Probabilistic Estimation of the Driver's Gaze from Head Orientation and Position

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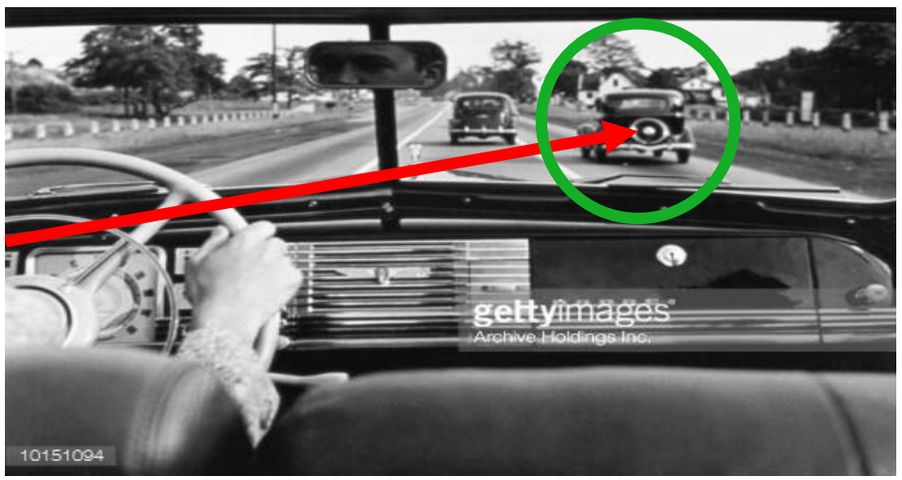
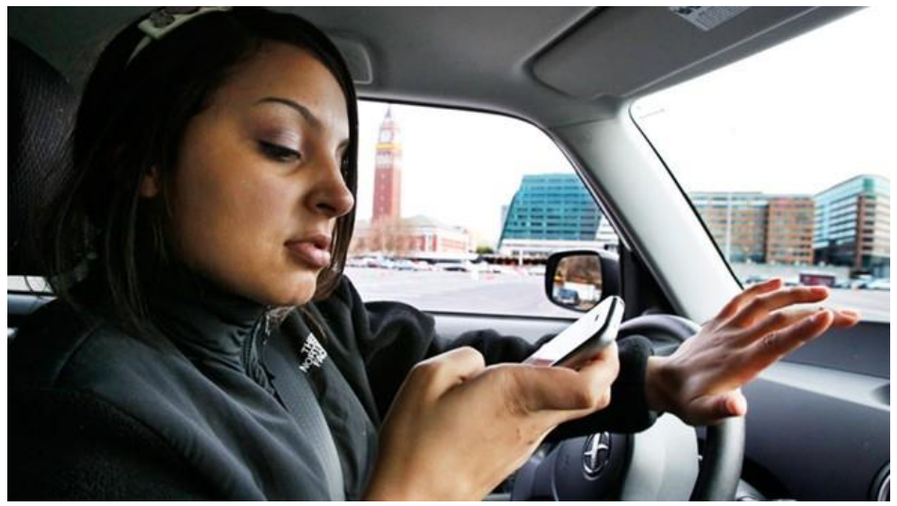


Drivers' Visual Attention

- Primary driving related task
  - Mirror checking actions [Li and Busso, 2016]
  - Lane change
  - Turns and cross sections



- Secondary tasks
  - Mobile phones and in-vehicle entertainment unit
  - Co-passengers in the car
  - Billboards and other distractions from the environment

Nanxiang Li and Carlos Busso, "Detecting drivers' mirror-checking actions and its application to maneuver and secondary task recognition," IEEE Transactions on Intelligent Transportation Systems 17 (4), 980-992.

Motivations

- Gaze detection challenging in car environment
- It is often approximated by head pose
- While head pose is strongly correlated with gaze, a one-to-one relation does not exist [Jha and Busso, 2016]

