EYE GAZE TRACKING FOR AUTOMOTIVE HMI

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  - Distraction Detection
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I³D

Context

Issues with Dashboard

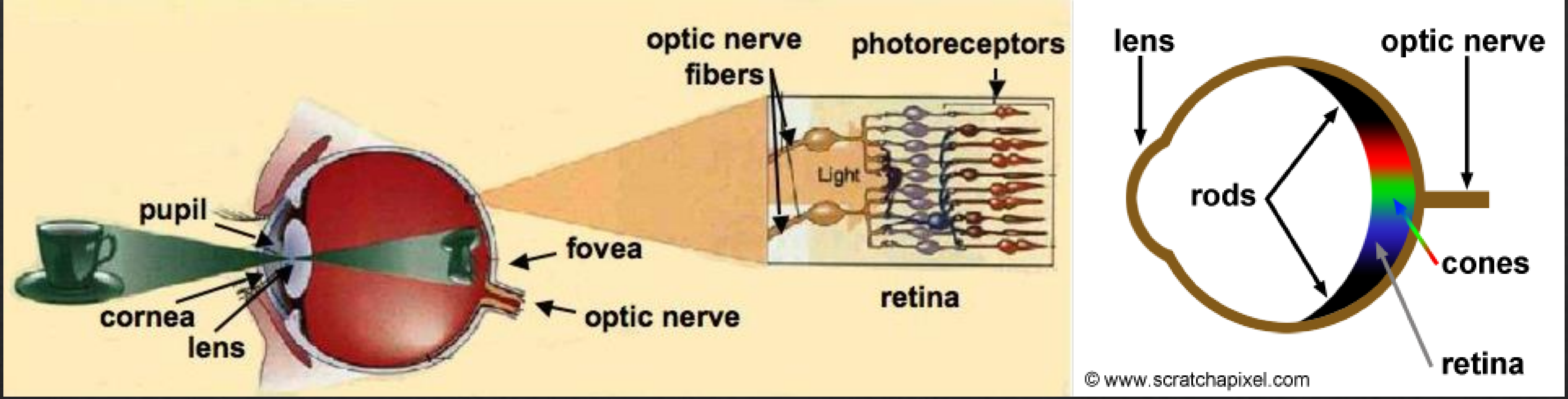
- Drivers take eyes off from road while operating dashboard
- Dashboard requires physical touch

