Real-time Eye and Head Pose Detection Using Active Shape Models with Stasm

Zeming Li
Supervised by: Prof. K. N. Plataniotis
M.Eng Project

University of Toronto
Department of Electrical and Computer Engineering

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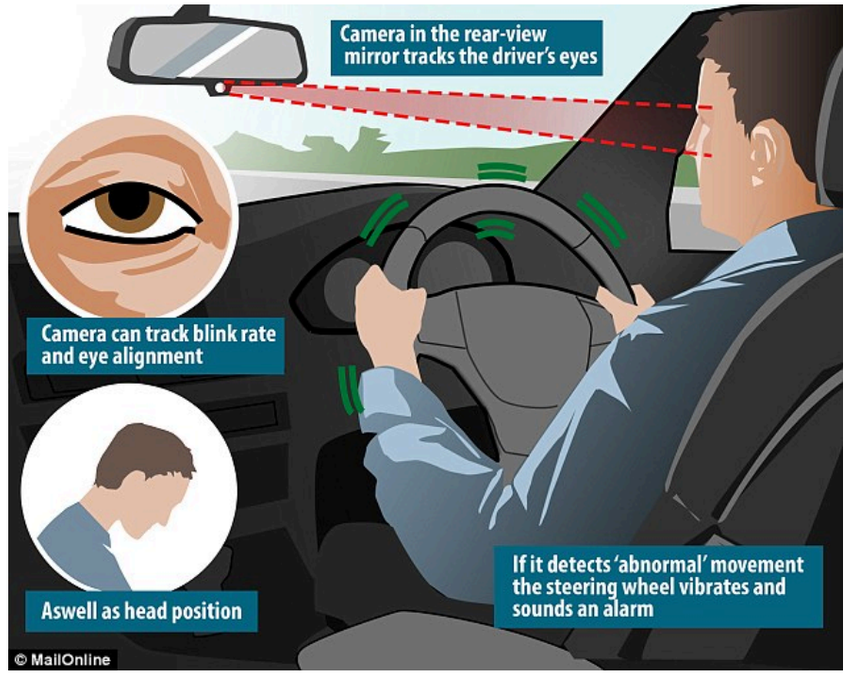
Applications & Motivations

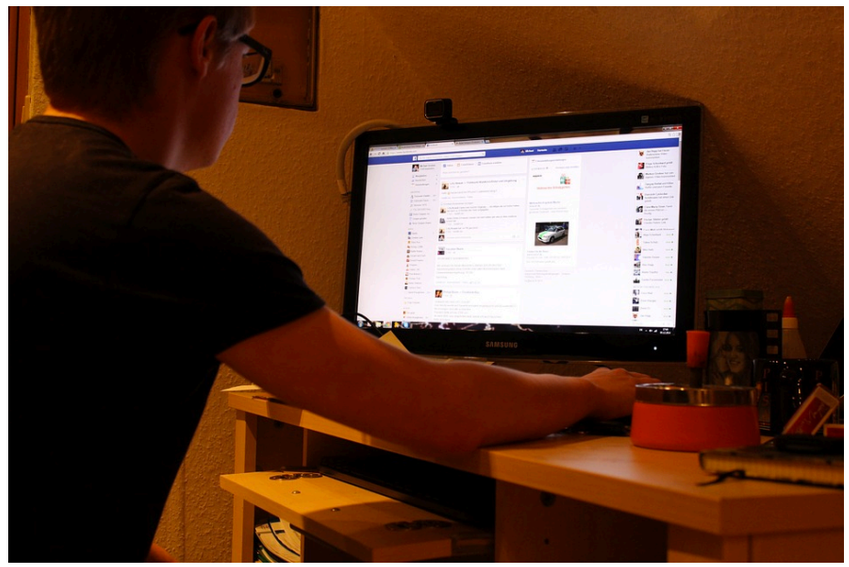
1. Eyes Off the Road Detection System

- Locates facial features under various conditions
- Estimates head movement
- Gives a reminder to the diver



