Driver Drowsiness Detection: Physiological Monitoring and Impact of Missing Inter-Beat Intervals

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Problem Statement

Motivation: Annually around 1.35 million people die worldwide because of road accidents. Driver drowsiness can contribute to up to 20% of all road accidents.

Goal: Use physiological measurements to accurately and reliably detect and warn, in real-time, when the driver is unfit for a driving task, regardless of automation level.

Background

Drowsiness: Drowsiness is a state of strong desire for sleep or an increased tendency to fall asleep, often caused by insufficient rest, circadian rhythm disruptions, or sedative effects of medications. It is characterized by reduced alertness, difficulty keeping eyes open, and slowed reaction times.

Inter-Beat Interval (IBI): Inter-Beat Interval (IBI) refers to the time interval between consecutive heartbeats, typically in milliseconds (ms). It is derived from the time difference between successive heart contractions. IBI provides a fundamental measure of heart rate analysis.

Heart Rate Variability (HRV): Heart Rate Variability (HRV) refers to the variation in the time intervals between successive heartbeats (IBIs). It is a key indicator of autonomic nervous system activity, reflecting the balance between the sympathetic (fight-or-flight) and parasympathetic (rest-and-digest) nervous systems. Higher HRV generally indicates better cardiovascular adaptability and overall health, while lower HRV is associated with stress, fatigue, or disease conditions.

Challenges

- Participant Non-cooperation
- Sensor Noise
- Novelty
- Ethics - Personal Data Privacy
- General Safety Regulation (GSR)
- New Car Assessment Program (NCAP)

Conclusion

- Reasonable amount of missing data does not significantly degrade ML performance
- Individual variability affects ML performance

Future Work

- Multimodal learning
- On-device AI
- Federated learning

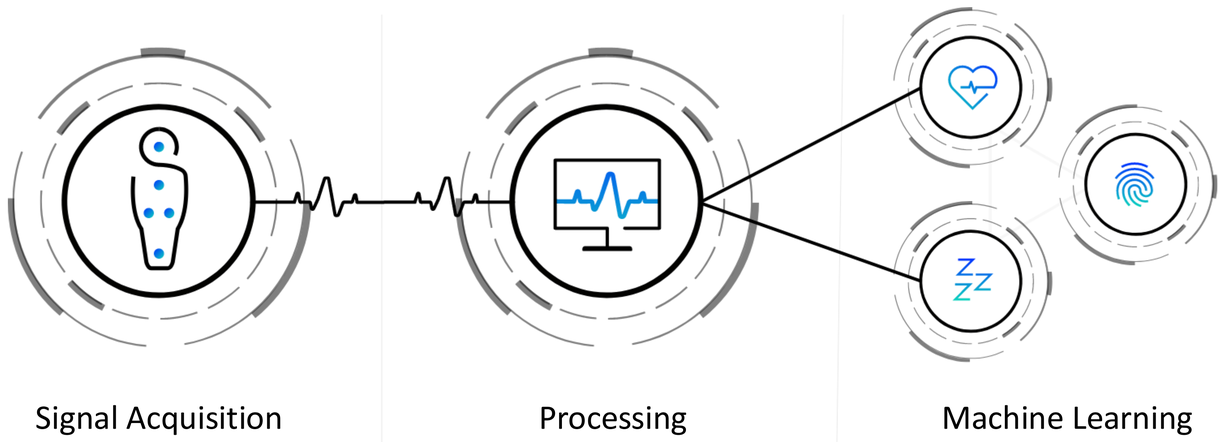

Figure 1. Acquisition – Processing – Machine Learning pipeline

Figure 2. Sensors for IBI deviation

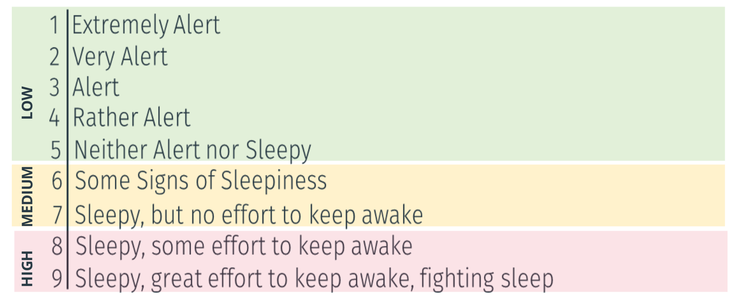

Figure 3. Karolinska Sleepiness Scale (KSS)

