Analysis of Head Pose as an Indicator of Driver's Visual Attention

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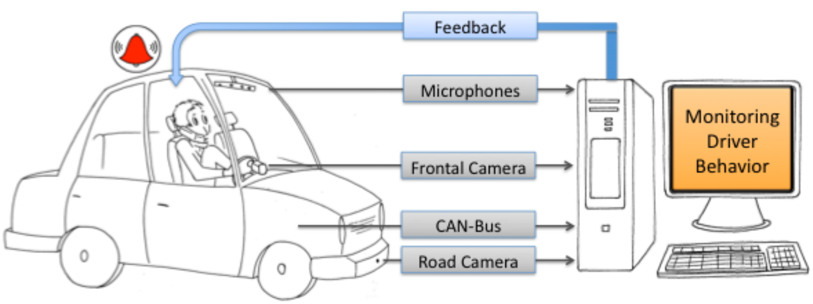
Detecting Driving Distraction at MSP

- Key Problems:
  - Detect inattentive drivers using noninvasive sensors
  - Study realistic scenarios with real car driving in real roads

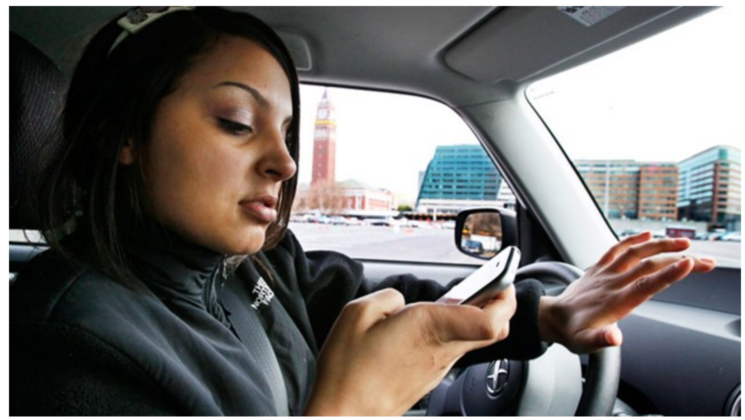
Nanxiang Li, Jinesh J. Jain, and Carlos Busso, "**Modeling of driver behavior** in real world scenarios using multiple noninvasive sensors," IEEE Transactions on Multimedia, vol. 15, no. 5, pp. 1213-1225, August 2013.

Nanxiang Li and Carlos Busso, "**Predicting perceived visual and cognitive distractions** of drivers with multimodal features," IEEE Transactions on Intelligent Transportation Systems, vol. 16, no. 1, pp. 51-65, February 2015.



Drivers' Visual Attention

- Primary driving related task
  - Mirror checking actions (situational awareness)
  - Lane change
  - Turns and cross sections



- Secondary tasks
  - Visual Distraction for longer duration or one with high angle generally involves more head movement.[Zhang, 2008]
  - Cognitive distraction ("*looking but not seeing*")

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, vol. To appear.

Motivations

- Gaze detection is a challenging problem in car environment
- It is often approximate by head position [Lee et al., 2011]
- Coarse direction of driver's gaze is enough for most in-vehicle applications [Tawari & Trivedi, 2014; Doshi & Trivedi, 2009]

Left mirror

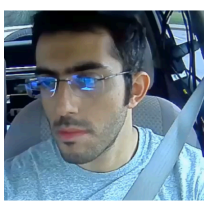
Right mirror

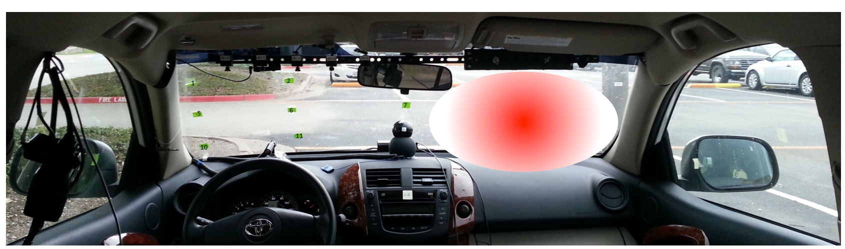
Rear mirror

- Goal of this study is to analyze the relationship between gaze and head pose

Objective

- Questions
  - How well does the head pose of the driver represent his/her gaze (visual attention)?
  - How much does the head pose varies when the driver is looking at a certain direction?
  - Can we define a confidence map for the drivers' gaze (visual attention) using head pose?