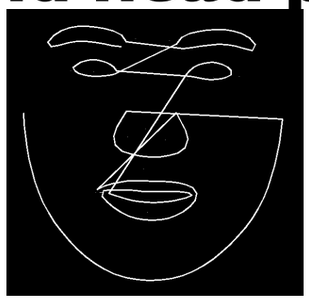
2. Reading Behavior Monitor

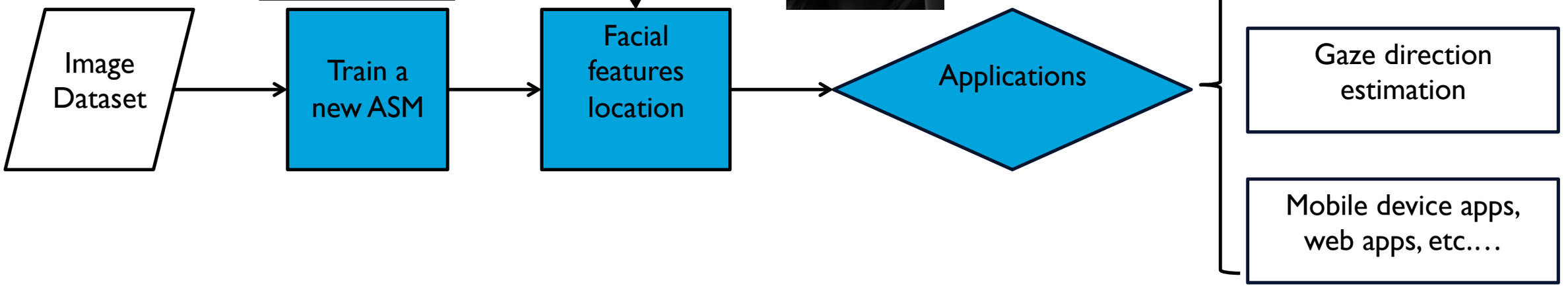
- Estimates gaze direction
- Calculates residence time on the screen
- Generates a gaze density map for analysis



Project Overview

Objective: To train a new active shape model & implement it for eye and head pose detection





- Train a new ASM
  - Use HELEN dataset and optimized methods to obtain a 194-landmarks shape model
- Facial features location
  - Locate 194 facial features on each input image

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Problem Statement

The new ASM training

- Problem: Training a 194-landmarks model of the shape of faces on HELEN dataset
- Input: Images, shapefiles, landmark table, optimized methods
- Output: A statistical model of the 194 facial features