State of the art

- Direct Voice Input
- Gesture Recognition system
- Hand/finger movement tracker

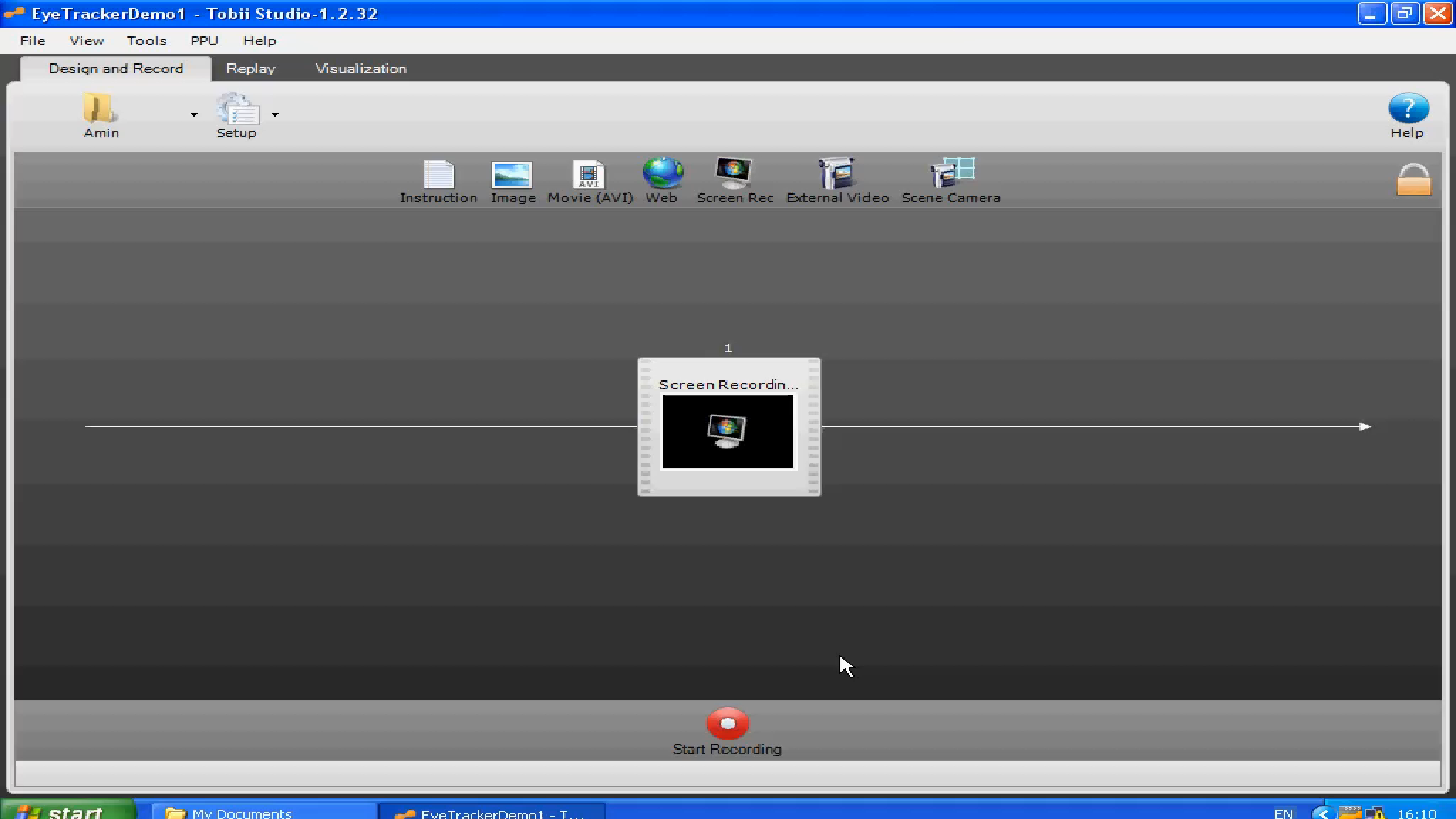
Existing Problem

- Accuracy of DVI changes for different languages and affective state
- Need to remember a set of gestures or screen sequence
- Intelligent prediction algorithm can not improve latency in infrared sensor