Experimental Design

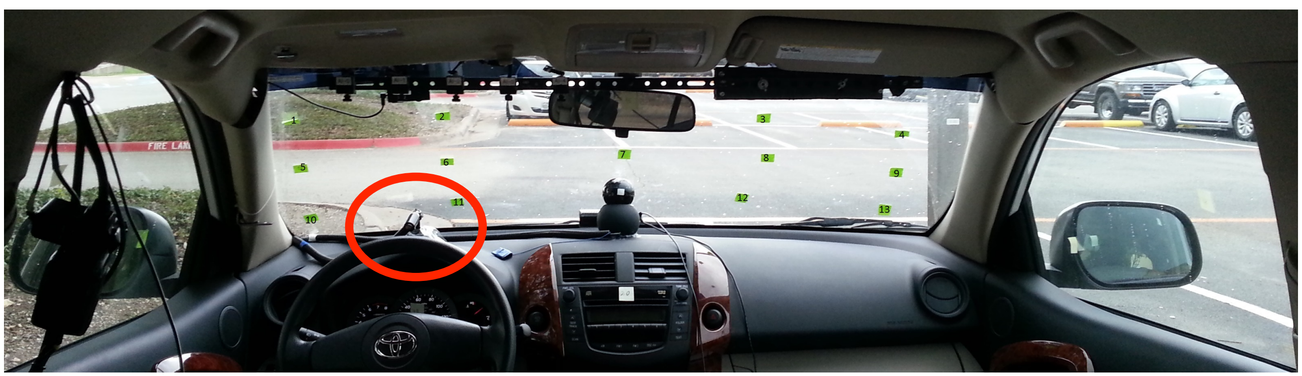
- Markers placed at the windshield and other locations of visual interest (mirrors, blind spot) in the UTDrive platform
- Participants are asked to look at markers

Unconstrained: "look at the point #4"

  - When the car is parked
  - When the subject is driving

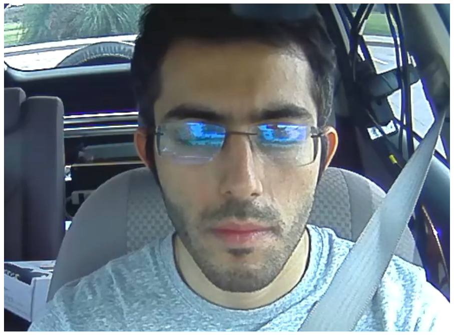
Constrained: "head pose directed towards the mark"

  - When the car is parked

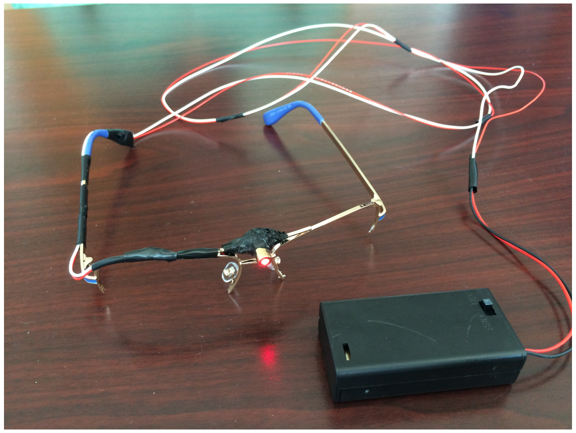


Unconstrained Condition

- Natural head poses
- Driver asked to look at various locations without further instructions
    - Collected when the car is parked and when driving
    - Multiple reading for each mark to capture the variance