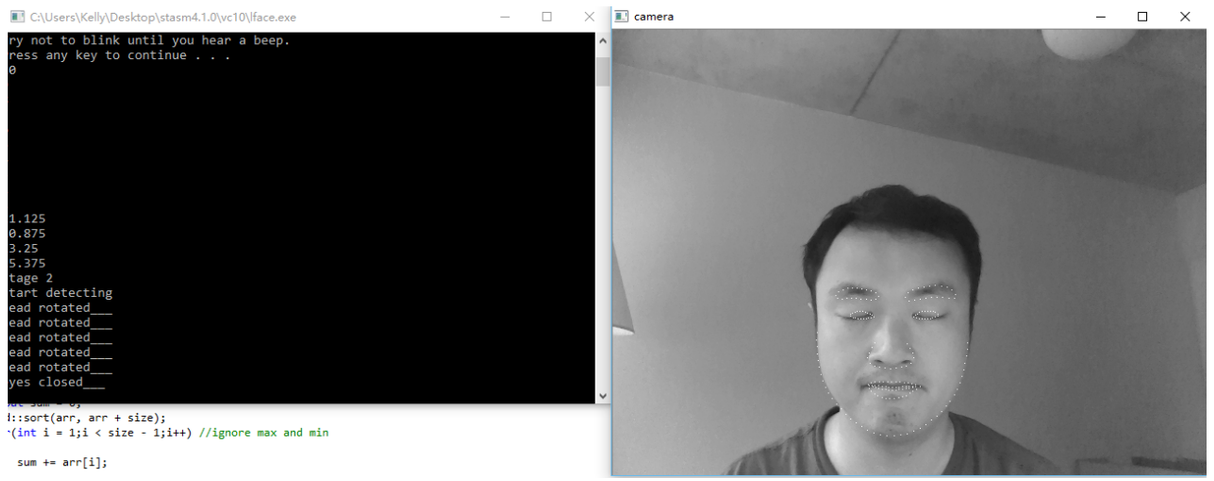
Facial features locating

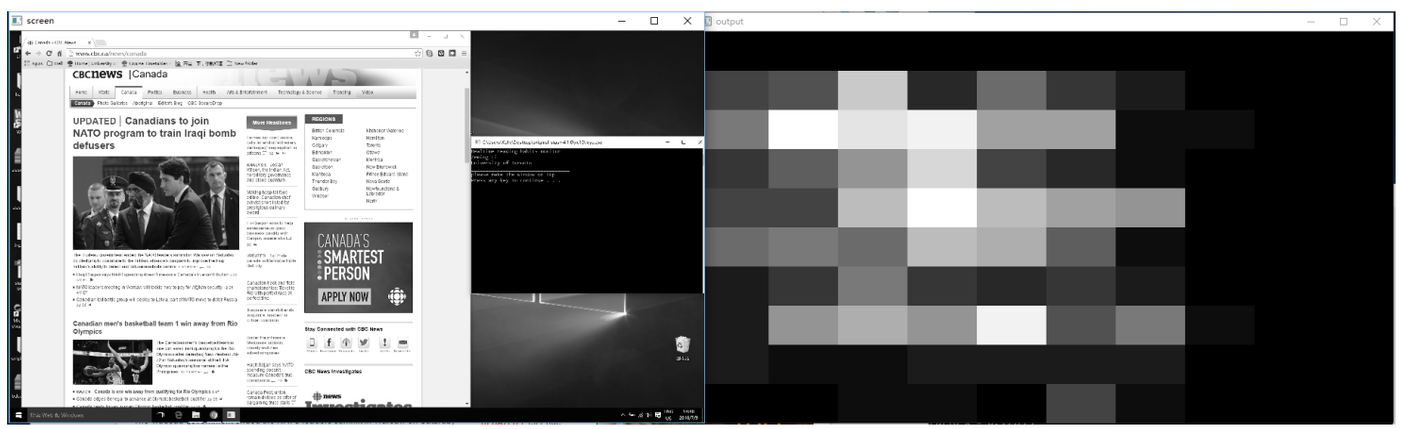
- Problem: Automatically locate each landmark on the facial features in a new image
- Input: Digital color face image
- Output: A matrix(194x2) which contains landmarks location information

Contributions

- Proposed a newly trained robust active shape model on HELEN dataset which locates 194 landmarks under various illumination conditions

- Created a real-time head pose and closing eyes detection system a reading habits monitor





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Organization

Contribution 1

A newly trained robust active shape model on HELEN dataset which locates 194 landmarks under various illumination conditions

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Background: Facial Features Locating Framework

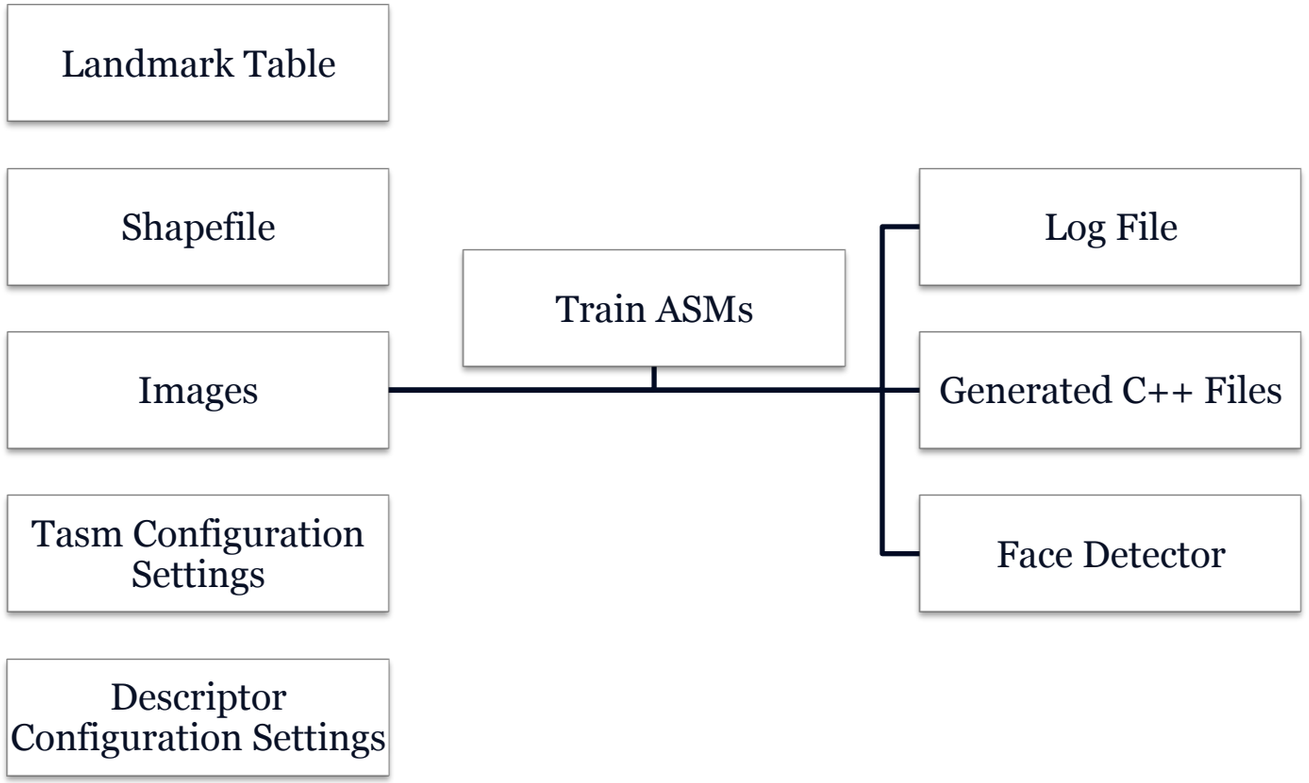
Active Shape Models(ASMs)[T. Cootes]

