Digitalization of ECG and Abnormality Screening to Enable Tele-Health Monitoring in Rural Areas

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June 24, 2025

Outline

Heart

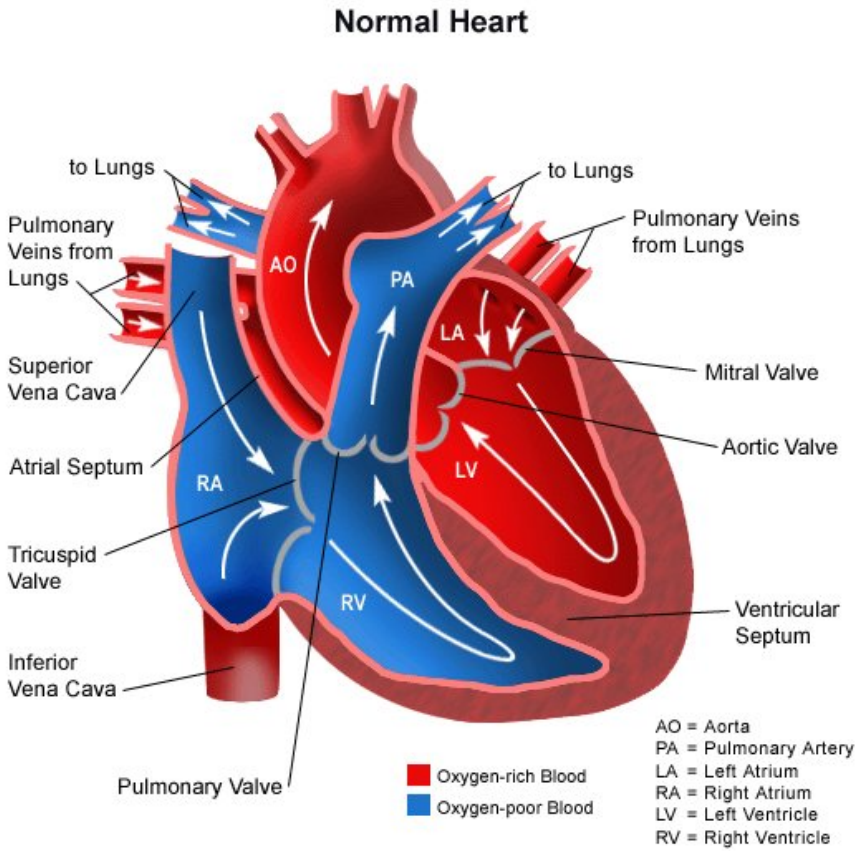

Figure 1: Cross-sectional view of human heart and corresponding labels[1]

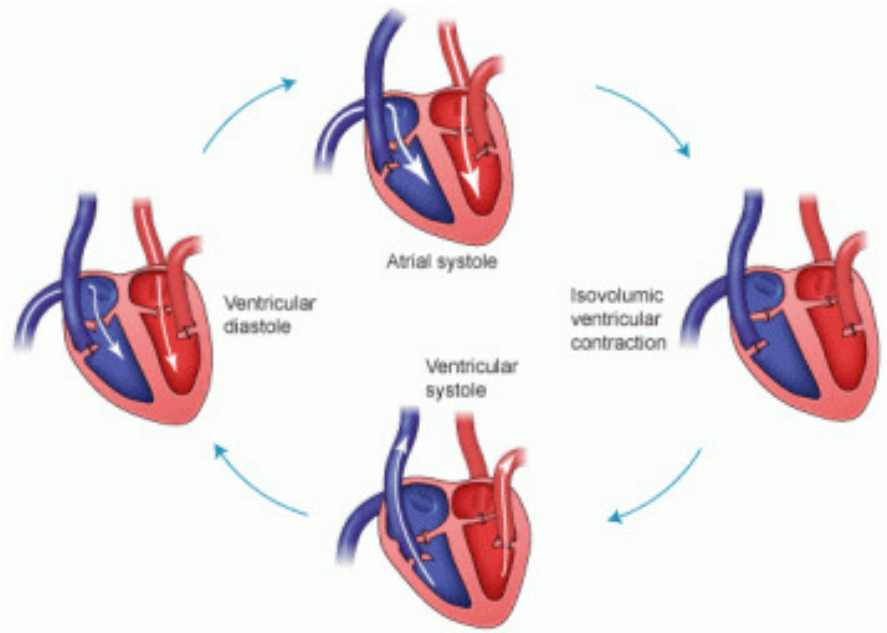

Figure 2: Cardiac Cycle.[1]

