Driver State Monitoring with Computational Fabrics for Safer Driving

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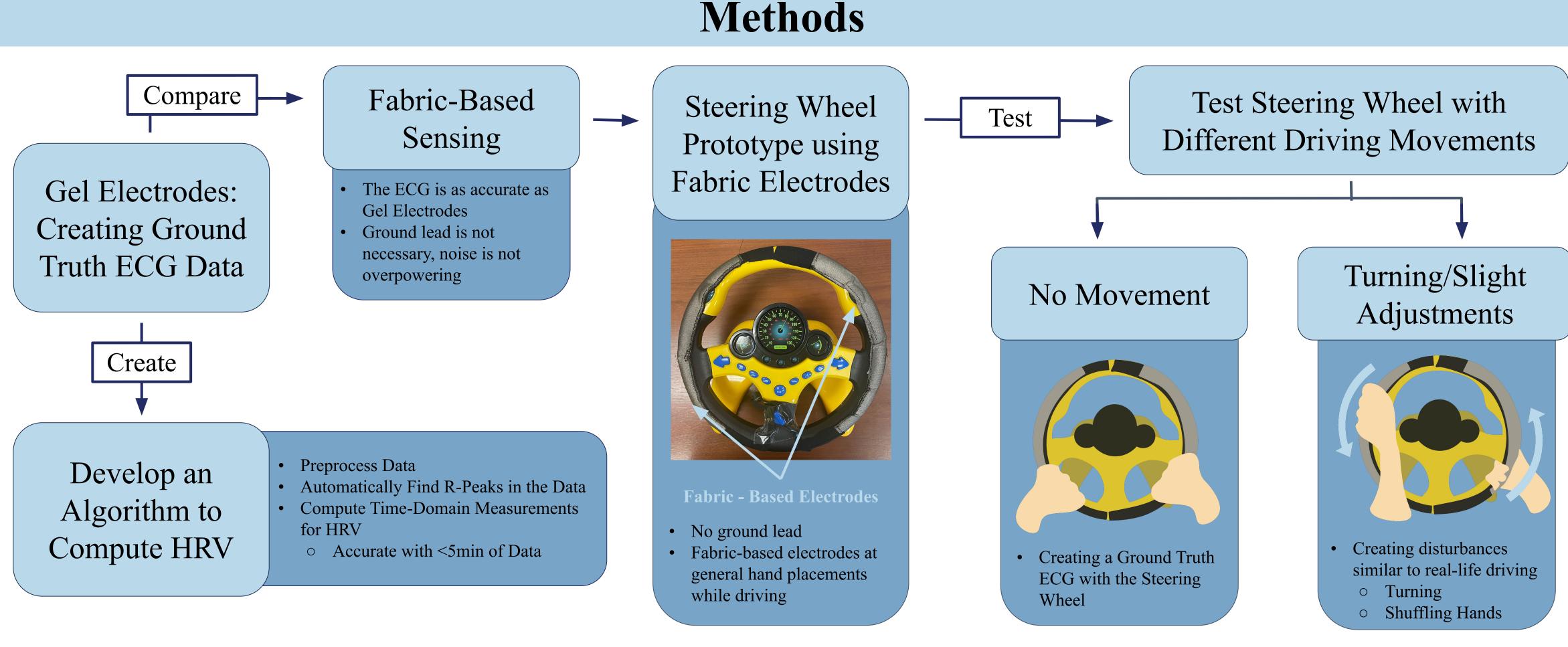
Motivation

- Drowsy drivers remain as the main risk factor for road accidents
- Current physiological state monitoring: computer vision, driver sonar, and rigid wearable sensors
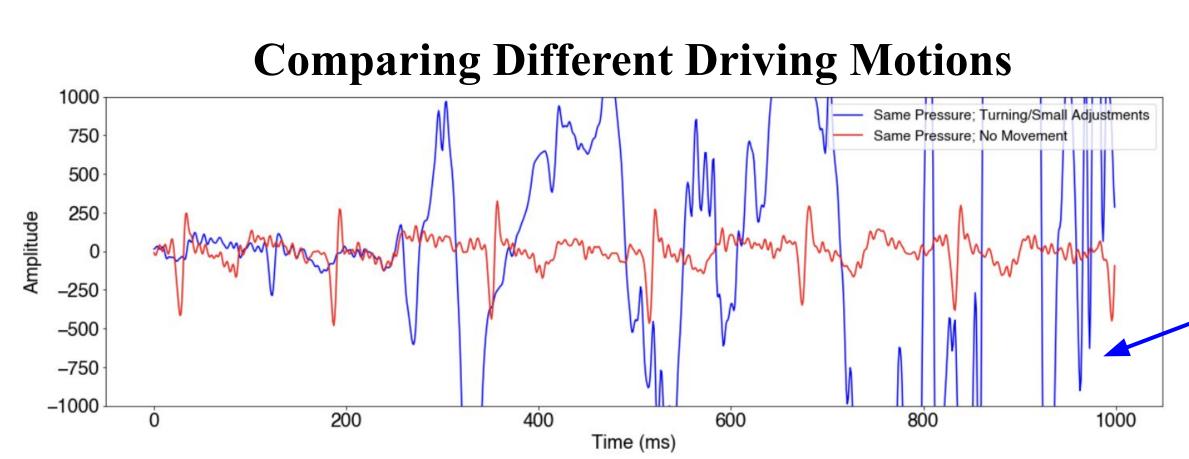- Fabric electrodes: unobtrusive physiological state monitoring