- Statistical Models represent the shape of objects by a set of landmarks
- Iteratively deform to match the model to a new image
- Can be trained on a set of labeled examples in images

Location framework

- Mean shape is obtained in training stage
- Different ASMs have different shapes(landmarks amount N)
- After iteration, each landmark is located to match the new object in the image

Training ASMs



- Edit the annotation file of HELEN dataset by Shell script
- Identify face conditions of face images and label them
- Train ASMs with different settings

ASMs Experiments

Objectives: to evaluate the different ASMs performance under the following scenarios

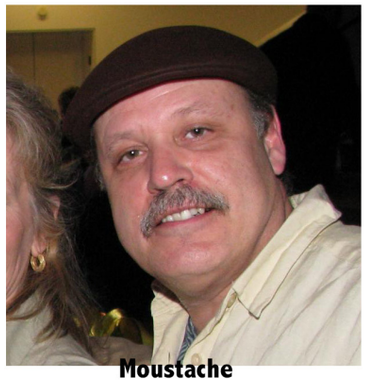
- Facial landmarks location accuracy under different environment
- Facial landmarks location speed
- The advantage of the proposed model comparing to ASM proposed by S. Milborrow(Stasm)

Glasses

Bad Image

Bad Eyes

Beard



Moustache

Experimental Setup

:

- Has 1,512 gray level images in 384x286
- Presents the frontal view of 23 different subjects' faces
- The images recorded in uncontrolled conditions by a webcam
- "Real-world" indoor environment

Evaluation Methodology:

- The Euclidean Distance *d(p1,p2)* between the annotated point 1 and estimated point 2
- Normalized by the Inter-Ocular Distance (IOD)

$$\delta_i^k = \frac{d\left((x_i^k, y_i^k), (\hat{x}_i^k, \hat{y}_i^k)\right)}{IOD} \qquad \mathrm{P} = \frac{\sum_{i=1}^{\iota}\sum_{k=1}^{\kappa}\delta_i^k}{\mathrm{K} \times \mathrm{I}}$$