[a] https://clinical.stjohnwa.com.au/clinical-skills/assessment/vital-signs/electrocardiography

ECG leads position

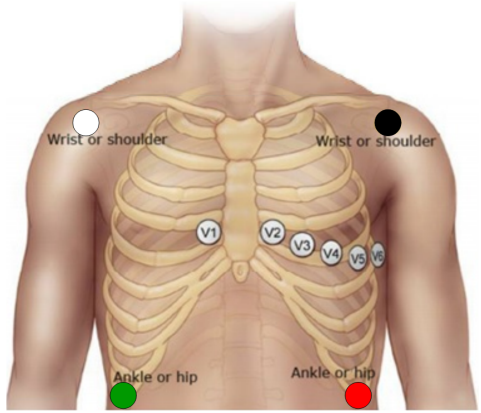

Figure 3: ECG leads and their positions in a human body. [1]

Table 1: ECG leads and their positions.

SL. NO.	Leads			Positions	Heart view
1	6-limb	3-bipolar	Lead I	Left arm & right arm	Left side
			Lead II	Left leg & right arm	Inferior left view
			Lead III	Left leg & left arm	Inferior right view
		3-Augmented	aVR	Right arm (+), Left arm , Left leg	Upper right side
			aVL	Left arm (+), Right arm , Left leg	Upper left side
			aVF	Left leg (+), Right arm , Left arm	Inferior wall of heart
2	6-chest		V1	4th intercostal space	right sternal border
			V2	4th intercostal space	left sternal border
			V3	4th intercostal space	midway between V2 and V4
			V4	5th intercostal space	midclavicular line
			V5	Left anterior axillary line	at the same level as V4
			V6	Left mid-axillary line	at the same level as V4 and V5

[1] https://www.bplmedicaltechnologies.com/blog/12-channel-ecg–electrode-placement-24560/

ECG signal morphology

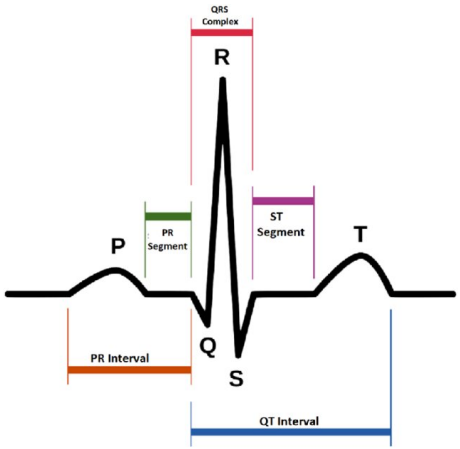

Figure 4: ECG morphology: different segments of ECG signal for a normal person [1]

Table 2: Specification of morphological features in normal ECG

Sl. No.	Waveform	Duration (in seconds)	Amplitude (in mV)	Remarks
1	P-wave	0.08–0.12	0.25	Depolarization of LA
2	Q-wave	0.03	0.2 0.4	Initial ventricular depolarization
				Depolarization of the ventricles
3	R-wave	–	1.6	
4	S-wave	–	1.8–3.0	Final ventricular depolarization
5	T-wave	0.1–0.25	0.1–0.5	Ventricular re-polarization
6	U-wave	–	0.1–0.33	Purkinje fibers re-polarization
7	PR interval	0.12–0.20	120	Atrial & ventricular depolarization
8	QRS duration	0.06–0.12	2.5–3.0	Depolarization of ventricles
9	QT interval	0.35–0.44	-	Reflect ventricular re-polarization
10	RR interval	0.6–1.2	-	Measures heart rate variability
11	PP interval	0.60–1.04	-	Interval between two P-waves
12	ST segment	0.08	0.1–0.2	Early re-polarization