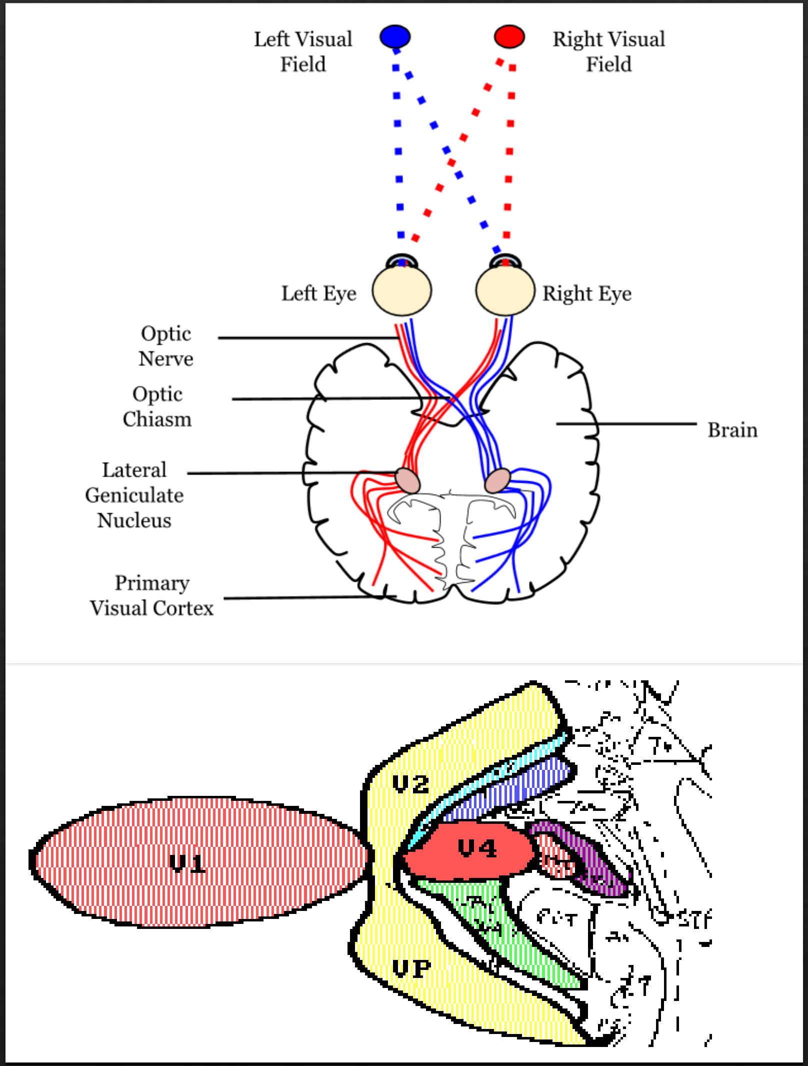


Human Eye

- FoV, both eyes combined 200-220°
- Peak visual acuity 0.5-1°
- Fovea 1-2°
- Head movement range approximately 50°
- Ratio of maximum to minimum perceivable light intensity is 10^{10}


EyeTrackerDemo1 - Tobii Studio-1.2.32
File
View
Tools
PPU
Help
Design and Record
Replay
Visualization
Amin
Setup
Help
Instruction
Image
Movie (AVI)
Web
Screen Rec
External Video
Scene Camera
1
Screen Recordin...
Start Recording
start
My Documents
EyeTrackerDemo1 - T...
EN
16:10

Visual Cortex



- Visual Pathway
  - Where and What Pathway
  - M and P pathway
- V1 – Primary visual cortex
  - Feature extraction
  - Colour and orientation feature
  - Mapping of retina on surface of cortex
- V2 region
  - Visual orientation map
  - Colour map
  - Disparity map
- V4 region
  - Colour recognition
  - Object discrimination
- V3 and V5 regions
- Motion
- Stereoscopic vision
- Visual guidance and scanning

Types of Eye Trackers

I^{3}D

Non-Intrusive

- Records natural interaction
- Have issues with ambient illumination, screen size and head movement

Intrusive

- Needs to wear glasses or head mounted device
- Supports head movement
- Works for small and big screen devices
  - Mobile phone, big display etc

Eye gaze tracking

Types of eye gaze

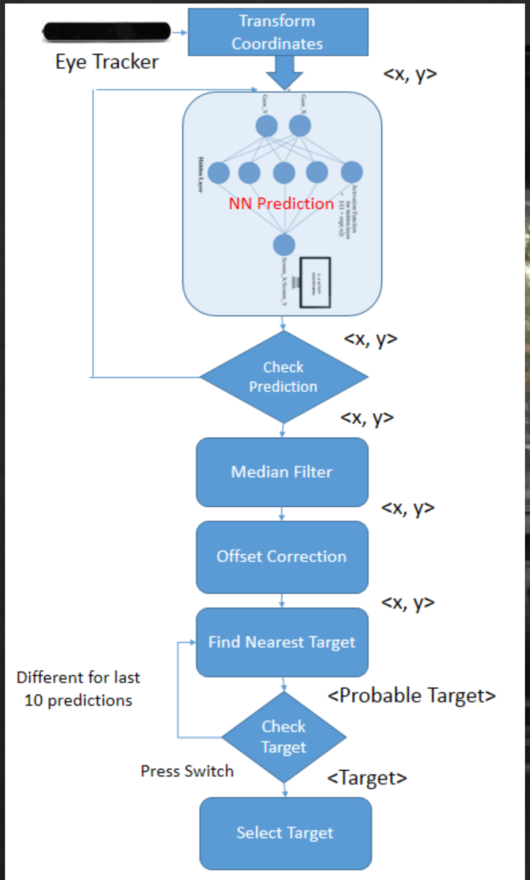
- Saccade
- Smooth pursuit
- Vergance
- Visual Search
  - Serial
  - Parallel