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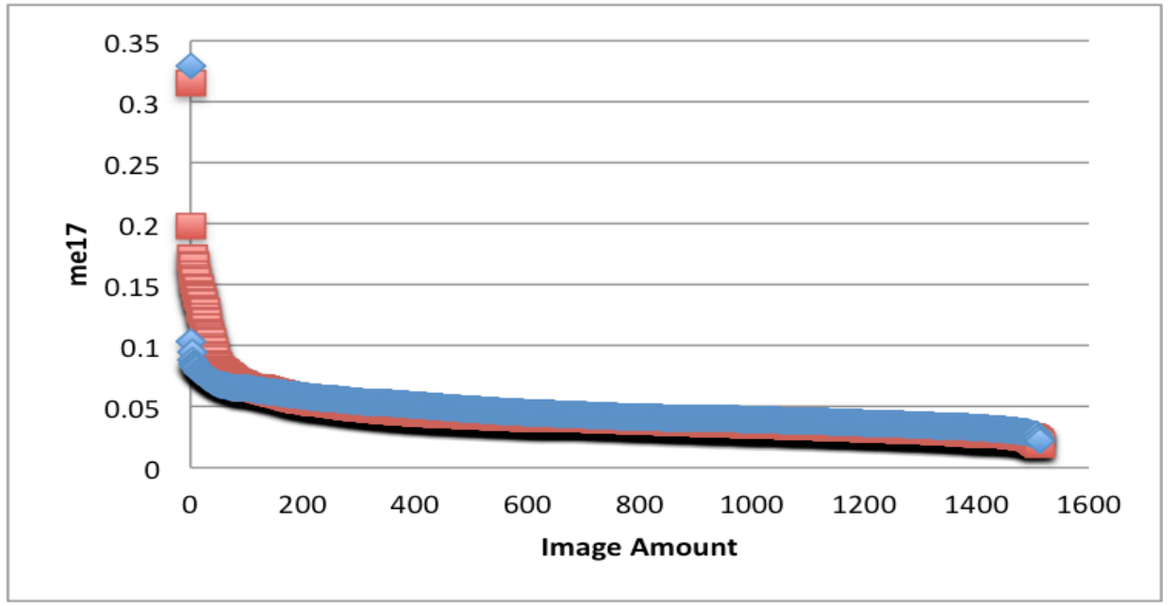
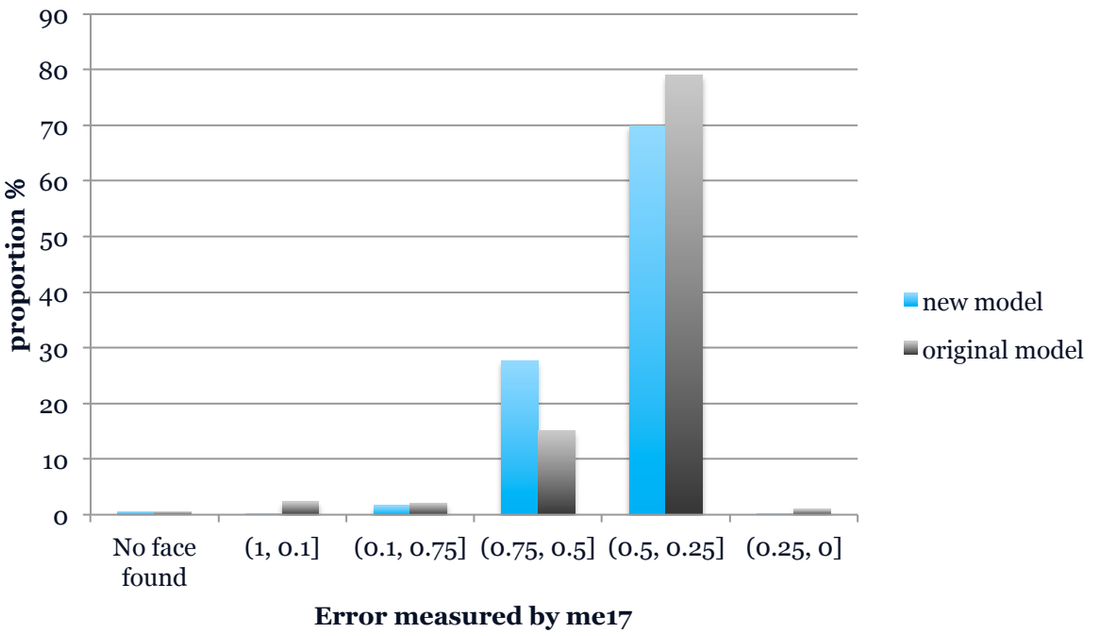
Results

Accuracy analysis

- Performance of the new model (blue) and the original Stasm model (red)
- “me17” is the average Euclidean distance over 17 points



- The proportion of landmarking results in different error ranges
- The new model has fewer results with huge errors