Types of CVD

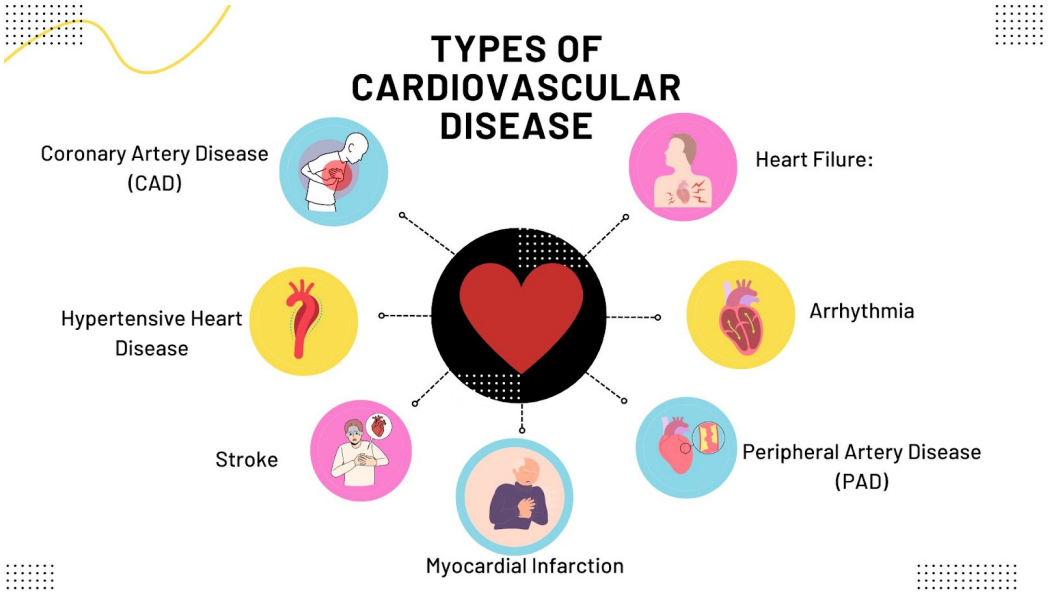

Figure 5: Types of cardiovascular diseases.[1]

[1] https://www.gargashhospital.com/blog-details/22/cardiovascular-disease-types-causes-and-symptoms

ECG signal and image

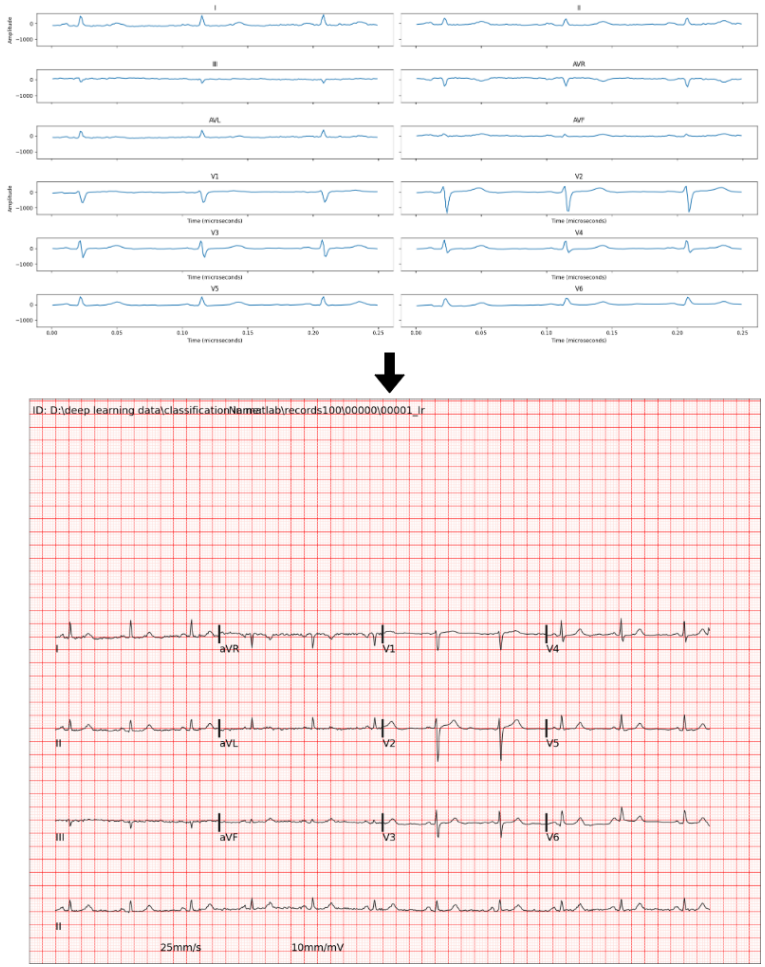

Figure 6: ECG report taken from one subject.

