Occupant Classification by Seatbelt

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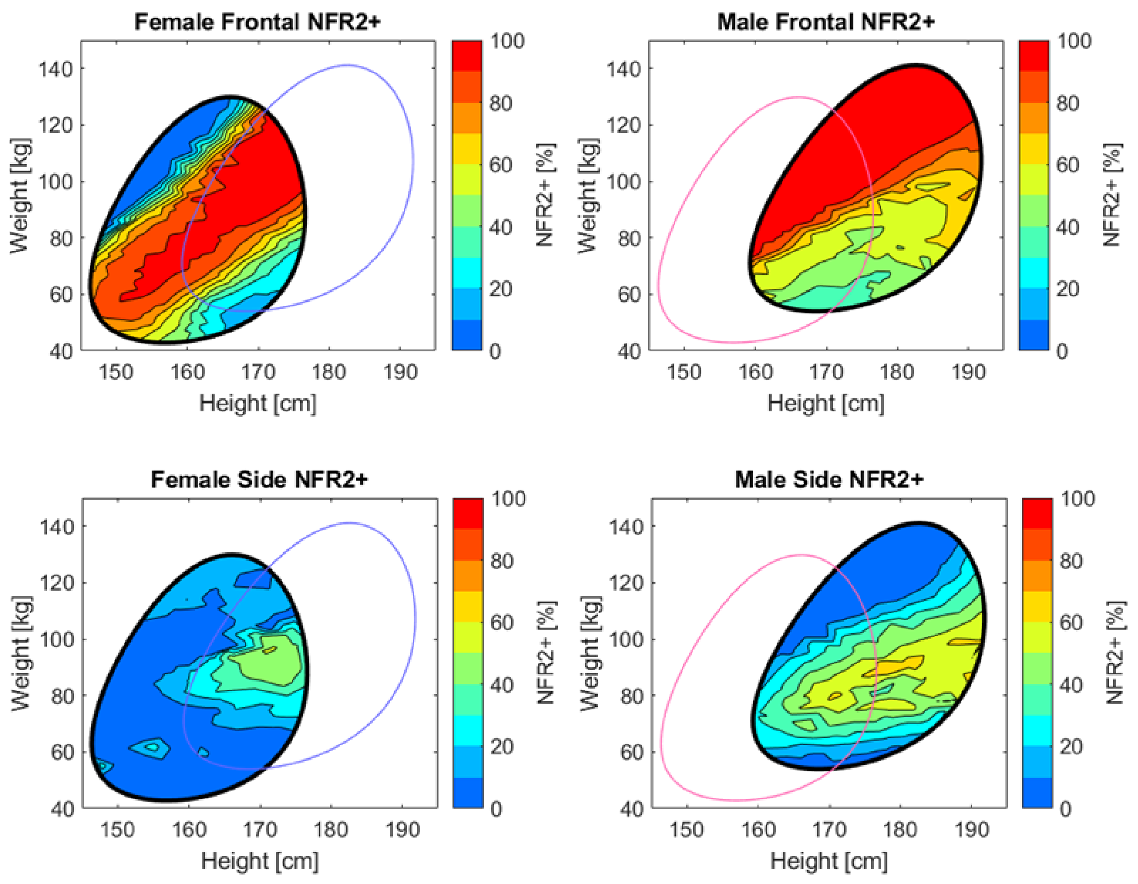
Occupant Classification by Seatbelt

- Background and methodology
- Body size estimation in Belt-In-Seat
  - Configuration
  - Field test
  - Linear regression
  - Machine learning
- Body size estimation in B-pillar mounted seatbelt
  - Configuration
  - Static car test
  - Simulation test
  - Machine learning
- Conclusion and next step

Background

- Simulation results shows body size variability influences crash injury risk in the generic car restraint system
- An adaptive restraint system can reduce injury risk
  - Finetuned seatbelt force
  - Finetuned airbag fire timing
- Classification of occupant:
  - Estimate height and weight of occupants
- We want to develop a camera-free and low power consumption monitoring system
  - Works alone or with a camera-based system



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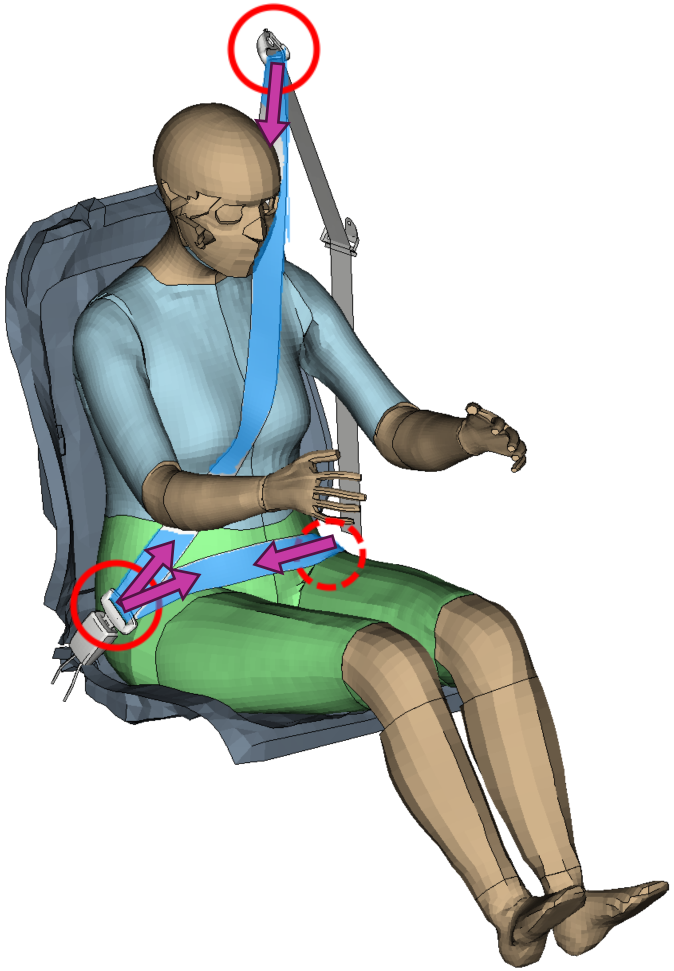
Methodology