Constrained Collection



- We use a glasses' frame with laser pointer at the center
- The participants wore the frame, pointing to the target marks
  - Helps to establish a reference head pose without bias due to pupil movement (i,e., head pose = gaze)



Data Collection

- Cameras placed to record the driver's face and the road scene.
  - Used commercially available Dash camera (Blackvue dr650gw 2 channel) for the recording
    - Front camera for the road and rear camera for driver's face
    - Also records GPS and accelerometer data

- Pilot recording with four participants
  - Markers are randomly asked
  - Operator marked when the subject looks at markers

Data Collection (cont.)

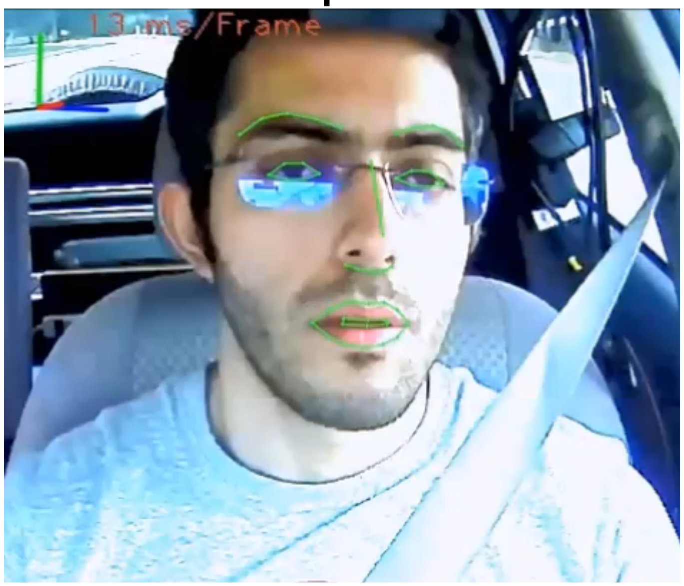
Unconstrained
parked

Unconstrained
driving

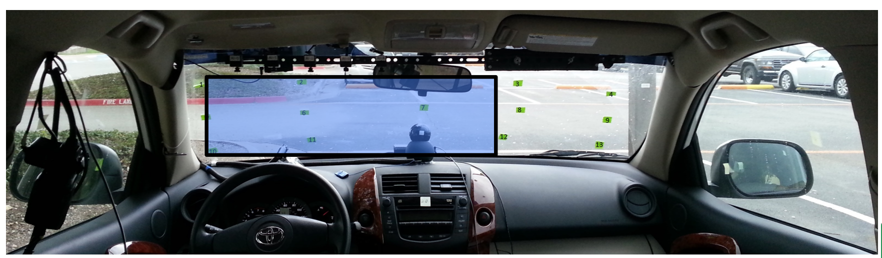