Left mirror

Right mirror

Rear mirror

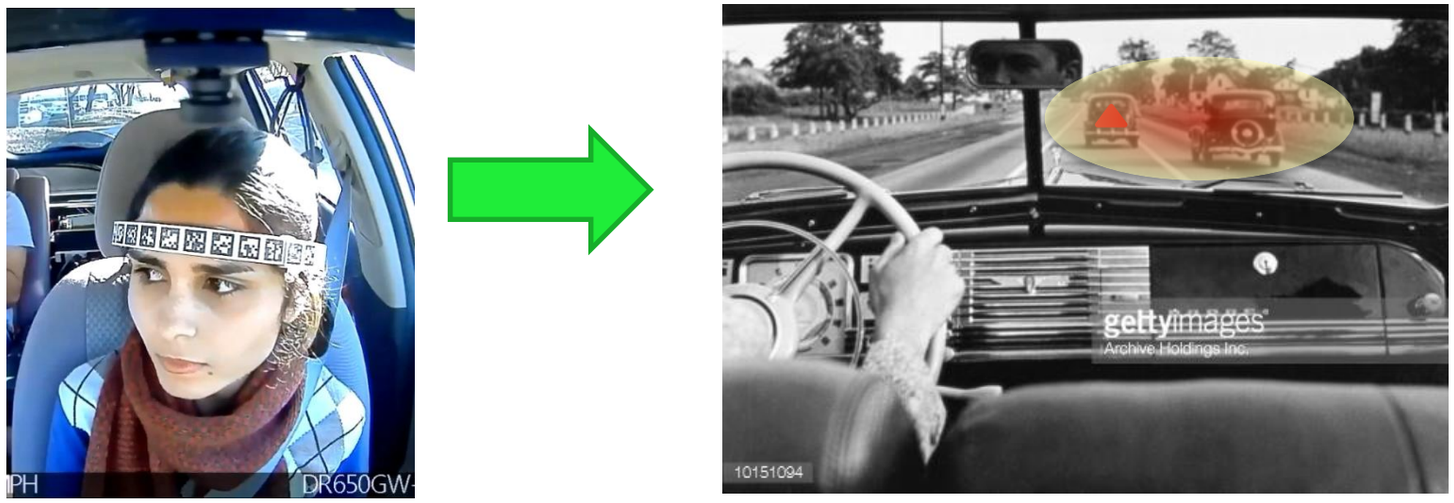
- Goal of this study is to provide a probabilistic prediction of driver's visual attention from head pose

S. Jha and C. Busso. Analyzing the relationship between head pose and gaze to model driver visual attention. In *International Conference on Intelligent Transportation Systems (ITSC 2016)*, pages 2157–2162, Rio de Janeiro, Brazil, November 2016.

Objective

- Head pose – Gaze relation non-deterministic, depends on
  - Location of gaze
  - Driver
- Use probabilistic model that can provide a distribution of confidence

Visual Attention Estimation



Outline

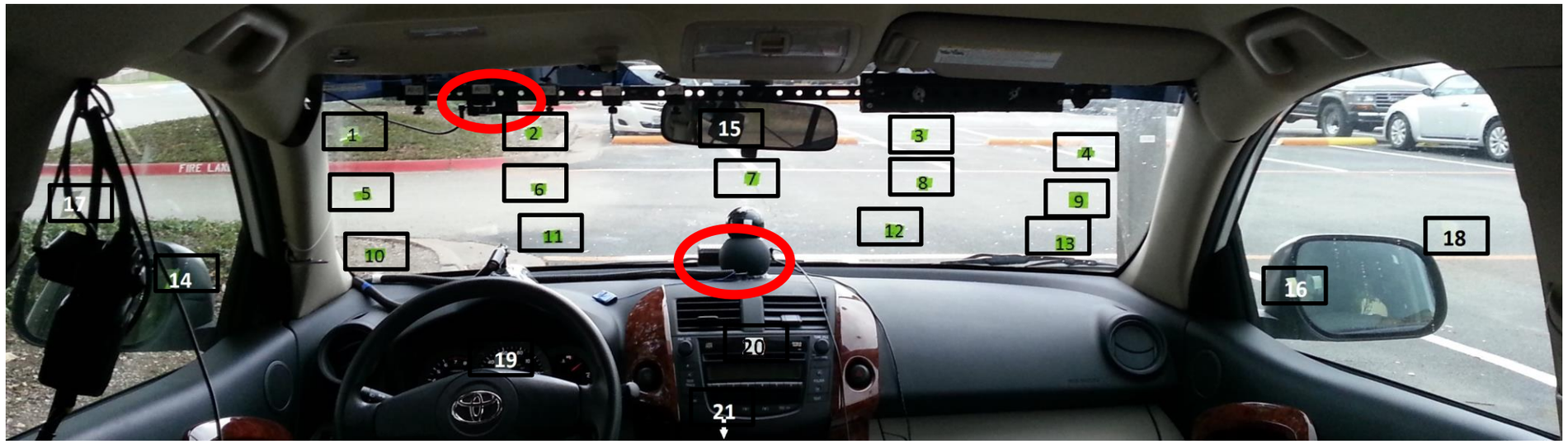
- **Dataset**
- Gaussian Process Regression (GPR) model
- Experimental Evaluation
- Conclusions