- Seatbelt wrap around human (upper) body
- Body shape determines seat belt spatial shape
- The inverse problem: space shape to estimate body shape
- To estimate seatbelt space shape, we need to know:
  - The 3 fixations of the belt
    - Can be different between belt-in-seat and b-pillar installation
  - Length of webbing between the 3 fixations:
    - Diagonal belt
    - Lap belt
  - Seat belt extension direction:
    - Near outlet (belt-in-seat)
    - D-ring (b-pillar)
    - Near buckle
  - Belt tension: existence of webbing slack
  - Sitting posture
    - Off-position
    - Pan and back's position and inclination
    - Indicates quality of the belt routing (b-pillar)



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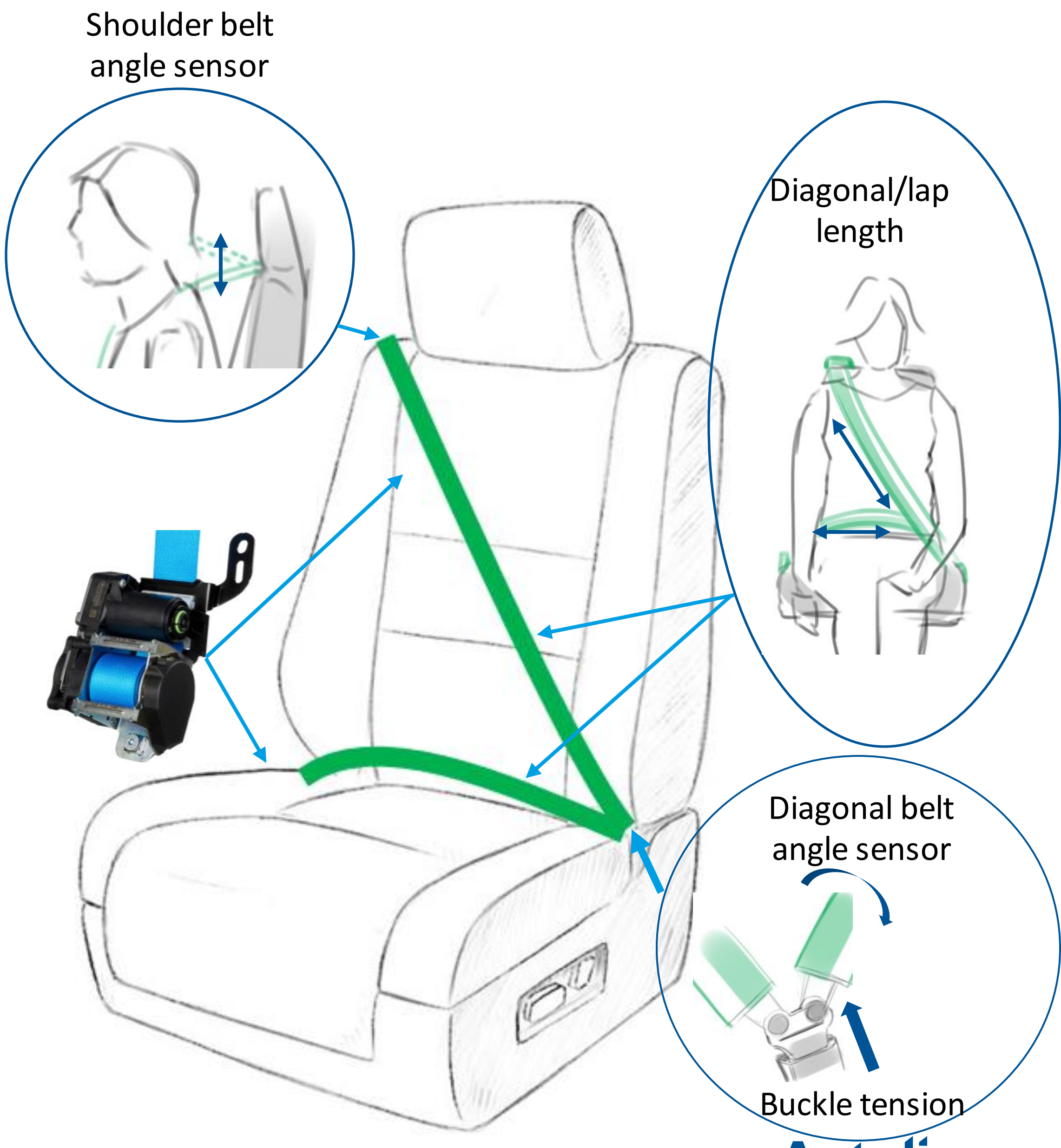
Belt-In-Seat: Configuration

- Test passenger seat
  - Seat pan and back are fixed
- Instrumentation
  - Payout length sensor:
    - Bobbin rotation sensor (BRS) in retractor
    - One for diagonal belt, one for lap belt
  - Shoulder belt angle sensor
  - Diagonal belt angle sensor
  - Buckle tension: BTS sensor