Example of log file

- Pupil diameter
- Pupil position
- Eye openness : Tells how wide the eye opened on a range of 0 to 1, 0 being the lowest, 1 being the highest
- Gaze direction: Gives the direction of the eye gaze in x,y,z coords
- Gaze origin: Gives the origin of the eye gaze, also in x,y,z coords
- Timestamp: Time spent in milliseconds looking at the object
- Object name

Challenge for eye gaze controlled interface in cars

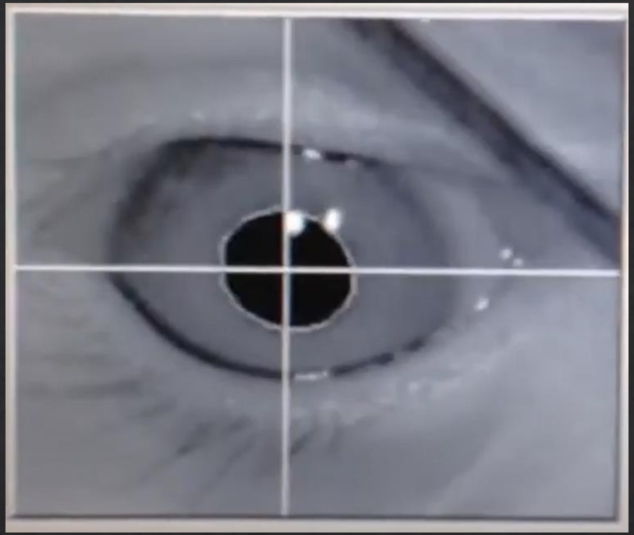
- Existing eye trackers are developed for desktop computing environment where
  - Tracker is attached below display
  - Display is bigger than car display and a flat screen
- We need to track eyes on a HUD or Central Stack
- Display was away from eye tracker
- Display surface may not be flat like a computer screen



G Prabhakar, A Ramakrishnan, LRD Murthy, VK Sharma, M Madan, S Deshmukh and P Biswas, Interactive Gaze & Finger controlled HUD for Cars, Journal on Multimodal User Interface, Springer, 2019

P. Biswas, S. Deshmukh, G. Prabhakar, M. Modiksha and A. Mukhopadhyay, System and Method for Monitoring Cognitive Load of a Driver of a Vehicle, Indian Patent Application No.: 201941052358, PCT Application No.: PCT/IB2020/062016, US Patent Application No.: 17/437,003