Constrained
parked

Head Pose Estimation

- Used CMU's Intraface tool for head pose estimation
  - Yaw, pitch and roll

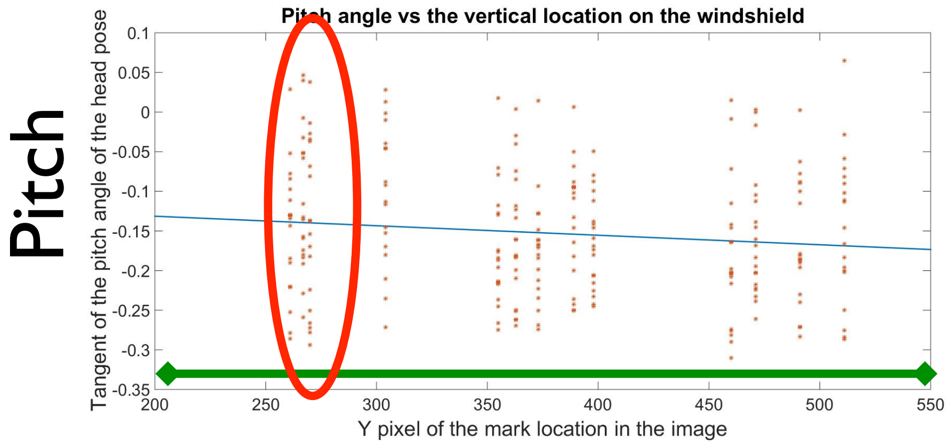


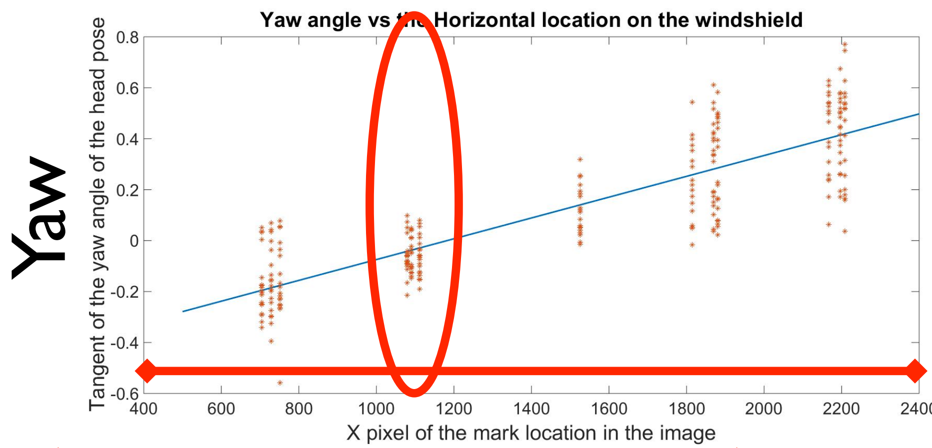
Very accurate when head pose is directed toward this area

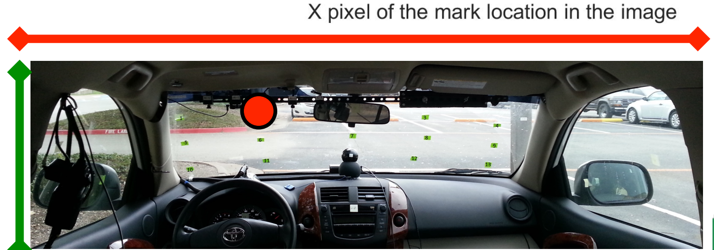


Head pose variability per marker

- Observations
  - Pitch highly unpredictable, low correlation with gaze direction
  - Yaw angle has high correlation
    - The mean of the angles have linear relationship
    - The variance increases as the gazes direction increases







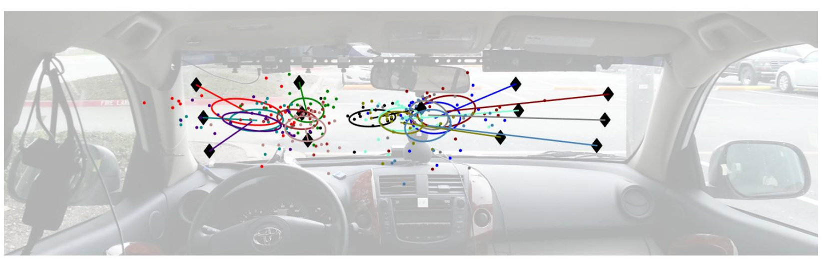
Mapping head pose to markers

- We train regression model to map head pose into x,y coordinates
  - Input variable: head pose angle
  - Output variable: x or y coordinate in the windshield (in pixels)