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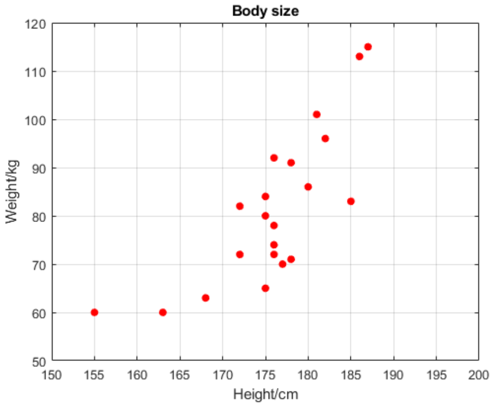
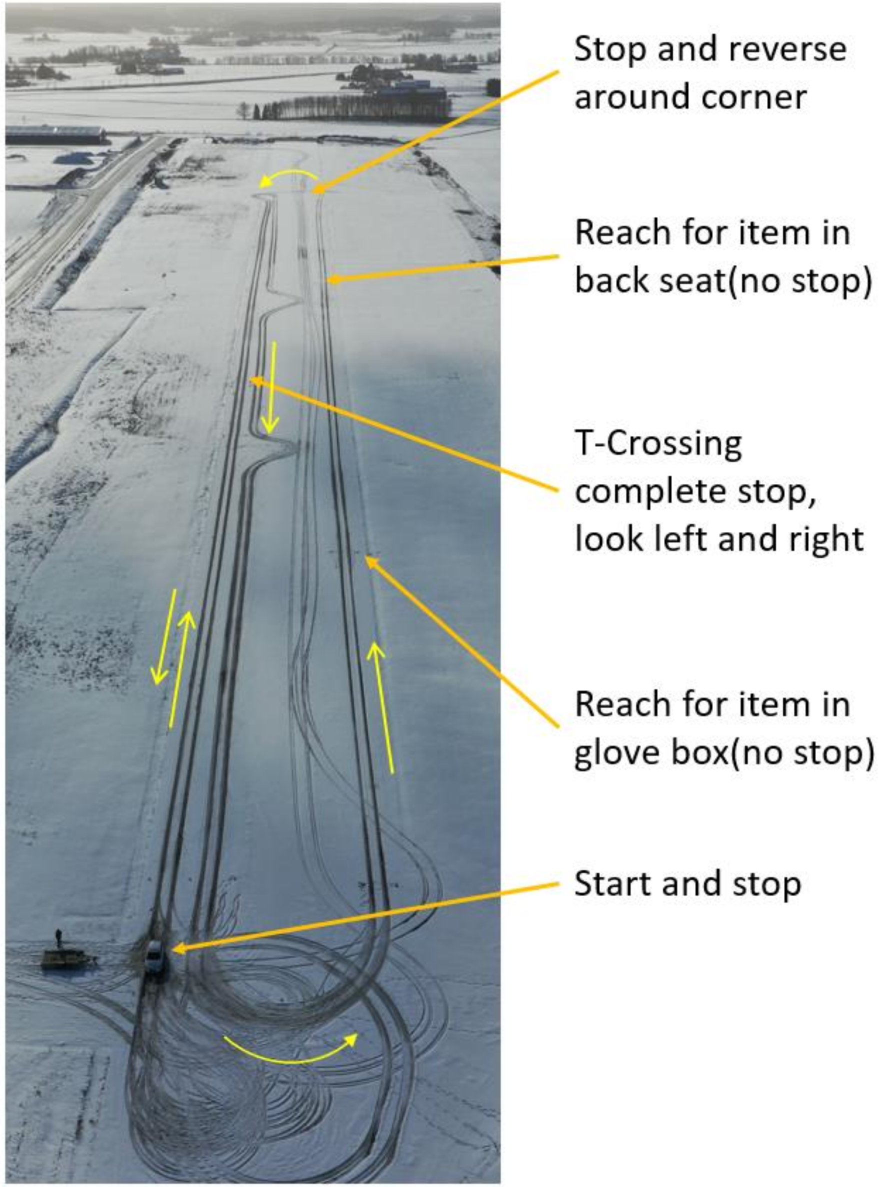
Belt-In-Seat: Field Test

- Measurement in driving
- Drive along the assigned route
- Different tasks were executed in predefined spot
- Record sensor data





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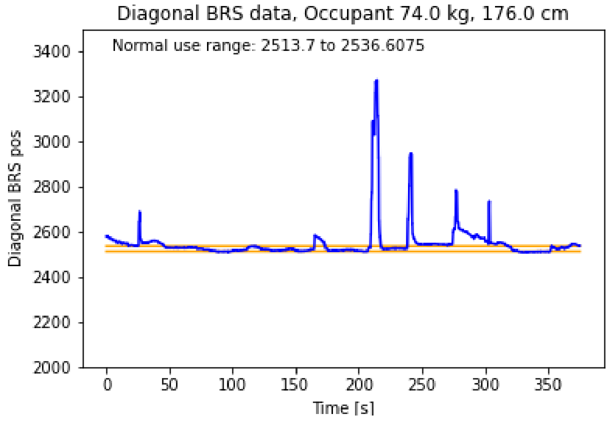
Belt-In-Seat: Linear Regression

- Due to a sensor issue, lap belt length only be valid for 6 participants, diagonal belt length is valid for all
- Diagonal belt length to weight model
- Min and max of diagonal belt length during “normal use” as input data:
  - Two data points from each participant
  - Errands period data is excluded
- Max error from regression line within test group: 11.9 kg
- Standard deviation for weight estimation: 5.77 kg