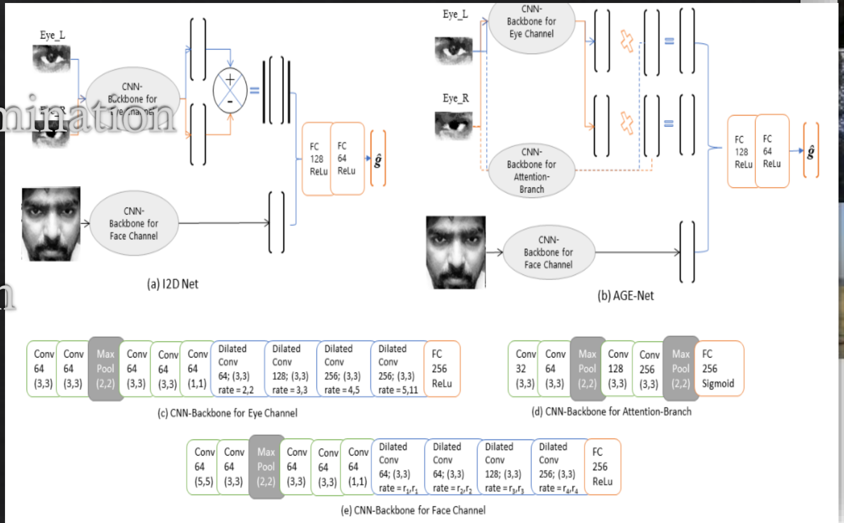
Problem with COTS trackers

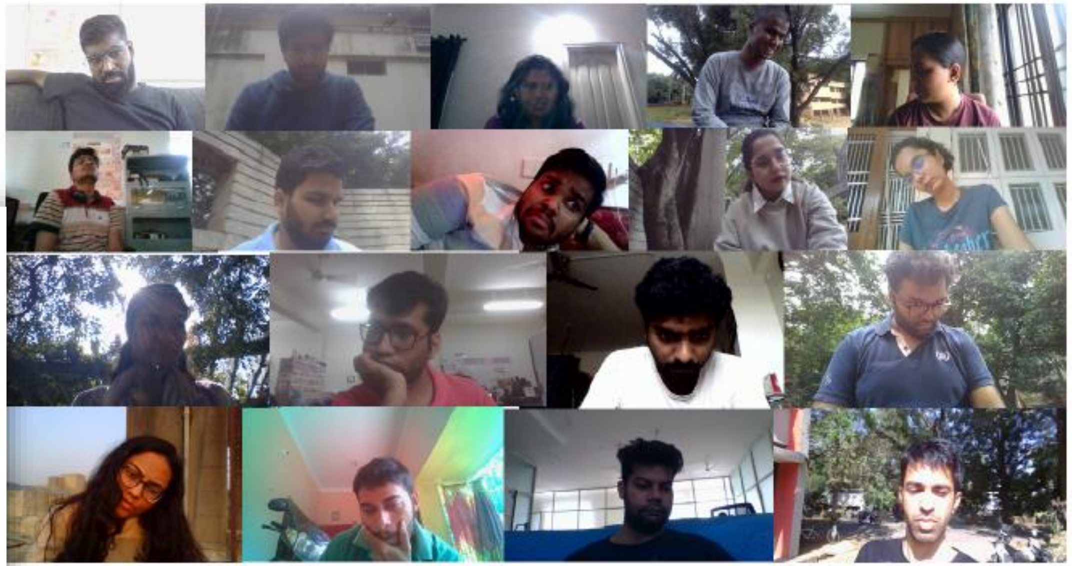


- Commercially-Off-The-Shelf Eye Tracker's limitations
  - Limited Operating distance
  - Failure under external illumination
  - Limited Head pose and gaze angle tracking
- Appearance-based gaze tracking:
  - Robust to external illumination, head pose and operating distance
  - Relies on Deep Learning methods and Large diverse Datasets
  - Does not require calibration

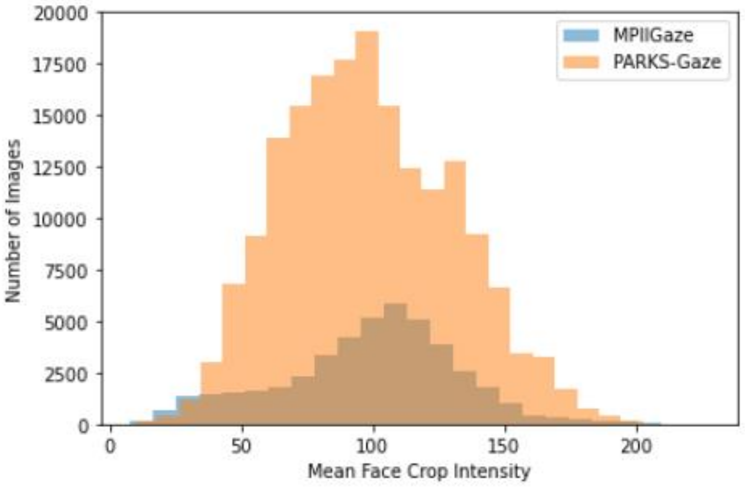
Appearance Based Eye Gaze Tracking in the Wild

- Wide range of Illumination
- Indian Population
- Head pose variation
- Low-cost webcam
- Realistic situation