Types of abnormality statement in ECG

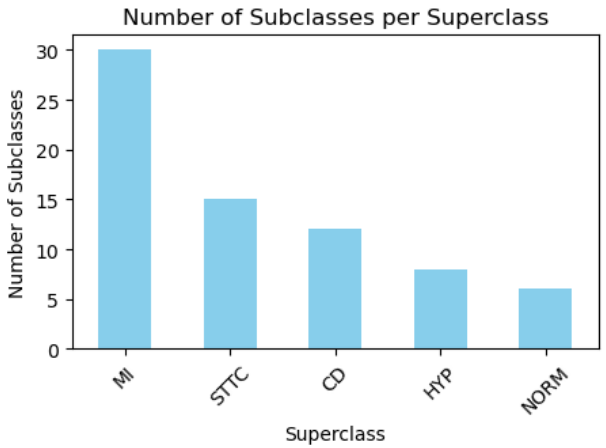

Figure 7: Diagnostic super classes

- **Myocardial Infarction (Heart Attack):**
  Leads to **Coronary Artery Disease (CAD)**.
  Can cause damage or death of heart tissue due to blocked blood flow.
- **Conduction Disturbance:**
  Leads to **Arrhythmias** (irregular heartbeats) or **Bradycardia** (slow heart rate).
  Can result in **Heart Failure** if untreated.
- **ST Segment Changes:**
  Associated with **Ischemia** (reduced blood flow) or **Myocardial Infarction**.
  ST elevation often indicates an acute heart attack.
  ST depression may signal ischemia or heart strain.
- **Hypertrophy:**
  Leads to **Hypertensive Heart Disease**.
  Can cause **Heart Failure** or **Sudden Cardiac Arrest** due to the increased workload on the heart.

PTB-XL Dataset[3]

Table 3: PTB-XL dataset details

Attribute	Details
Source	The George B. Moody PhysioNet Challenge 2024[1]
Dataset Name	PTB-XL
PTB Meaning	Physikalisch-Technische Bundesanstalt (Physical-Technical Federal Institute)[2]
Leads	12-lead ECG
Total Records	21,799
Total Patients	18,885
Duration per Record	10 seconds
Metadata Includes	Demographics, infarction characteristics, diagnostic ECG likelihoods, annotated signal properties
Super Classes	**NORM:** Normal ECG (9514) **MI:** Myocardial Infarction (5469) **STTC:** ST/T Change (5235) **CD:** Conduction Disturbance (4898) **HYP:** Hypertrophy (2649)
Total ECG Statements	71