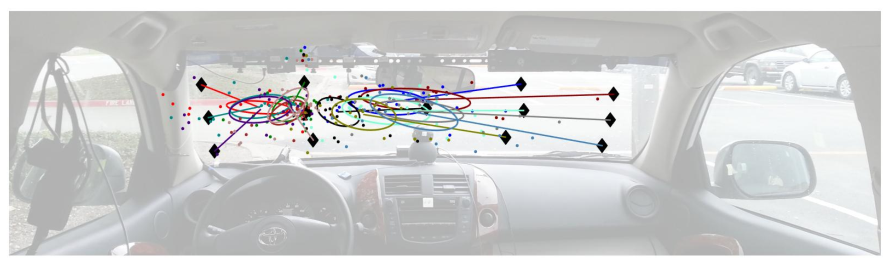
$$Estimated_x = \alpha_0 + \alpha_1 \tan(yaw)$$

$$Estimated_y = \alpha_0 + \alpha_1 \tan(pitch)$$

- We use constrained recordings where we know the intended coordinates
  - Ellipsoids define confidence regions



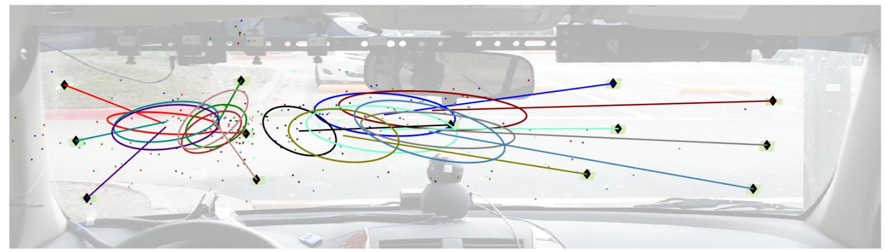
Unconstrained - parked



Unconstrained - driving

Mapping head pose to markers (cont.)