(a) Sample Images from PARKS-Gaze Evaluation Subset



(b) Mean Histogram Plot

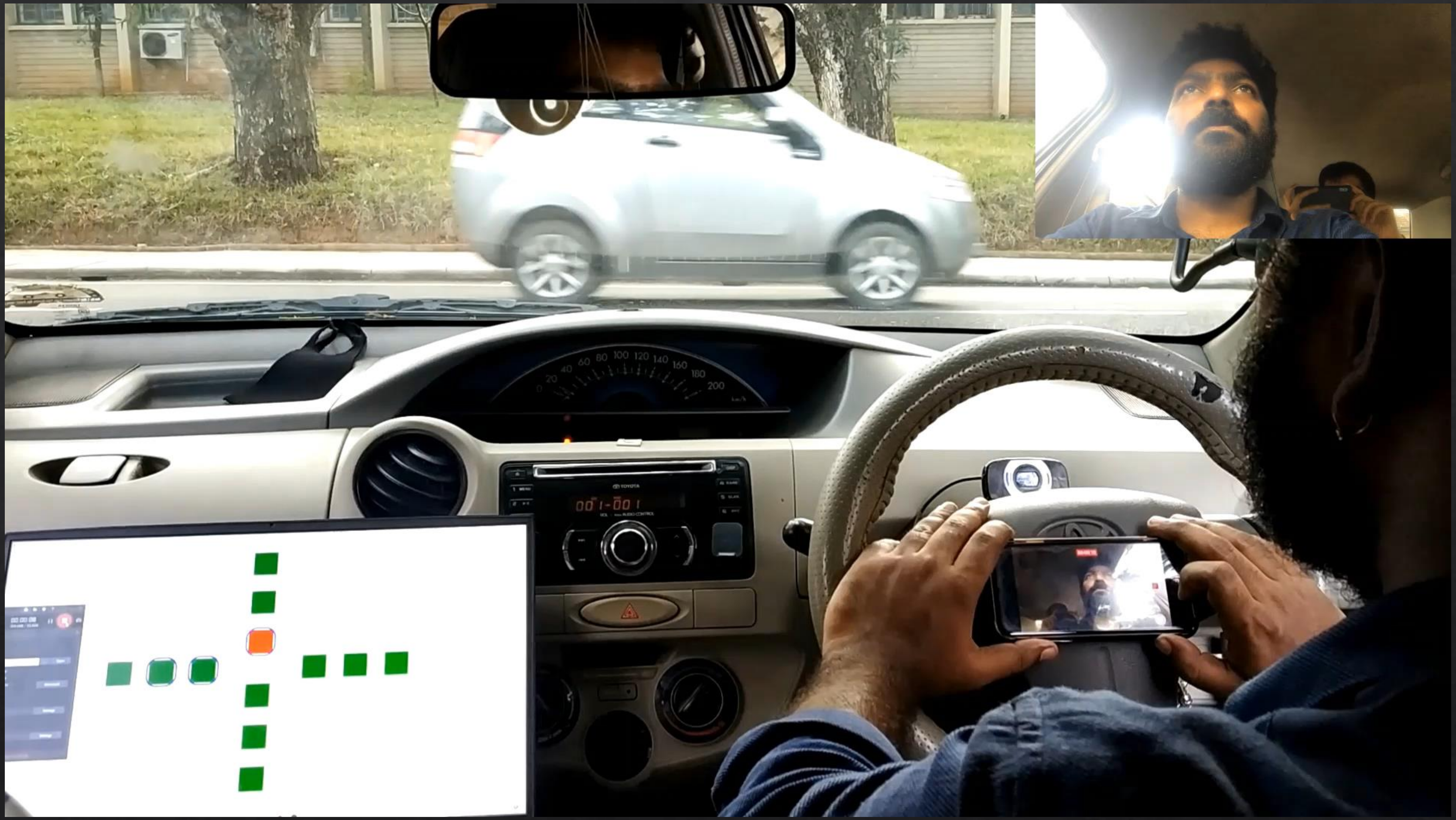
Table 1. A Brief summary of Screen-based Gaze estimation Datasets