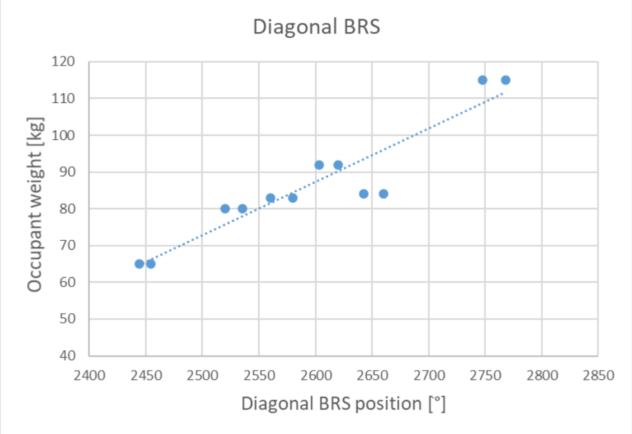


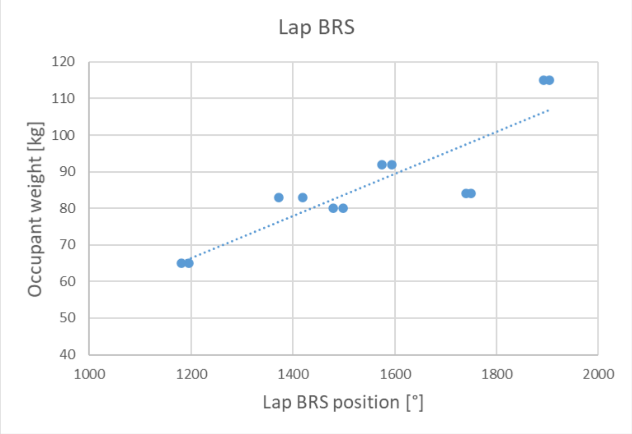
Belt-In-Seat: Linear Regression

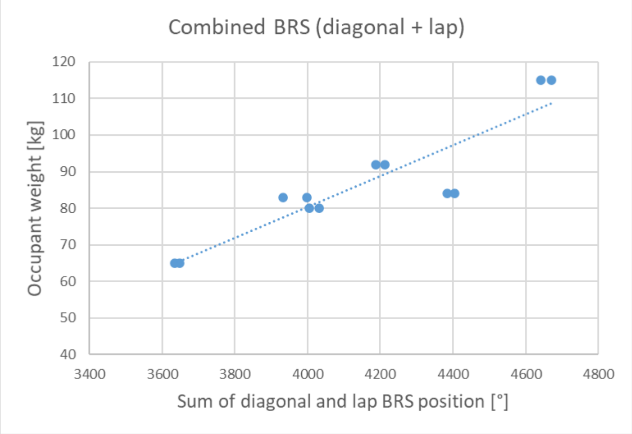
- Follow up analysis of lap belt length
- Diagonal belt length and lap belt length as input

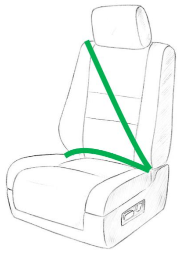
	Diagonal Only	Lap Only	Combined Length
Max. Error	12,1 kg	13,5 kg	13,1 kg
Std. Dev.	5,53 kg	7,60 kg	6,75 kg

- Diagonal belt length gives most accurate estimation while lap belt length doesn't bring in clear benefit.









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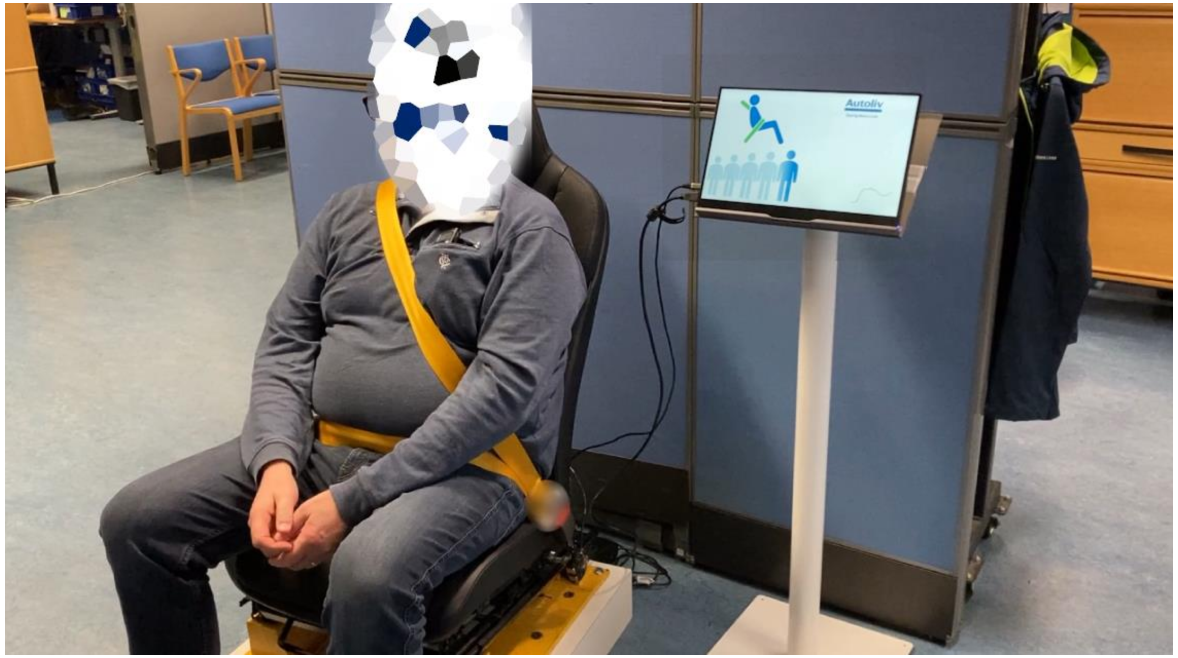
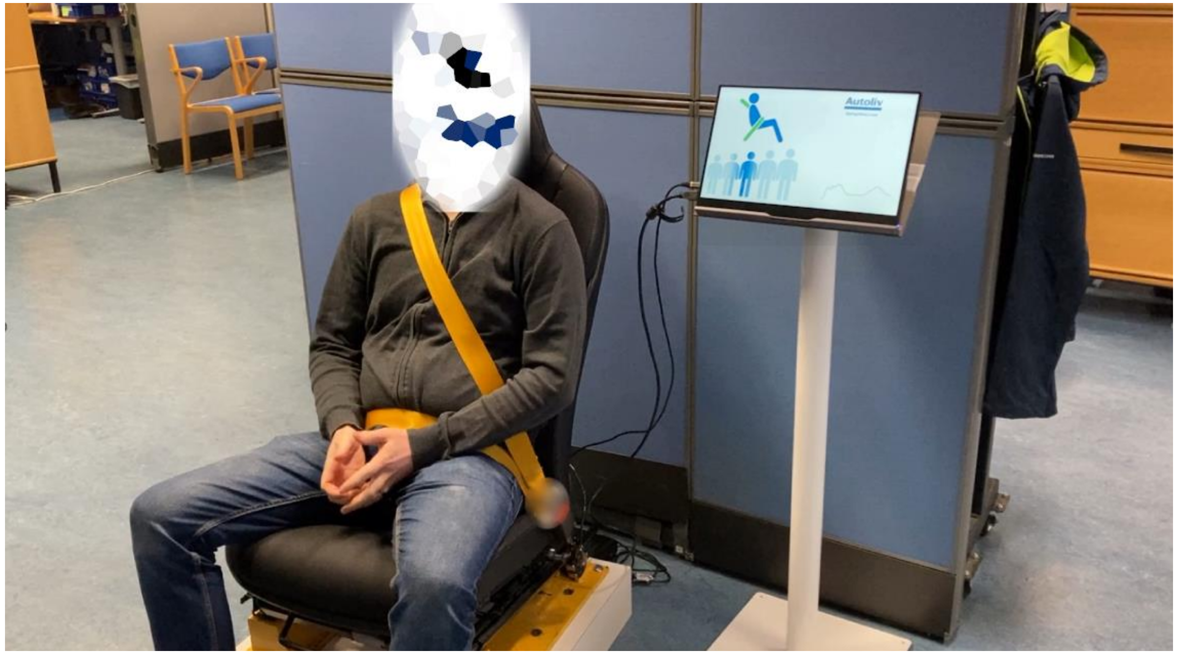
Belt-In-Seat: Linear Regression