PTB-XL Dataset statements

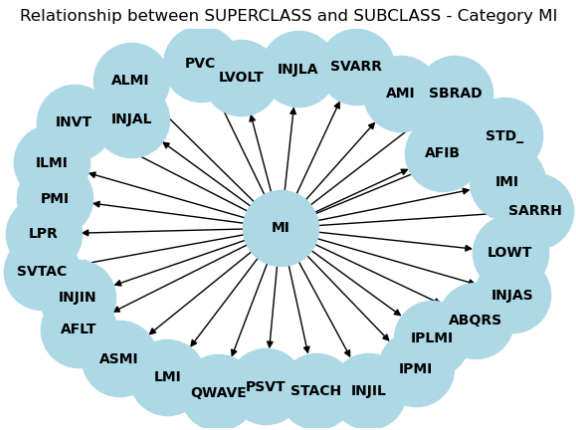

Figure 8: Subclass of MI Super class

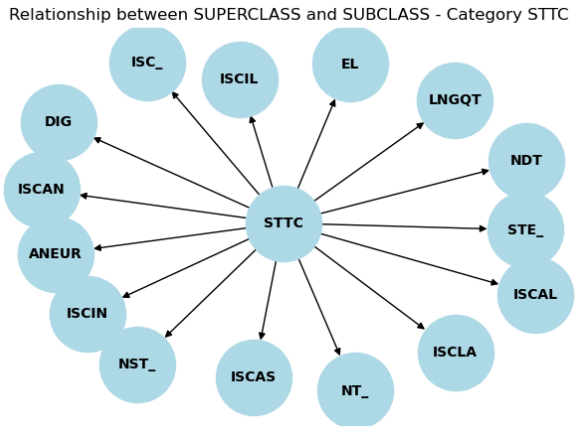

Figure 9: Subclass of STTC Super class

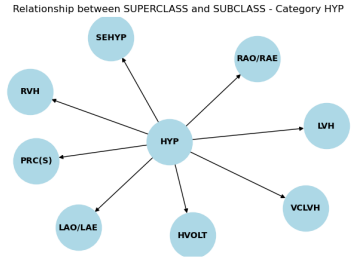

Figure 10: ECSubclass of HYP Super class

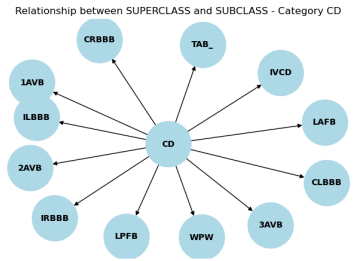

Figure 11: Subclass of CD Super class

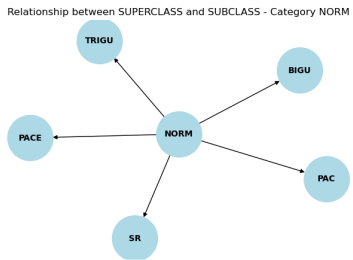

Figure 12: Subclass of normal Super class

ECG signal

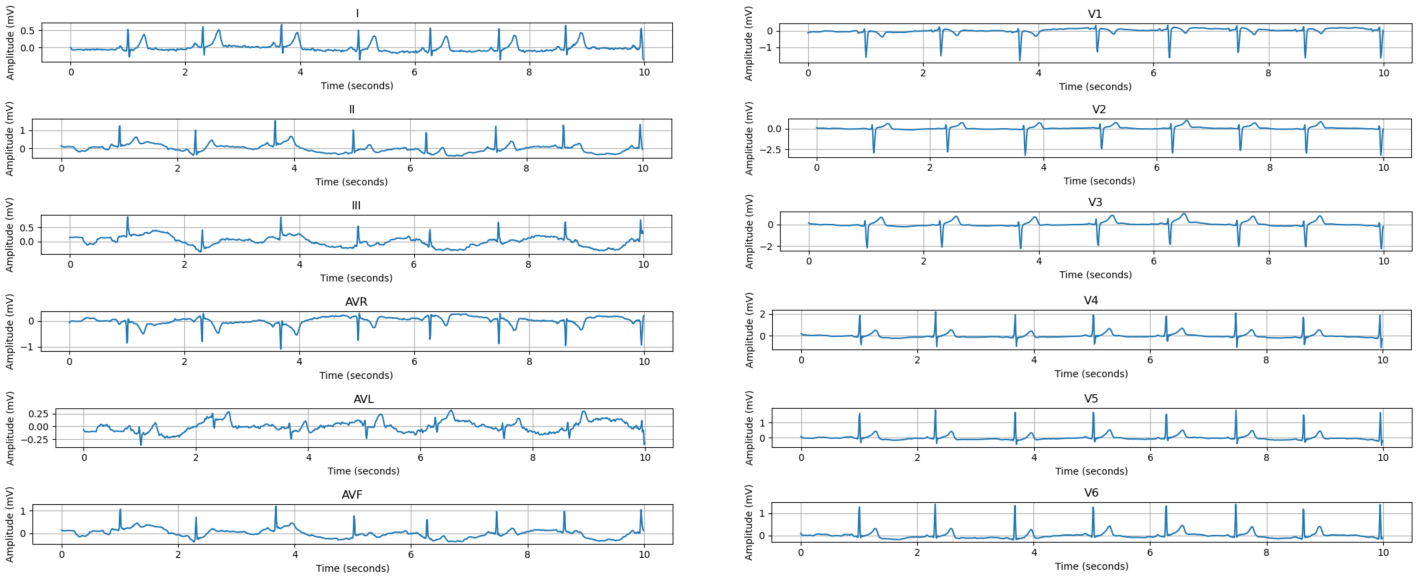

Figure 13: Machine generated ECG signal

Motivation

- GENEVA, 20 May 2023 – Deaths from cardiovascular disease (CVD) jumped globally from 12.1 million in 1990 to 20.5 million in 2021, according to a new report from the World Heart Federation (WHF).[1]
- CVD was the leading cause of death worldwide in 2021, with four in five CVD deaths occurring in low- and middle-income countries (LMICs).