Research Aim

- Embed fabric-based sensing into the steering wheel and/or car seat for an accurate echocardiogram (ECG).
- Accurate ECG sensing allows for the computation of heart rate variability (HRV) and creating an association with driver drowsiness using an objective rating scale (Kundinger)

Methods

Compare

Gel Electrodes: Creating Ground Truth ECG Data

Create

Develop an Algorithm to Compute HRV

Fabric-Based Sensing
- The ECG is as accurate as Gel Electrodes
- Ground lead is not necessary, noise is not overpowering

- Preprocess Data
- Automatically Find R-Peaks in the Data
- Compute Time-Domain Measurements for HRV
  - Accurate with <5min of Data

Steering Wheel Prototype using Fabric Electrodes

Fabric - Based Electrodes
- No ground lead
- Fabric-based electrodes at general hand placements while driving

Test

Test Steering Wheel with Different Driving Movements

No Movement
- Creating a Ground Truth ECG with the Steering Wheel

Turning/Slight Adjustments
- Creating disturbances similar to real-life driving
  - Turning
  - Shuffling Hands

Results

Comparing Different Driving Motions

- To visualize clean ECG signals, two points of contact are needed on the steering wheel
- Turning/ Small adjustments of the hand <u>create unclear ECG signals</u>
  - Disruption of contact with the fabric-based electrodes
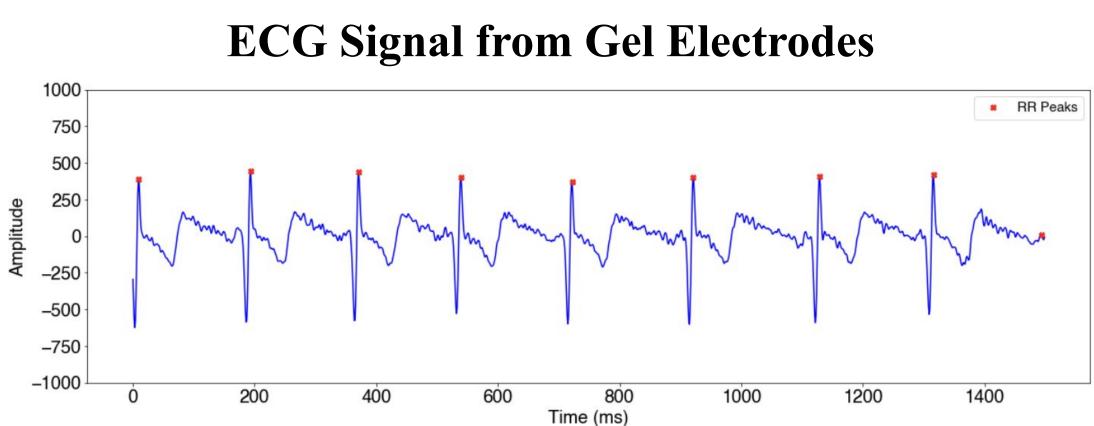- No Disruption = Clear ECG

Figure 3. ECG Detection using Fabric Electrodes Attached to the Prototype Steering Wheel

Results

ECG Signal from Gel Electrodes

Figure 2. R-Peak Detection Using a Ground Truth Gel Electrode

Time-Domain Calculations of HRV

RMSSD	190.2451 (ms)
SDRR	12.55927 (ms)
SDNN	0.616741 (ms)

Table 1. Time Domain Calculations of HRV using 5 Minutes of Data

- Time Domain Measurements: quantify and measure the amount of variability of the interbeat intervals (IBI)
  - Helps show quick changes in Heart Rate Variability due to physiological changes
    - Examples: Drowsiness & Stress

Discussion + Next Steps

- Manually check the R-Peaks to ensure HRV accuracy as there are outliers
- Collect ECG Data throughout the day while using the drowsiness scale to create an association.
- Larger fabric-based electrodes for the steering wheel
- Implement fabric-based electrodes into the car seat
  - Allows contact at all times
- Inconsistencies in the ECG make computing an accurate HRV difficult

References

- Kundinger, T.; Sofra, N.; Riener, A. Assessment of the Potential of Wrist-Worn Wearable Sensors for Driver Drowsiness Detection. *Sensors* 2020, 20, 1029. https://doi.org/10.3390/s20041029