Results

Improvement on accuracy

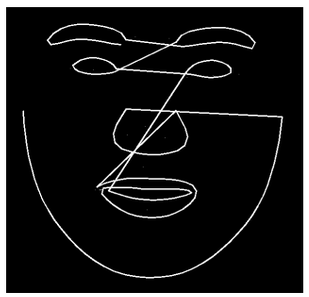
An example of how newly trained ASM improves facial landmarks locating performance

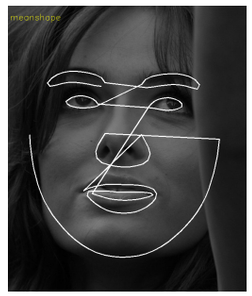
- Newly trained model (left) is better on the rotated face
- The me17 of Stasm is 0.078, about 29% higher than that of the newly trained model

Improvement on speed

Model name	me17	Mean time/number of landmarks (ms)
Stasm	0.043590	1.3377
The new model	0.045635	0.6546

Organization





Webcam

Image Dataset

Train a new ASM

Facial features location

Applications

Closed eyes and head pose detection

Gaze direction estimation

Mobile device apps, web apps, etc.…

Contribution 2

Created a real-time head pose and closing eyes detection system a reading habits monitor

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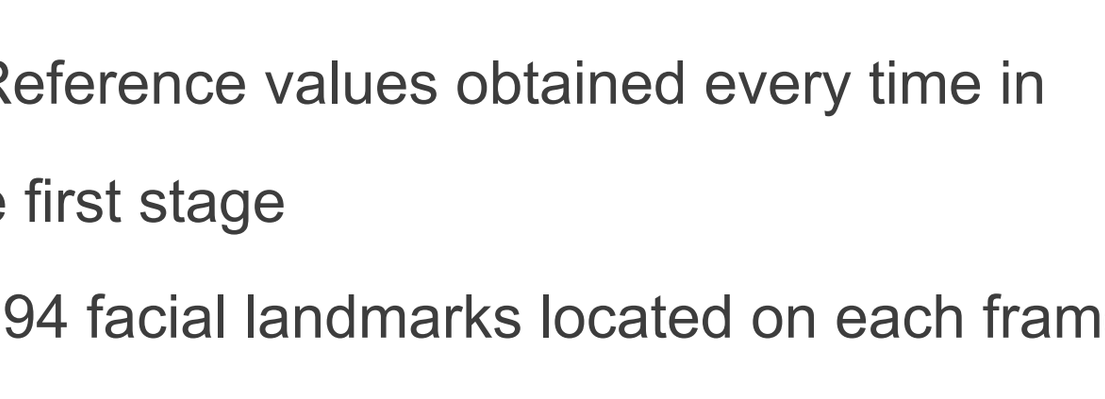
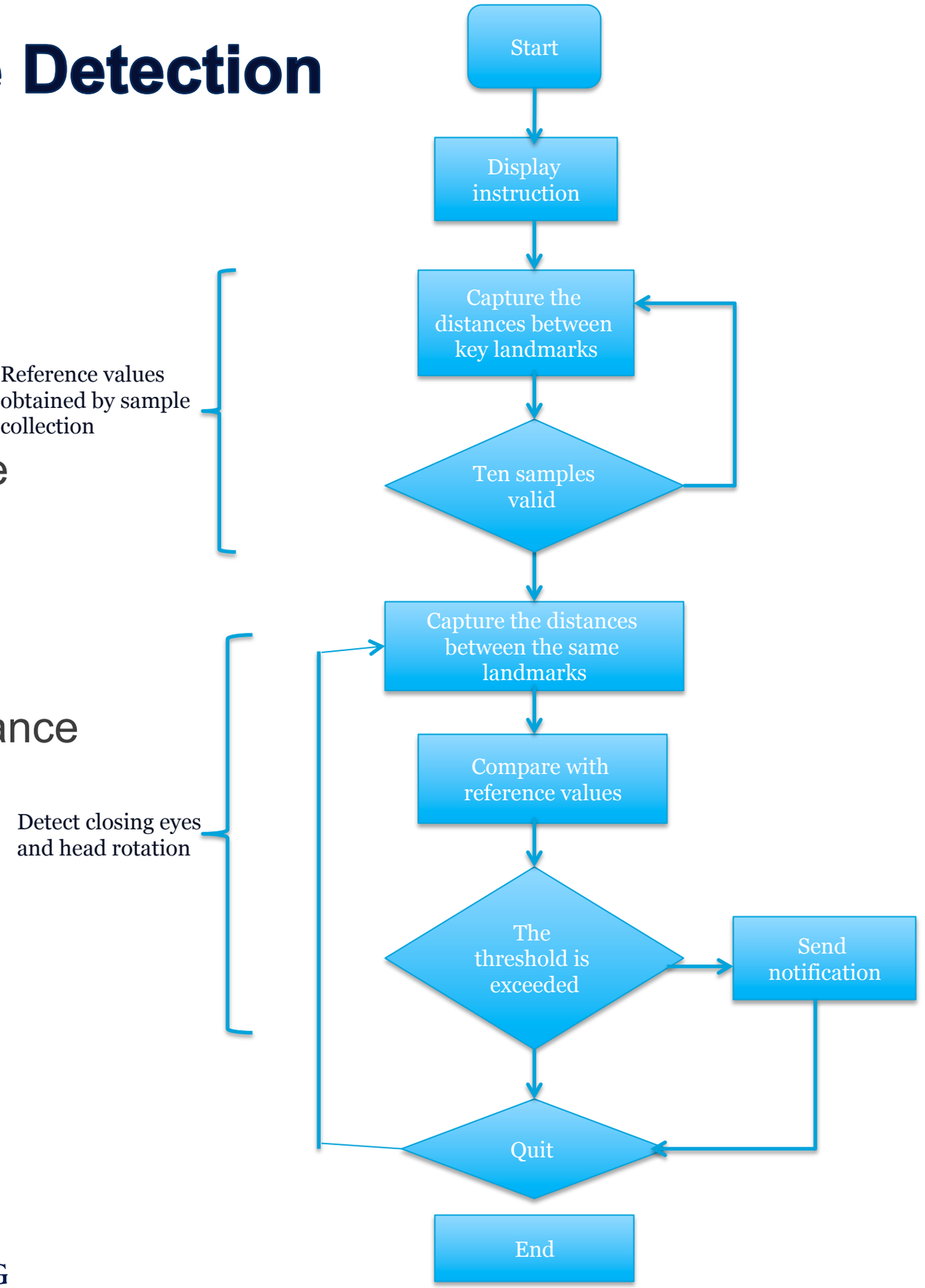
Closed Eye and Head Pose Detection