Data Collection

- Relate the head pose to ground truth gaze locations
- UTDrive platform

- Dash Cameras used instead of the on-board equipment
  - Blackvue dr650gw 2 channel

Experimental Setup



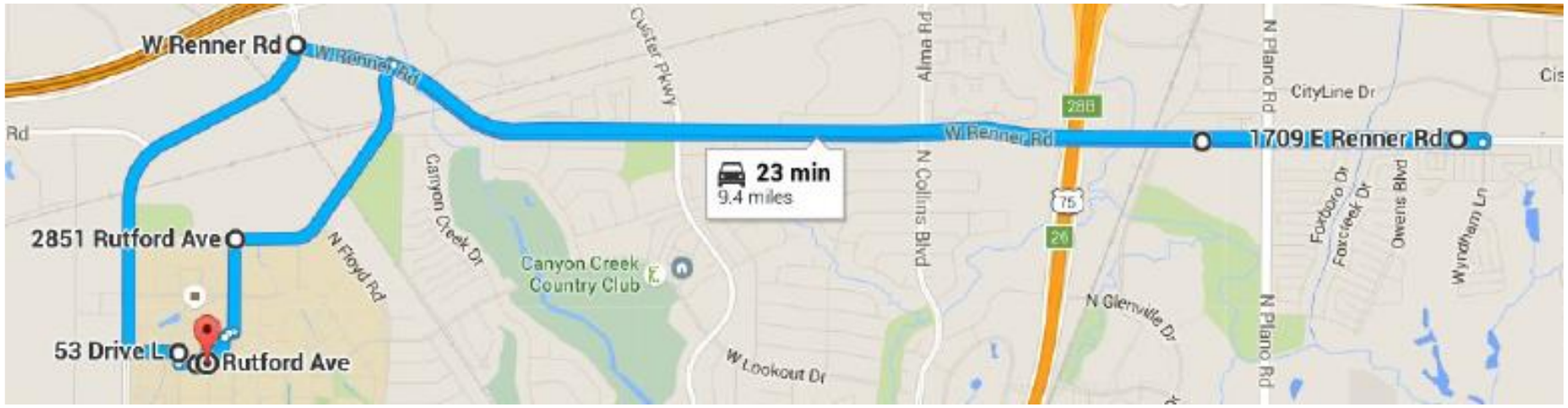
- Rear camera → Face
- Front camera → Road
- Markers placed at
  - windshield (no. 1-13)
  - mirrors(no. 14-16)
  - side windows (no. 17-18)
  - speedometer panel (19), radio (20), and gear (21)
- Data collected with 16 subjects (10 males, 6 females)

Phase 1
(Natural Gaze – Parked Vehicle)

- Collected in a parked car
- Subject asked to look at each point five times in a random order (21x5 = 105 data per subject)
- Natural variability in head pose without the constraint of driving task
- The driver familiarizes to the core task

Phase 2
(Natural Gaze - Driving)

- Collected when the subject is driving the car
- Subject asked to look at points
- Data collected in a straight road with minimum maneuvering task



AprilTags for Head Pose Estimation

- Head pose estimation challenging in driving environment
- AprilTags [Olson, 2011]
  - 2D barcodes that can be robustly detected in an image
- Headband designed with 17 AprilTags
- Useful for robust detection of head pose across conditions

Olson, Edwin. "AprilTag: A robust and flexible visual fiducial system." *Robotics and Automation (ICRA), 2011 IEEE International Conference on*. IEEE, 2011.