Dataset	Participants	Head Pose	Data	Data	Setting
ColumbiaGaze [23]	56	0, ±30°	5,880	Frame	Lab
UT-Multiview [24]	50	±36°, ±36°	64,000	Eyes	Lab
EYEDIAP [9]	16	±25°, 30°	237 Min.	Frame	Lab
RT-GENE [8]	15	±40°, -40°	122,531	Face + Eyes	Lab
ETH-XGaze [26]	110	±80°, ±80°	≈ 1.1*M*	Face	Lab
GazeCapture [13]	1474	±30°, [-20°, 40°]	≈ 2.5*M*	Frame	Daily Life
MPIIGaze [30]	15	±25°, [-10°,30°]	213,659	Eyes	Daily Life
MPIIFaceGaze [29]	15	±25°, [-10°,30°]	45,000	Face	Daily Life
PARKS-Gaze	**28**	**±50°, [-40°, 60°]**	**300,961**	**Face + Eyes**	**Daily Life**

- LRD Murthy and P. Biswas, Appearance-based Gaze Estimation using Attention and Difference Mechanism, 3rd International Workshop on Gaze Estimation and Prediction in the Wild **(GAZE 2021) at CVPR 2021**
- LRD Murthy, A. Mukhopadhyay, K. Anand, S. Aggarwal and P. Biswas, PARKS-Gaze - An Appearance-based Gaze Estimation Dataset in Wilder Conditions, **ACM International Conference on Intelligent User Interfaces (IUI 2022)**

