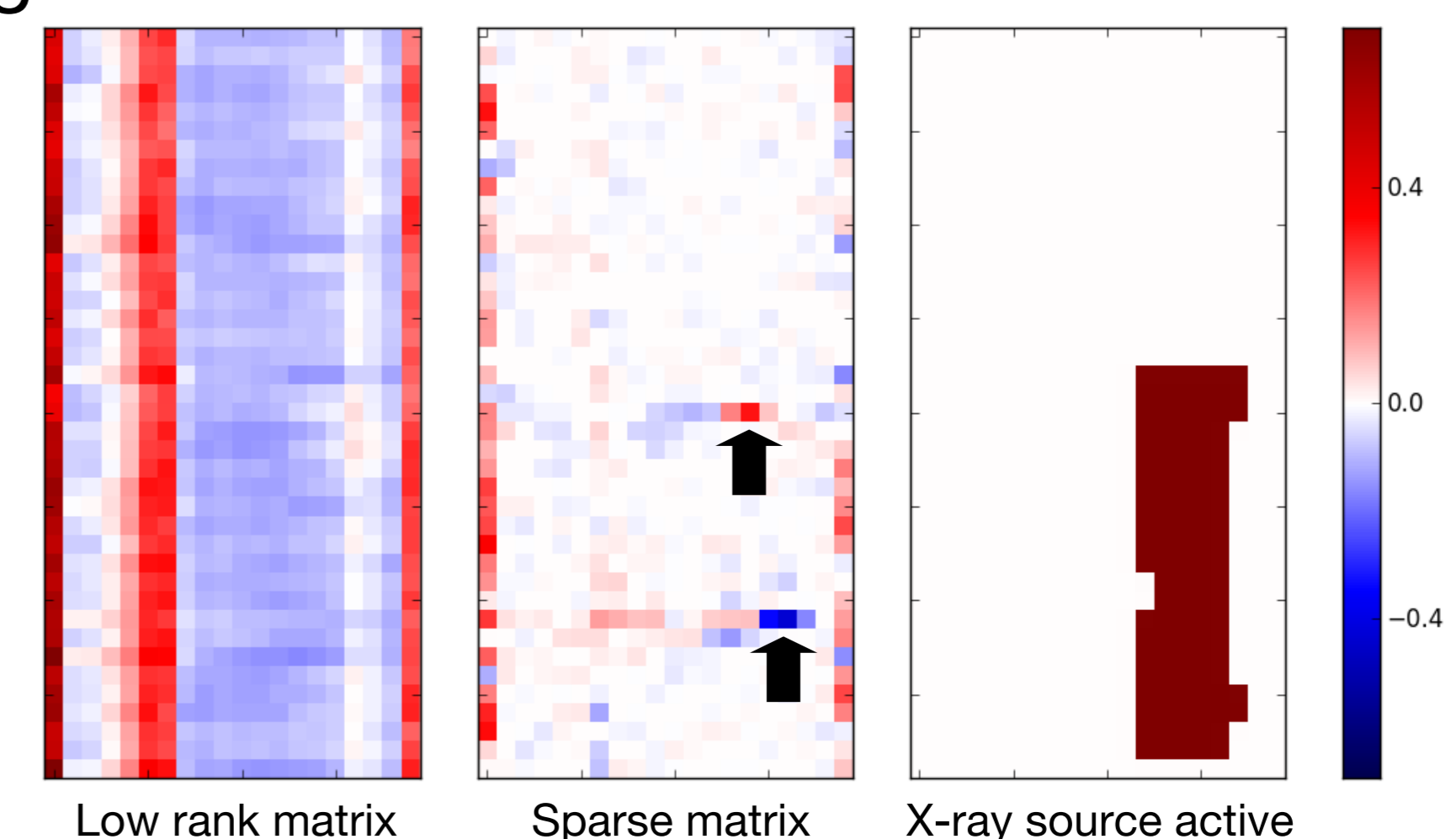
- Extract features describing global and localized noise patterns and combine them by training an ensemble of classifiers that ought to quantify the amount of noise.



- **Features describing global noise:** signal-to-noise ratio, and various statistics in time and frequency domain.^{3,4}
- **Discord beat discovery:** Finds the most unusual cardiac cycle within an ECG signal by dynamic time warping.⁵



- **Robust PCA:** allows localization of an anomaly, such as X-ray artifact, at the sub-beat level and reconstructing the “true”, noise-free signal.⁶



Internal And External Validation

- **Data:** 2,581 CT scans (501 with global noise, 391 with localized noise) from 60 medical centers from 18 countries (many ECG signals are affected by multiple artifacts).

Metric	Global (RF)	Localized (RF)	All (SVM)	All (RF)	All (Ensemble)
mean AUROC	0.998	0.996	0.996	0.997	0.997
mean AUPRC	0.997	0.989	0.993	0.994	0.996
mean accuracy	0.990	0.981	0.973	0.978	0.983
mean precision	0.990	0.963	0.964	0.979	0.985
mean recall	0.970	0.934	0.952	0.954	0.964

- **External validation** based on 150 previously unseen ECGs independently annotated by 2 domain experts.

Predicted	Expert 1					Expert 2				
	1	2	3	4	5	1	2	3	4	5
1	27	32	6	1		45	19	2		
2	3	5	7			5	5	5		
3		5	4			6	3			
4		2	3	5		5	3	1	1	
5	2	4	17	20	7	3	2	20	14	11

	Expert 1	Expert 2	Combined
AUPRC	0.875	0.905	
AUROC	0.898	0.942	
Kendall's <i>W</i>	0.859	0.896	0.863

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 6. Candès et al., Robust principal component analysis? J ACM 58(3), 2011