Outline

- Dataset
- **Gaussian Process Regression (GPR) model**
- Experimental Evaluation
- Conclusions

Linear Regression Model for Gaze Estimation

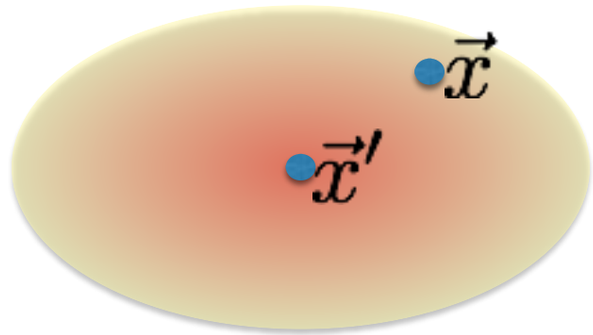
- linear relationship between Head Pose and Gaze location
  - $x_0 = a_0 + \overbrace{a_1 x + a_2 y + a_3 z}^{\text{Position}} + \overbrace{a_4 \alpha + a_5 \beta + a_6 \gamma}^{\text{Orientation}}$
- R-squared value

	Phase 1 (Parked)		Phase 2 (Driving)	
	Train	Test	Train	Test
x_0	0.78	0.77	0.69	0.73
y_0	0.36	0.12	0.36	0.16
z_0	0.25	0.10	0.24	0.12

- High correlation but not enough for a practical gaze prediction from head pose

Gaussian Process Regression

- Get a confidence region instead of a deterministic output
- Output assumed to be a Gaussian Process generated from the input variables



$$Y = \boxed{h(\vec{x})^T \beta} + \boxed{f(\vec{x})}$$

Deterministic component

Probabilistic component

$$f(\vec{x}) \sim GP(0, K(\vec{x}, \vec{x}'))$$

$$K(\vec{x_1}, \vec{x_2}) = \sigma_f^2 \exp\left(\frac{-|\vec{x_1} - \vec{x_2}|^2}{2l^2}\right)$$

The value of the cross covariance is high for close points

GPR Implementation

- Used GPR to model the gaze direction from the head pose
- Inputs → Head position (x,y,z) and angles (α (Yaw), β (Pitch) and γ (roll))
- Output → α_{gaze} and β_{gaze}(angle of the vector between the head and the gaze location)
- Leave one out cross-validation (LOOCV) – train with 15 subjects and test with the 16^{th}