Large size



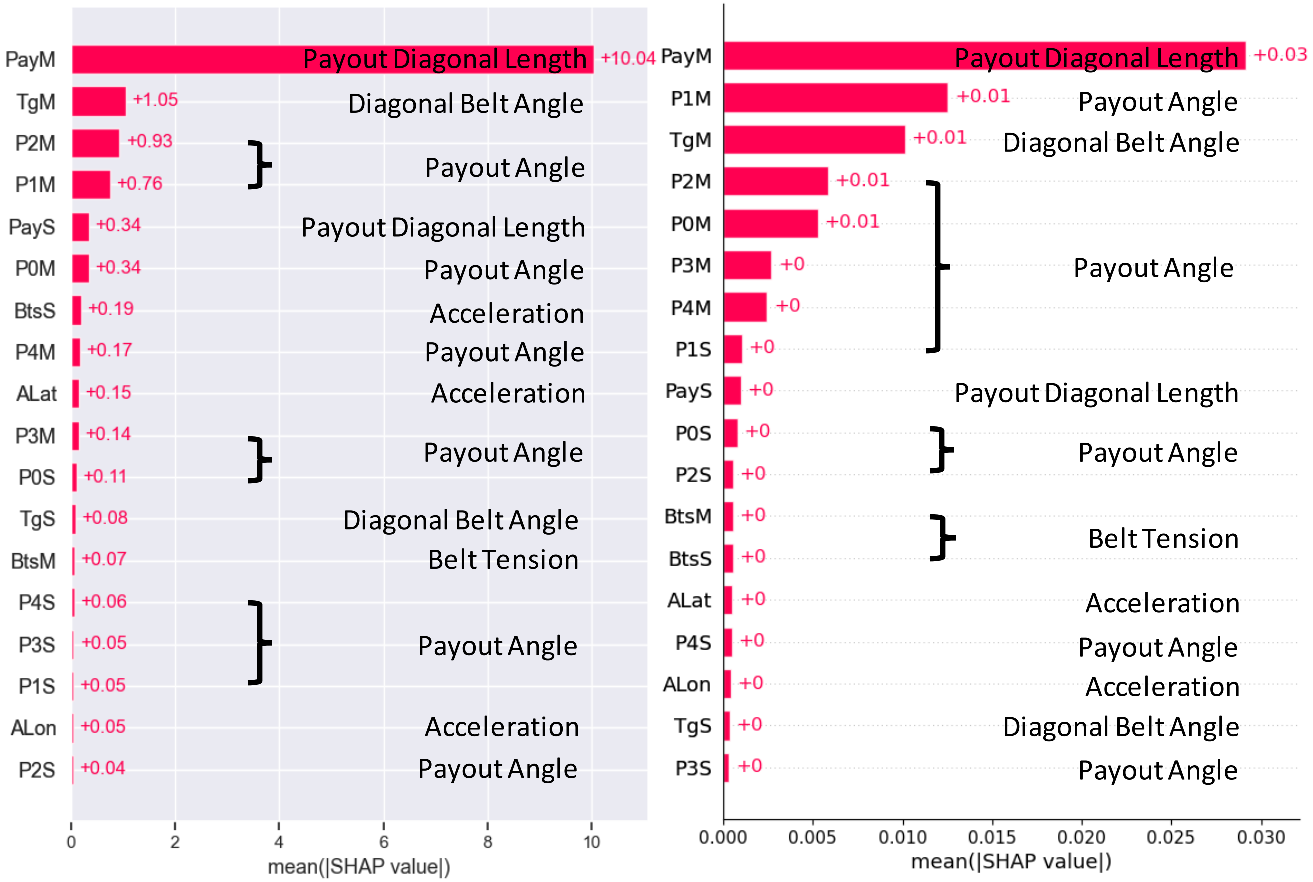
Medium size



Belt-In-Seat: Machine Learning

- Decision tree regression model: XGBoost
- 18 Features:
  - Mean and standard deviation over *2 s* moving window:
  - Payout diagonal length
  - Payout angle
  - Diagonal buckle angle
  - Buckle tension.
  - Acceleration
- Accuracy level:
  - Average height error: ~ 5 cm
  - Average weight error: ~ 5 kg
- Feature analysis:
  - SHAP (SHapley Additive exPlanations) analysis: value connects to contribution
  - Suggest minimum model of features:
    - Payout angle mean
    - Payout diagonal length mean
    - Diagonal buckle angle mean