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Rural India is struggling with shortage of doctors, paramedical staff

Updated - July 10, 2022 at 09:39 PM

The tale of empty hospitals is due to a lack of incentives extended to doctors prompting them not to work in rural health facilities, says a specialist

By PARVATHI BENU, LONI DAS

COMMENTS SHARE READ LATER

A doctor at the Odisha's Malkangiri village: The government should create a framework for the right staffing, duration and incentives and career paths for doctors to work in a rural health centre.

Figure 14: Real-world scenario[2]

[1] https://world-heart-federation.org/news/deaths-from-cardiovascular-disease-surged-60-globally-over-the-last-30-years-report

[2] https://www.thehindubusinessline.com/data-stories/deep-dive/rural-india-is-strugglingwith-shortage-of-doctors-paramedical-staff/article65623110.ece

S. N	Name of Test	Suggestive Reporting Time Frame	
SEROLOGY			
27	RPR Rapid Test@		Within 30 min
28	HIV Rapid Test@	Up to 2 days in routine/ ELISA	Within 30 min using RDK and Up to 1 days in routine/ ELISA
29	Dengue (Rapid test)@		Within 30 min
30	Malaria (Rapid test)@		Within 30 min
31	Sputum for AFB@	Up to 2 days	Up to 1 days
URINE			
32	Urine Sugar / Albumin@	Up to 8 hours	Up to 8 hours
33	Urine Pregnancy test (UPT)@	Up to 8 hours	Up to 8 hours
34	Urine Microscopy	Up to 2 days	Up to 1 days
35	Urine Complete by strip method (Bile Salts, Bile Pigment, Ketone bodies & Occult blood, sugar, albumin, Ph, specific gravity) and Leucocyte Esterase @		Within 30 min
STOOL			
36	Stool for OVA and cyst@	Up to 2 days	Up to 1 days
RADIOLOGY			
37	X-Ray (With/Without Contrast)*	Up to 4 hours	Up to 4 hours
38	USG**	Up to 4 hours	Up to 4 hours
CARDIOLOGY			
39	ECG	In sourcing of technician	Within 15 mins. In emergency

@ These 15 investigations are to be done at PHC also.
Note: All tests done using Rapid Diagnostic Kits should be done and reported in-house.

Figure 15: National Health Mission (NHM) report.[3]