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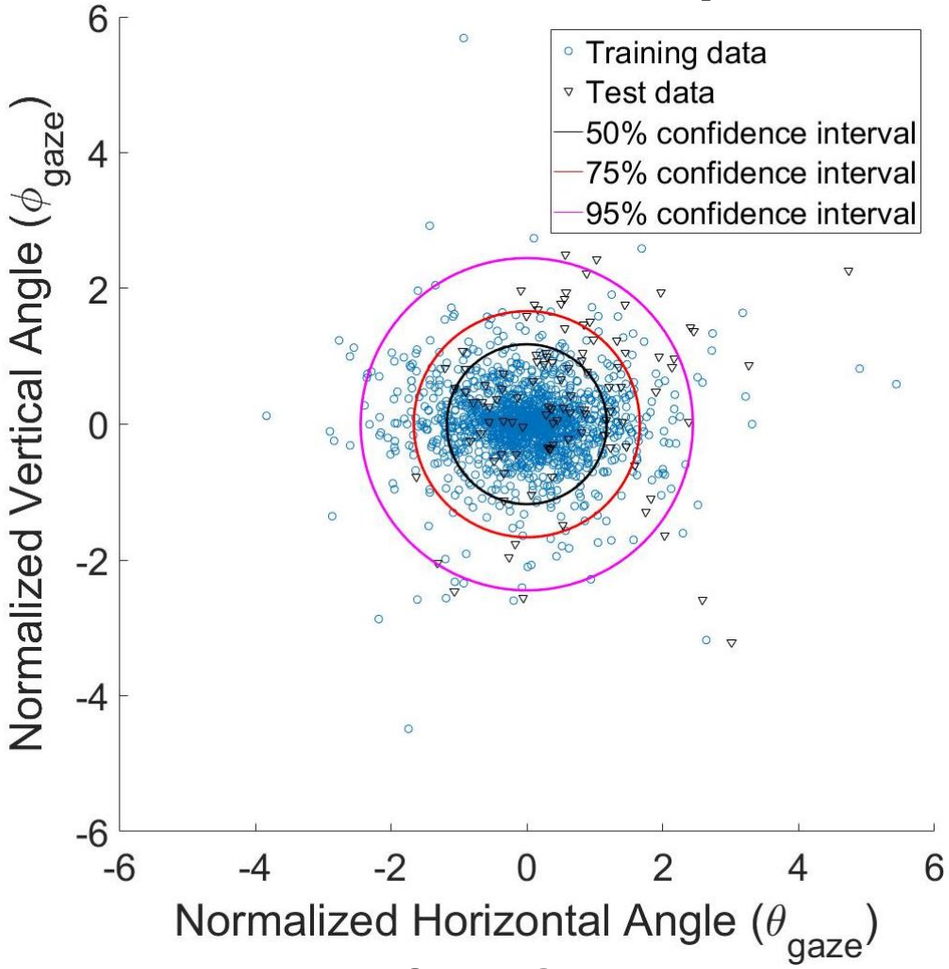
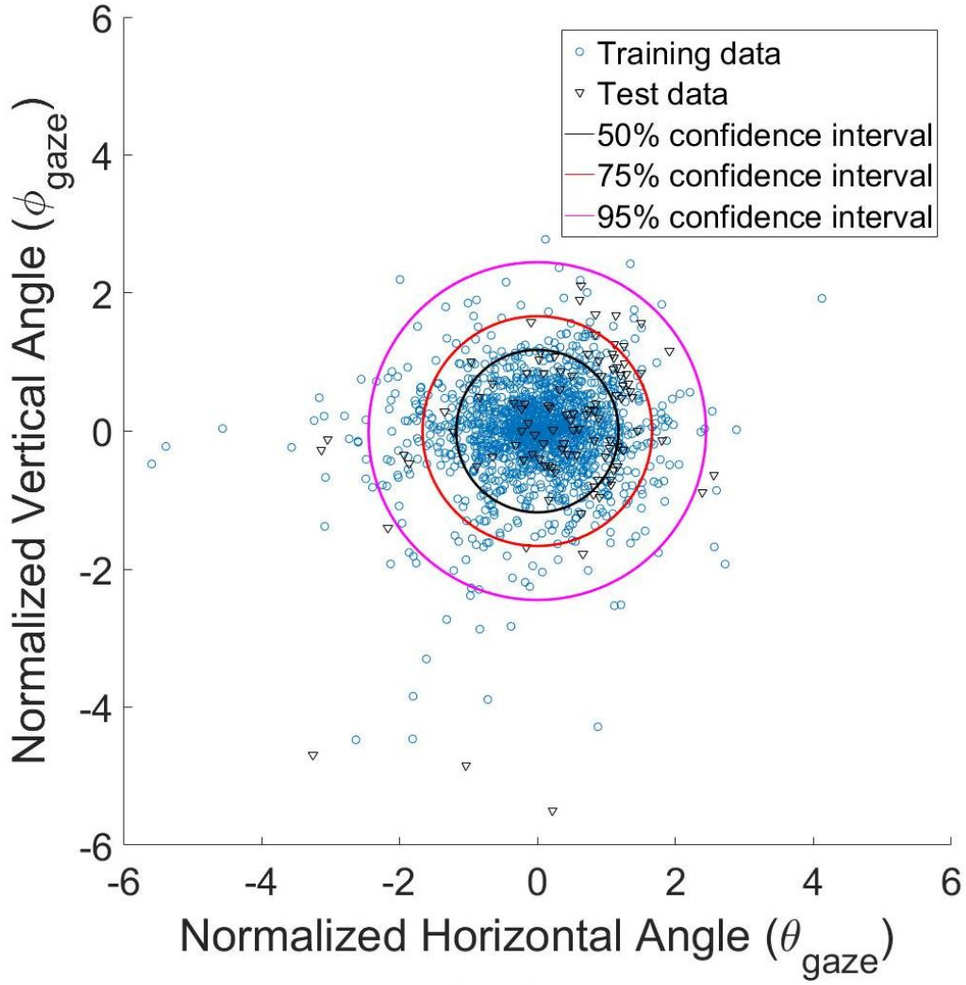
GPR Performance

- Normalized distance of the true gaze location from the predicted distribution
  - $\theta_{norm} = \frac{\theta_{true} - \mu_{pred}}{\sigma_{pred}}$