SHAP value



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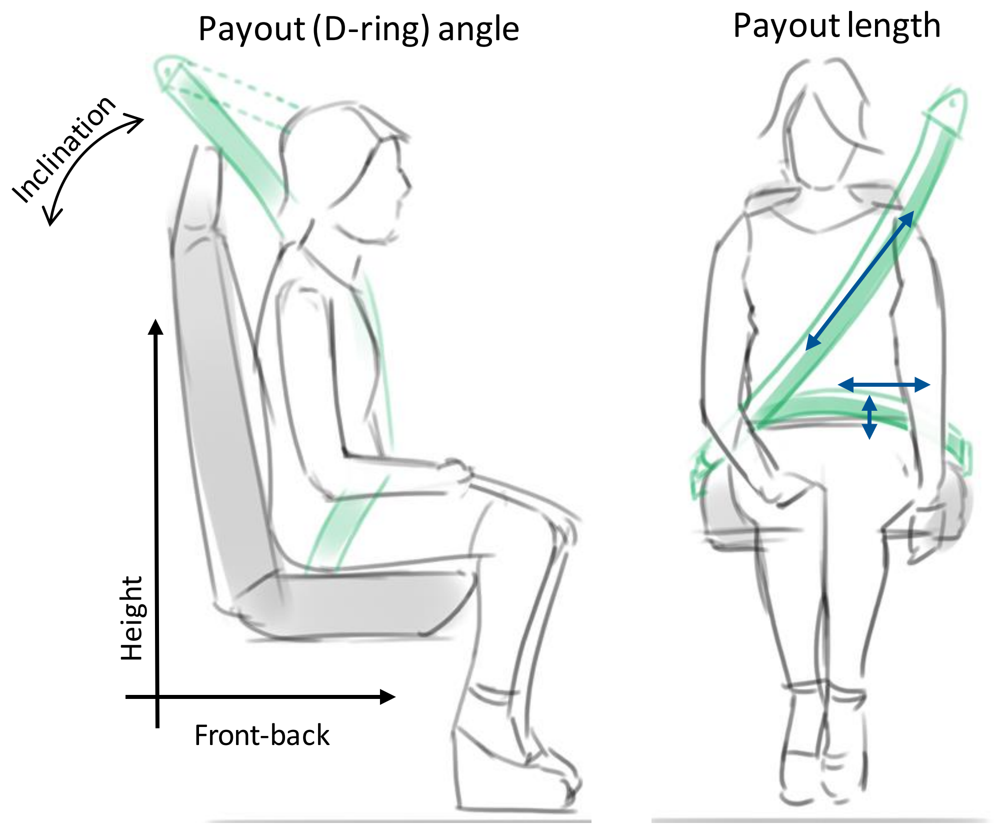
B-pillar Belt: Configuration

- Mainstream configuration in the market
- B-pillar outlet and floor fixation
  - Seat position affects measurement
  - Payout length changes while seat is moved
- Instrumentation
  - Belt sensors:
    - Payout angle sensor: rotation of D-ring
    - Retractor provides total length
    - Invented lap belt sensor: lap belt length and lifting angle (ongoing)
  - Seat sensors:
    - Pan position: front-back and height
    - Seat back inclination angle



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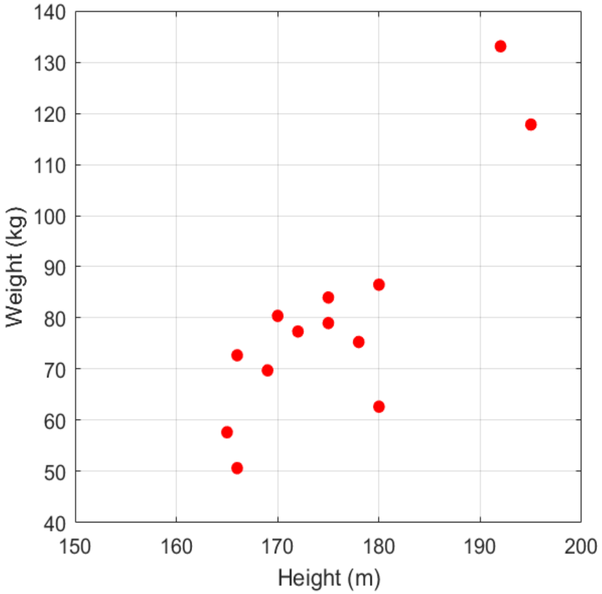
B-pillar Belt: Static car test