[3] https://www.google.com/search?q=NHM+report

ECG Paper

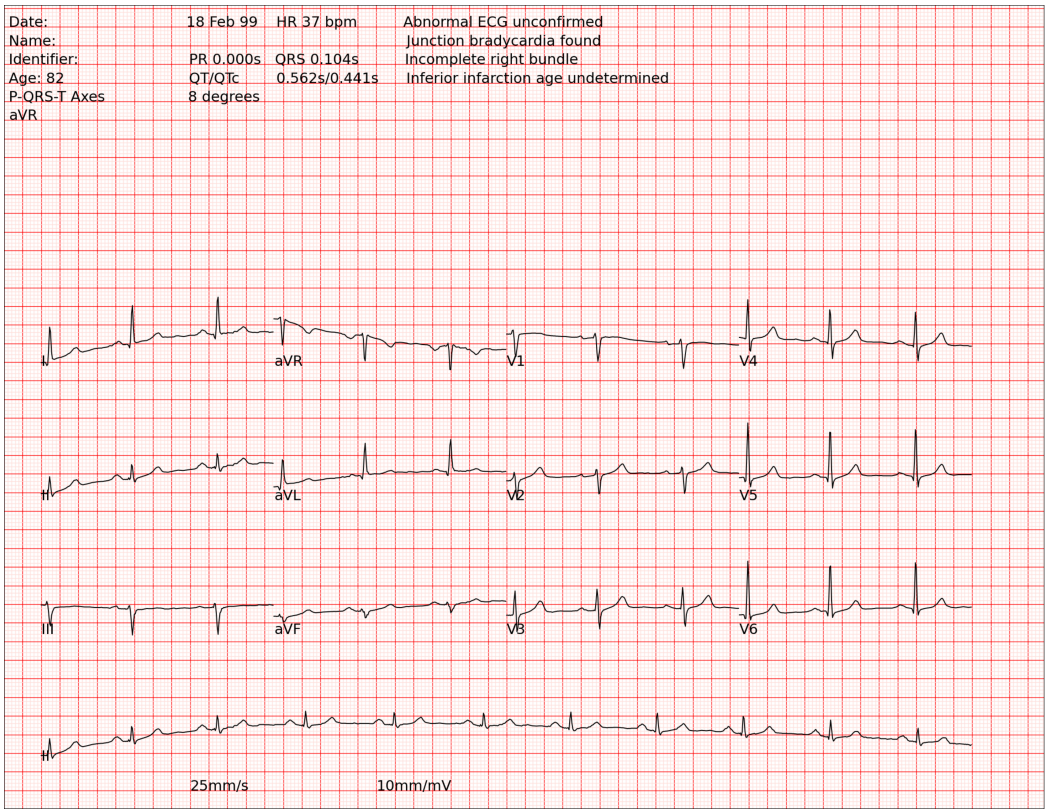

Figure 16: ECG report

ECG-Image-Kit tool

- January 2024, initial public release[2]
- ecg-image-generator
  - Image dimension 2200x1700(RGB)
  - 10mm/mv and 25mm/s
  - 3 by 4 standard
- ecg-image-digitizer
  - 2.5 seconds data of each lead

ECG Image Generator

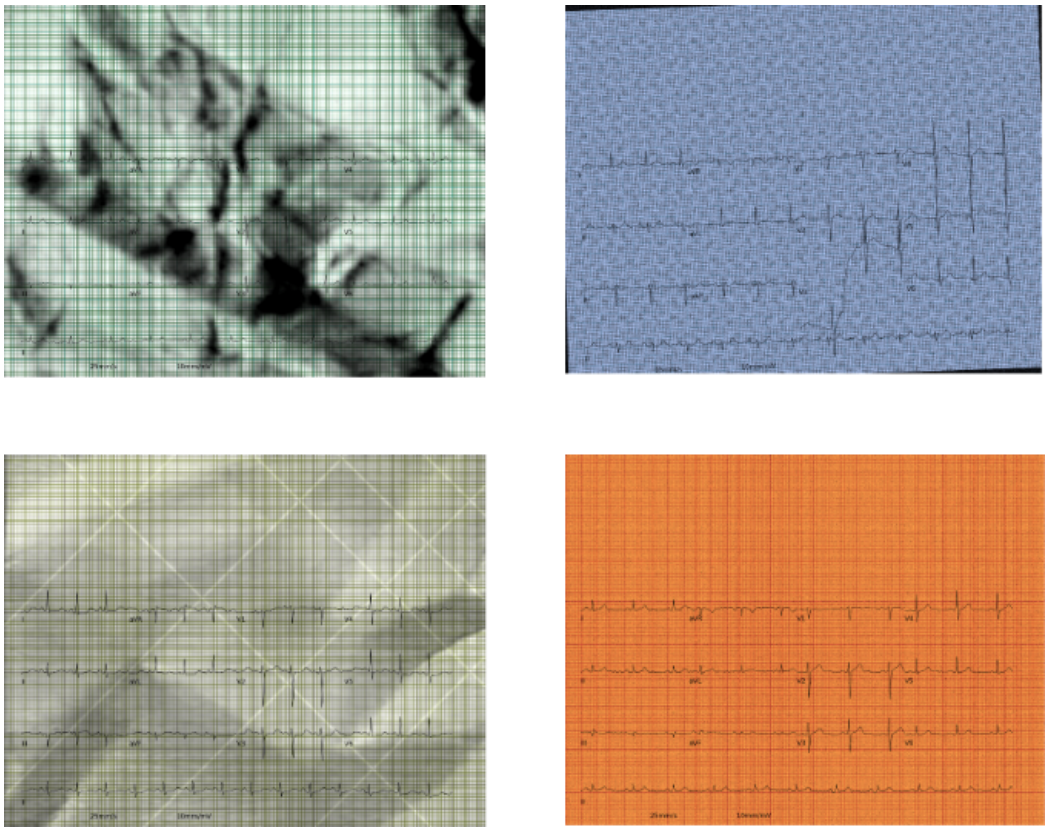

Figure 17: A collection of four images showing different instances from the dataset: Shadowed (top left), Wrinkled (bottom left), Inclined (top right), and Noisy (bottom right).