Unconstrained - parked

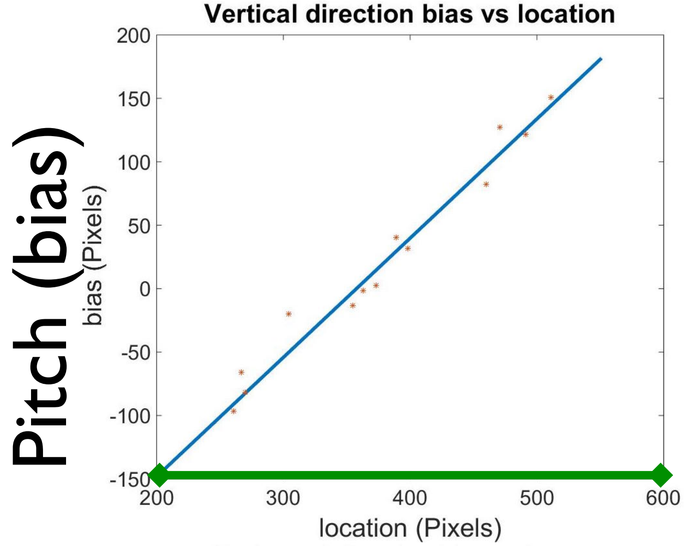


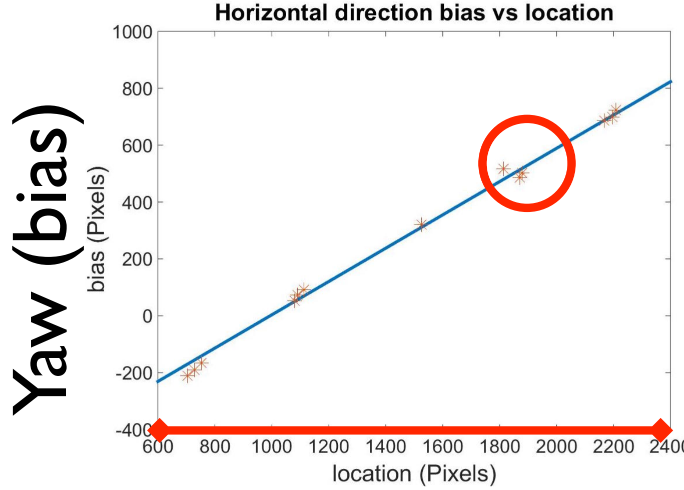
Unconstrained - driving

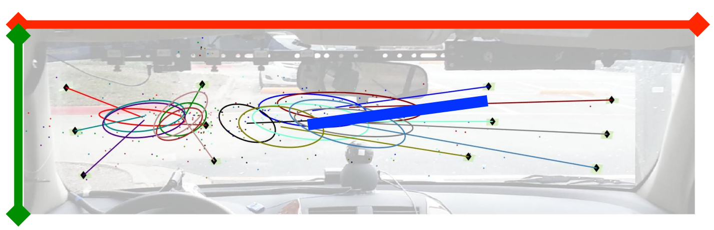
- Observations
  - More variance (hence less predictability) when driving
  - The length of the line represents the bias due to pupil movement between head pose and actual gaze
    - The bias increases as the direction moves away from the frontal pose
  - Clear separation of gaze zones (front vs left)

Head pose / gaze bias

- Bias increases for markers away from the center
  - Pupil movement is important
- Bias completely determines the vertical location
  - Slope in vertical direction is 1
  - No dependency on head pose





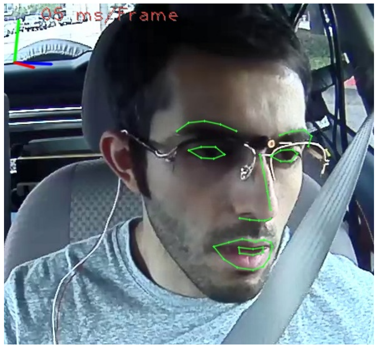


Discussion

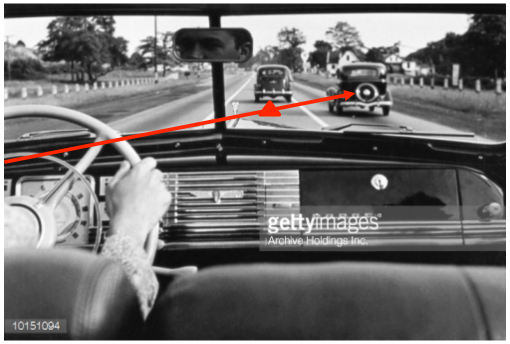
- High correlation in horizontal direction between head pose and gaze
- Low correlation in the vertical direction
- Most of the applications requires the knowledge of horizontal gaze (eg. blind spot, mirror checking etc.)
- Coarse estimation of gaze is possible using head pose which gives a general direction about visual attention

Challenges

- Getting accurate head pose for highly skewed rotation



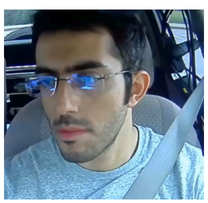
- Perspective mapping of point on the windshield to actual object in the road scene

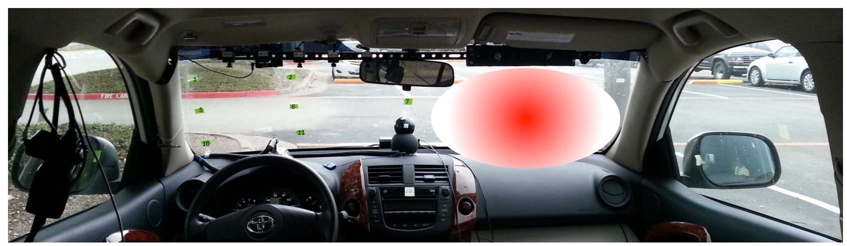


Future work

- Use probabilistic modelling approach to get confidence level on various gaze location given a certain head pose

$$P(gaze(x,y)|yaw,pitch,roll)$$





- Use road scene and contextual information for added confidence

- Extend the model to points not on the windshield (mirrors, windows, speedometer dial, radio etc.)

Thank you!

Questions?

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