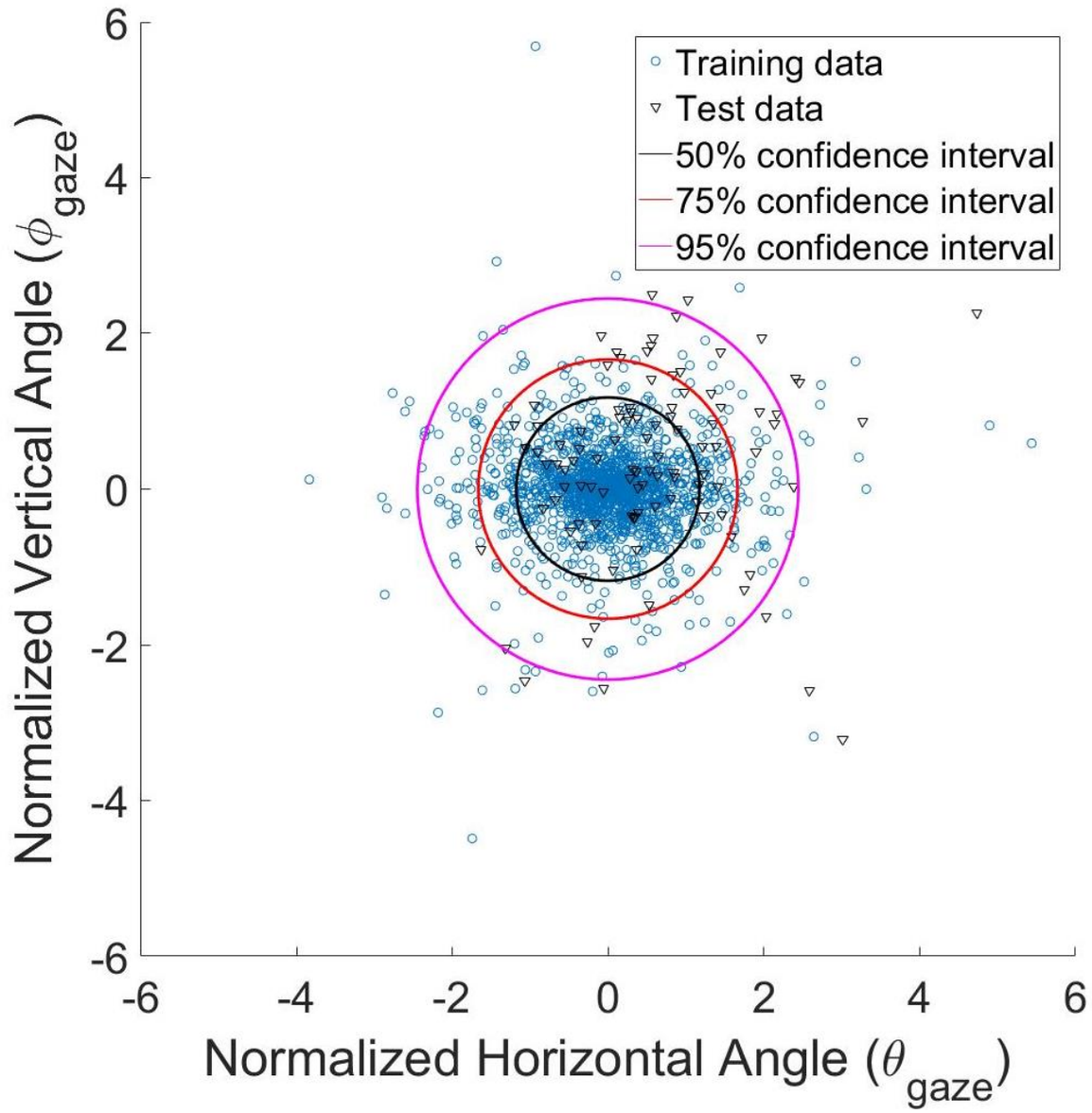
Parked car



Driving

GPR Performance Phase 1 (Parked Car)