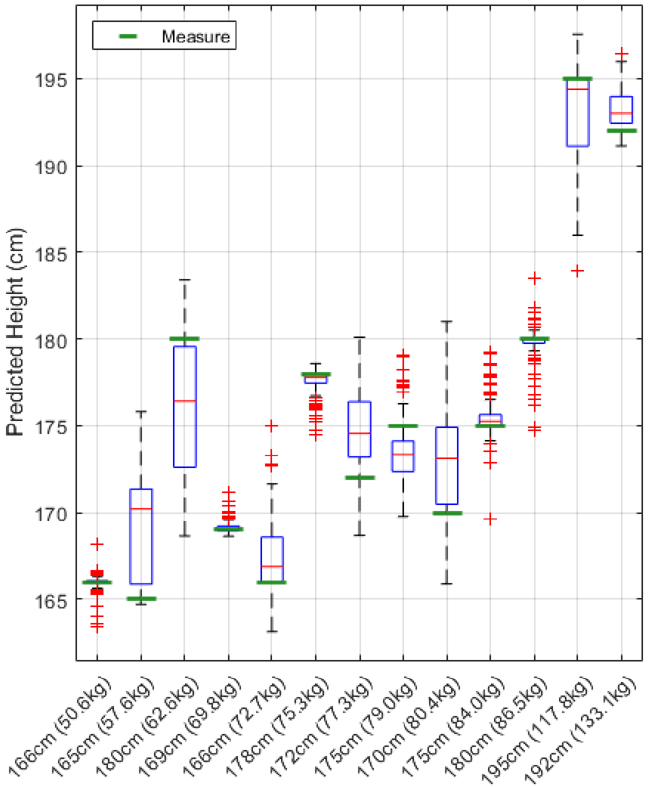
- Participants sit still on the seat and buckled on
  - 13 participants data are collected
- Test PC controls the seat moves to different pan and back position automatically
- At each seat and back position stop for 5s to collect data.

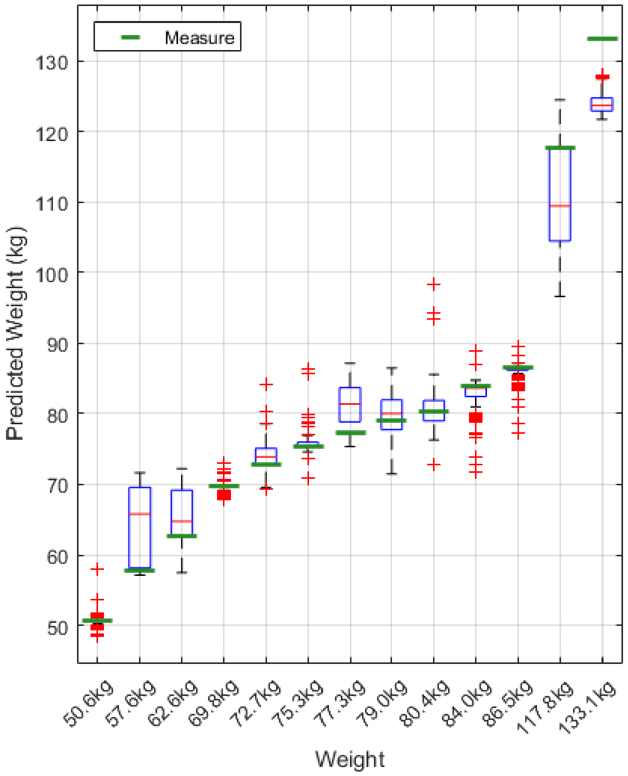
Test population



B-pillar Belt: Machine Learning

- XGBoost decision tree model
- Features are sampled mean and standard deviation when seat stops:
  - Payout length: diagonal, lap
  - Payout (D-ring) angle
  - Buckle tension
  - Seat pan height
  - Seat pan forward-backward position
  - Seat back inclination angle
- Preliminary result:
  - Prediction of all 100 seat positions for each participant
  - Prediction in general is not satisfactory
  - Weight prediction seems better for medium group
  - Small dataset leads to week performance





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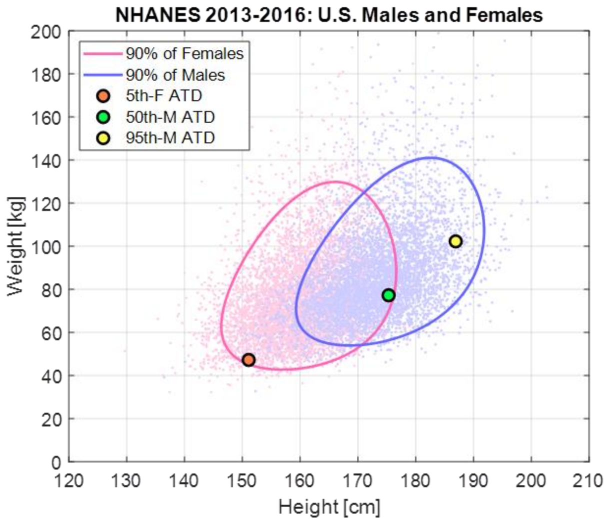
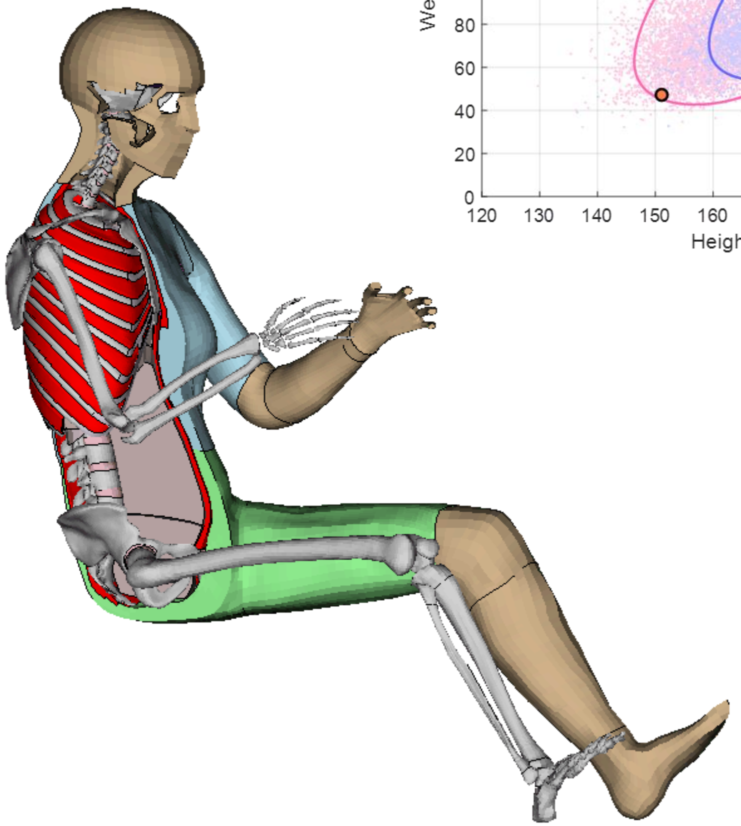
B-pillar Belt: Simulation Test