Table 1. Key differences between sensors

Sensor Type	Measurement Principle	Advantages	Limitations
Electrocardiography (ECG)	Electrical signals from the heart	High accuracy, clinical standard	Requires direct skin contact, often uses electrodes
Photoplethysmography (PPG)	Optical detection of blood volume changes	Non-invasive, used in wearables	Susceptible to motion artifacts, lower accuracy than ECG
Radar	Doppler-based detection of heart-induced chest movements	Contactless, good for remote monitoring	Expensive, less precise than ECG

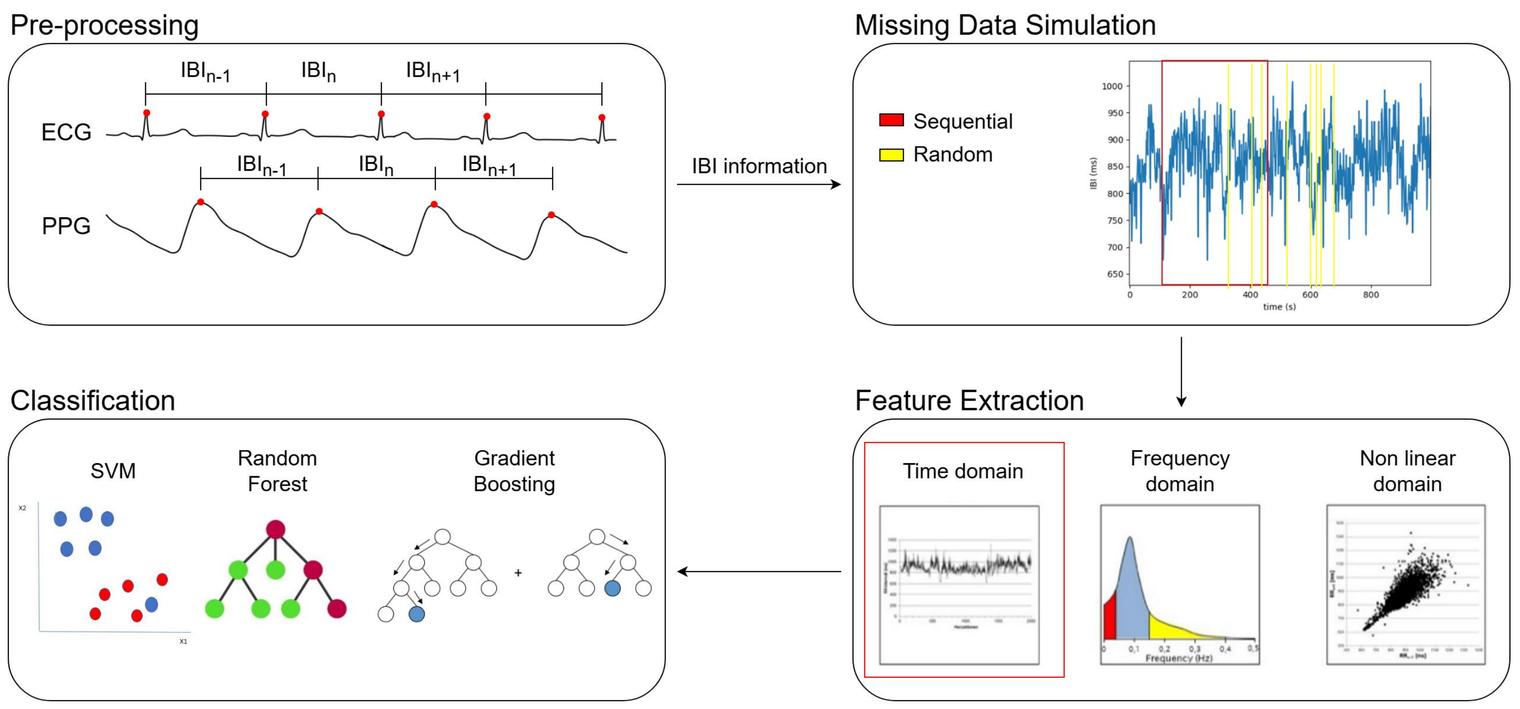

Figure 4. Missing Data Handling Workflow

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