Eye Gaze Controlled Display – Inside a Car

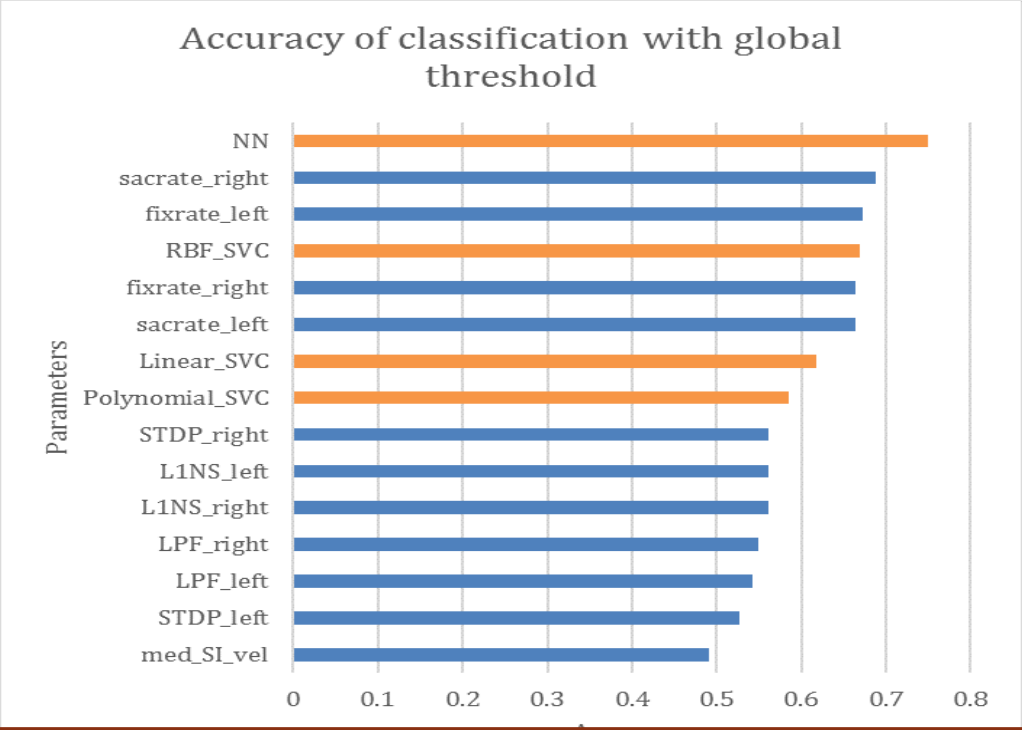
Distraction detection – Inside a Car



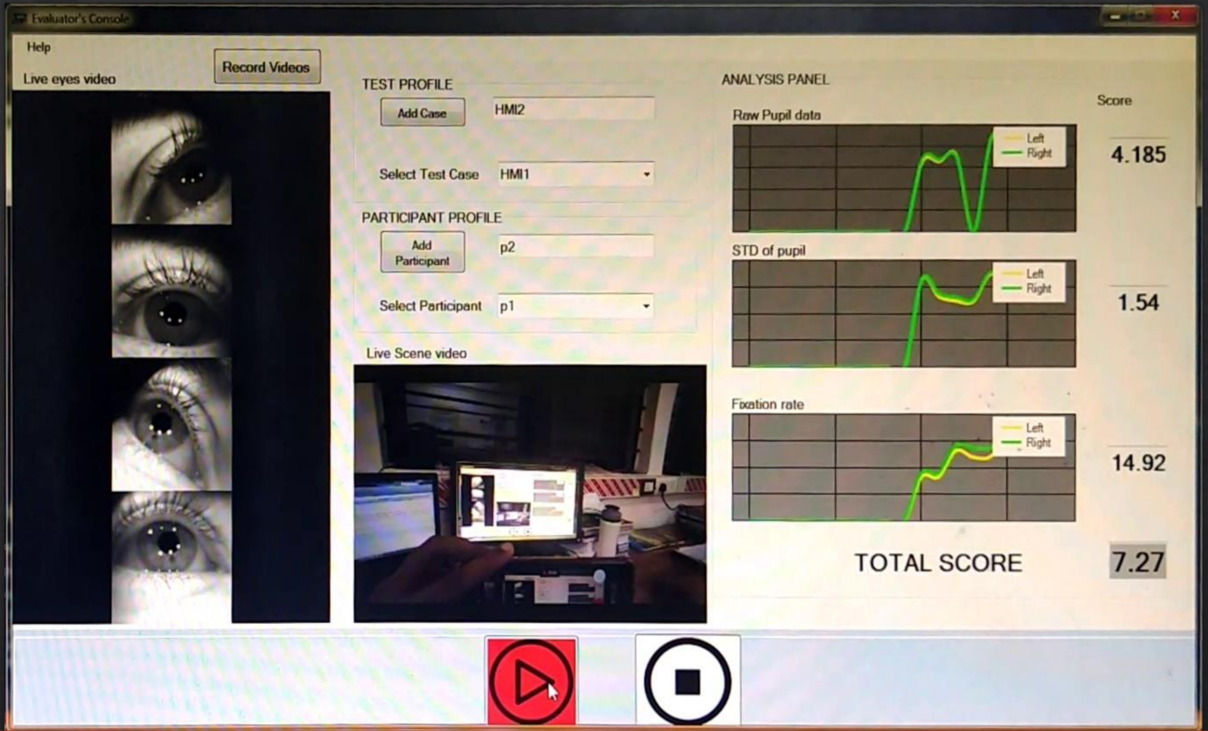
LRD Murthy, A. Mukhopadhyay and P. Biswas, Distraction Detection in Automotive Environment using Appearance-based Gaze Estimation, ACM International Conference on Intelligent User Interfaces (IUI 2022)

Machine Learning – Cognitive Load

Classification Results



Cog Load Dashboard



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G. Prabhakar, A. Mukhopadhyay, LRD Murthy, M. Madan, S. Deshmukh and P. Biswas, Cognitive load estimation using Ocular Parameters in Automotive, Transportation Engineering, Elsevier 2020

ML Model for Cognitive Load Estimation

- Developed filtering and machine learning models to increase accuracy of cognitive load estimation model
- Undertook user studies involving drivers in actual road condition
- Developed new software for
  - Tagging video and logging events
  - Comparing HMI through CogLoad Dashboard
- Undertook subjective evaluation of technology developed

Summary

Eye trackers are useful in car cockpit for

- Distraction detection
- Direct control of VM
- Cognitive load estimation

Most COTS eye trackers are NOT

- Automotive compliance
- Tested in wide illumination range
- Tested in automotive conditions (vibration, illumination, head movement etc.)

Role of Standardization

- Acceptance Criteria for
  - Eye tracker technical specification
    - Accuracy, precision, latency in different illumination level
  - Distraction Detection
    - Accuracy and Latency
    - Eye movement and Head movement
    - Inattentional Blindness
  - Direct Display Control
    - Accuracy and Latency
- Design Guidelines for Eye Gaze Controlled VM
  - Size of Screen Element
  - Density of Screen Element