- Motivation:
  - Understand influence of body shape and seat position towards belt shape
  - Generate data of rare body size
- Automated belt routing in pre-processing software ANSA
- Human body model: SAFER HBM
- UMTRI morphing method: parametric human body model morphing





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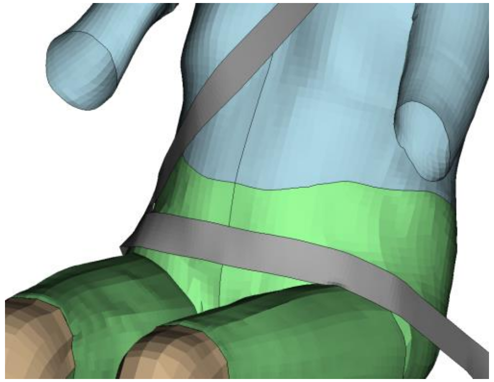
B-pillar Belt: Simulation Evaluation

- Simulate belt routing of participants "daily" seat position
- Compare payout length between simulation and car test
- Simulated payout length longer than test measurement:
  - 19 ~ 105 mm longer
- Possible source of discrepancy:
  - Inconsistency between the car body and the CAD model
  - Differences in body shape:
    - Soft tissue: checked by laser scanning
    - Athletic stature vs. HBM population average
  - Belt routing
  - Sitting posture: more straight up or more slack



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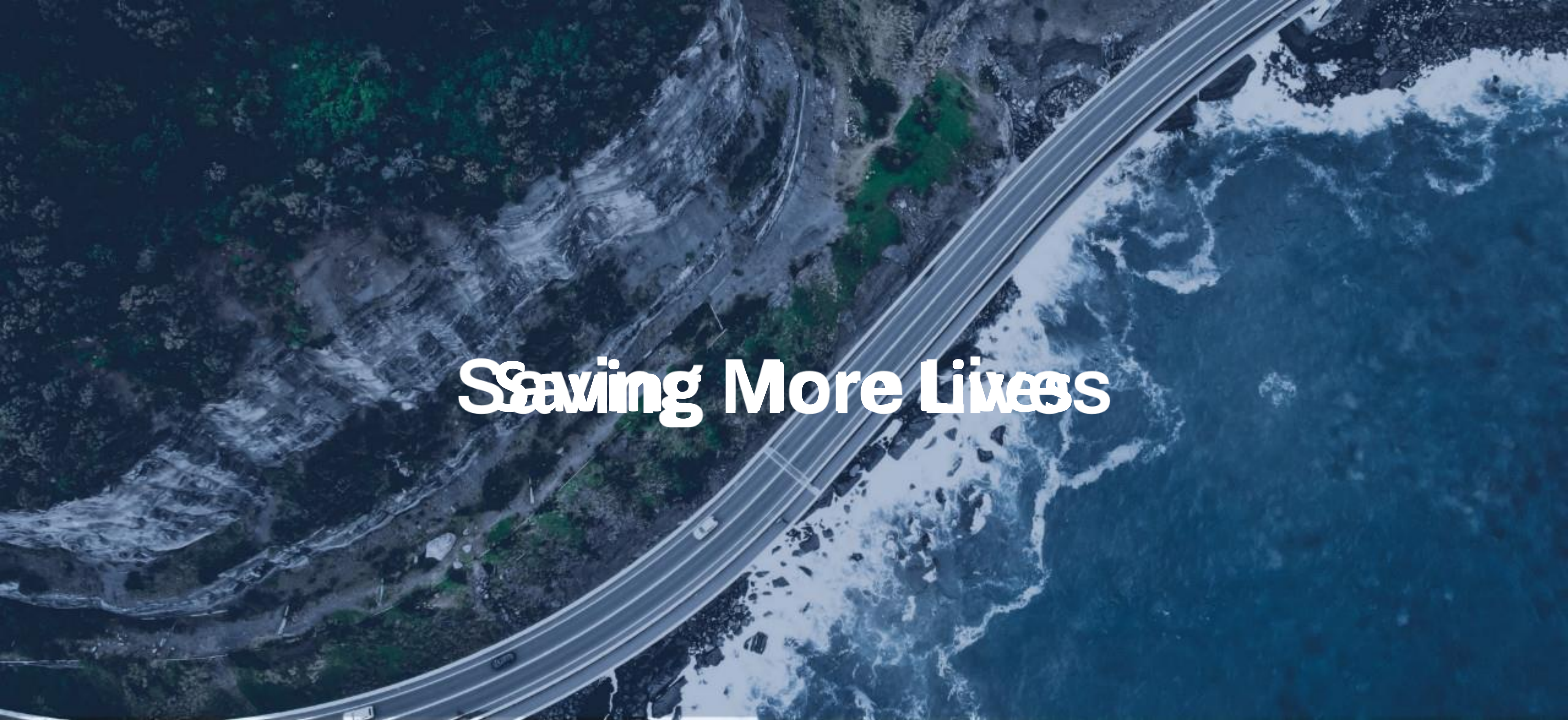
- Conclusion:
  - Belt based body estimation is possible
    - In belt-in-seat configuration the result is satisfactory
  - Data distribution is important to the prediction accuracy

- Next step:
  - Continue data collection in the car test
  - Driving car test on the test track
  - Consider introduce more variance in HBM shape and sitting posture
  - Create data by simulations

Question and Answer



Saving More Lives

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