ecg-image-digitizer

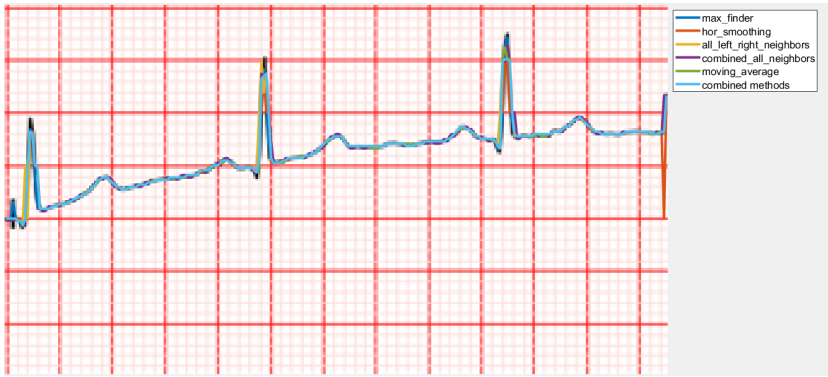

Figure 18: signal extraction methods

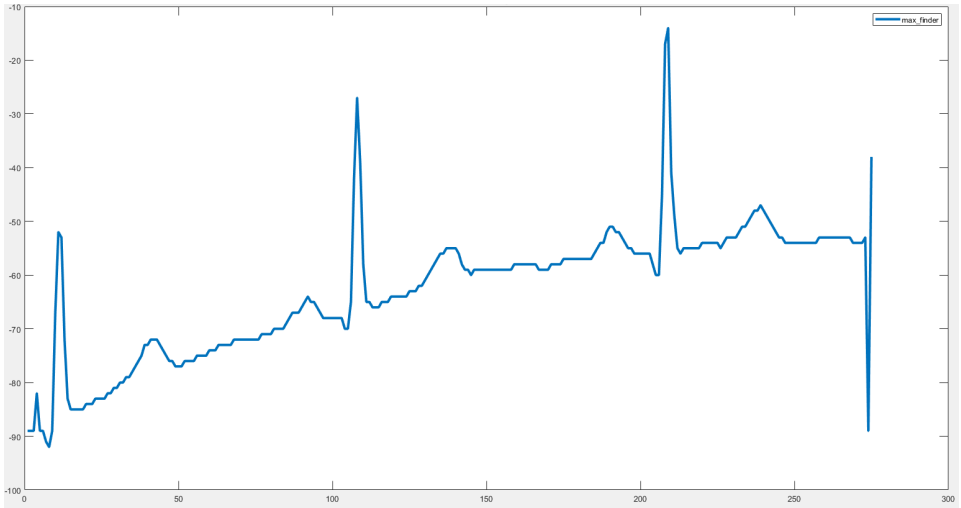

Figure 19: Recovered signal

Conclusion

- Classification based on ECG paper images involves analyzing visual features of the ECG patterns to detect abnormalities and diagnose cardiovascular conditions using image processing techniques.
- Classification based on digitized ECG signals involves processing the numerical data from the digital signals to identify key patterns and anomalies through signal processing and machine learning algorithms.

References

[1] Thivya Anbalagan, Malaya Kumar Nath, D Vijayalakshmi, and Archana Anbalagan.
Analysis of various techniques for ecg signal in healthcare, past, present, and future.
Biomedical Engineering Advances, 6:100089, 2023.

[2] Kshama Kodthalu Shivashankara, Afagh Mehri Shervedani, Gari D Clifford, Matthew A Reyna, Reza Sameni, et al.
Ecg-image-kit: a synthetic image generation toolbox to facilitate deep learning-based electrocardiogram digitization.
Physiological Measurement, 45(5):055019, 2024.

[3] Patrick Wagner, Nils Strodthoff, Ralf-Dieter Bousseljot, Dieter Kreiseler, Fatima I Lunze, Wojciech Samek, and Tobias Schaeffter.
Ptb-xl, a large publicly available electrocardiography dataset.
Scientific data, 7(1):1–15, 2020.

Thank You!