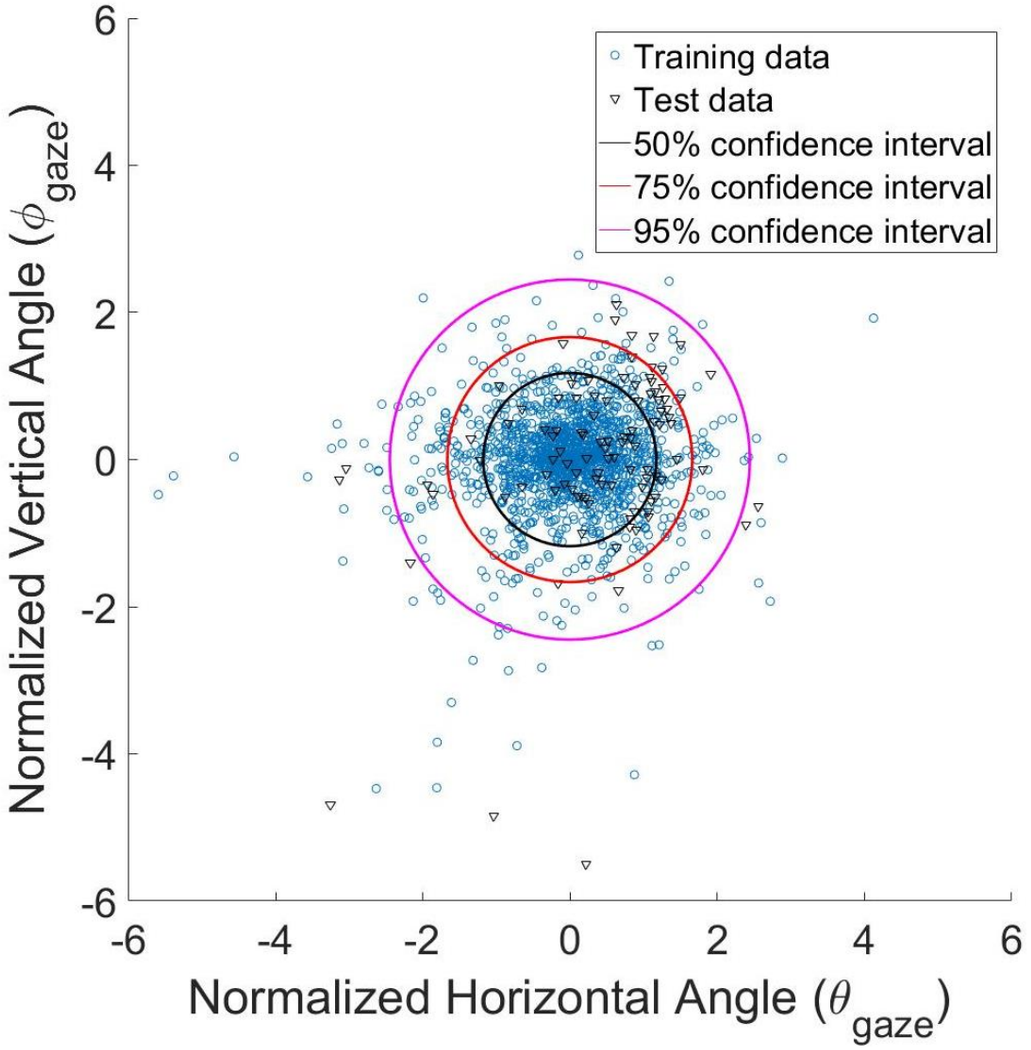
- Observations
  - 60% data is concentrated within 50% CI
  - 95% CI includes 90% gaze target



Gaussian Confidence Interval	Training Data	Test Data
50% region	77.77%	61.34%
75% region	89.45%	78.44%
95% region	96.51%	90.35%

GPR Performance Phase 2 (Driving)

- Observations
  - Slightly lower performance and generalization
  - 95% CI includes 89% gaze target



Gaussian Confidence Interval	Training Data	Test Data
50% region	74.5%	56.3%
75% region	88.5%	76.6%
95% region	96.8%	89.4%

Mapping Region of Gaze on the Windshield

- Project the predicted confidence interval of gaze on the windshield
- Compare with the ground truth
- Small area shows high confidence in prediction of visual attention
- Larger area more accurate but low confidence






Mapping Region of Gaze on the Windshield

Mapping the Distribution to Road

- Distribution obtained at different depth value from the distribution of α and β angles
- PDF values for the 3D coordinates summed up for depth values for each Pixel

Region of Gaze on the Road

Conclusions and future work

- Probabilistic approach to gaze from head pose
- Confidence region instead of deterministic regression gives more intuitive results
- Future Works
  - Relate with ground truth on the roads
    - Road signs
    - Other cars
  - Study different types of gaze shifts
    - Exogeneous shifts – based on external stimuli
    - Endogenous shifts – based on driver's intention

Prospective Applications

Warning: Pedestrians on the Road Driver Unaware!!

Info: House no xxxx located Arrive at destination

Thank you!

Questions?

Warning: Pedestrians on the Road Driver Unaware!!

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