Overview

- Reference values obtained every time in the first stage
- 194 facial landmarks located on each frame of video captured by webcam
- Closing eyes and head rotation detection is judged based on the normalized vertical distance between some key landmarks





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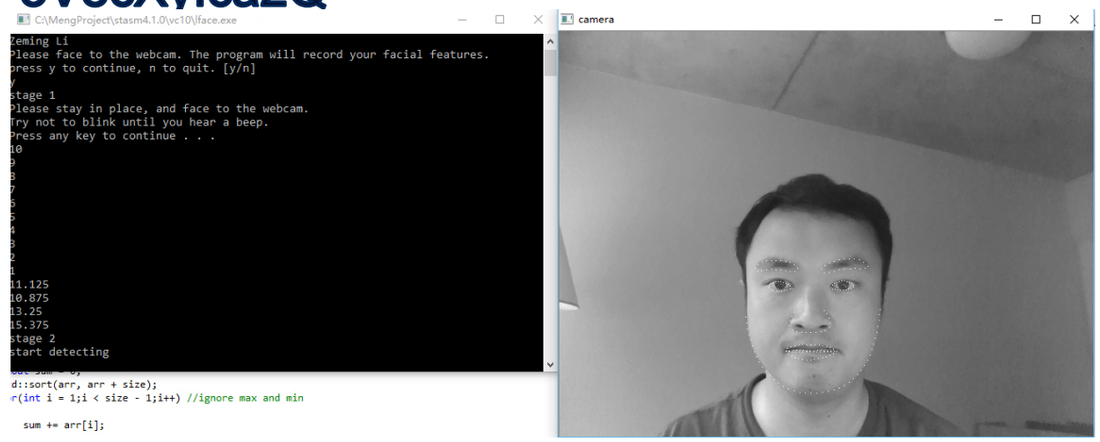
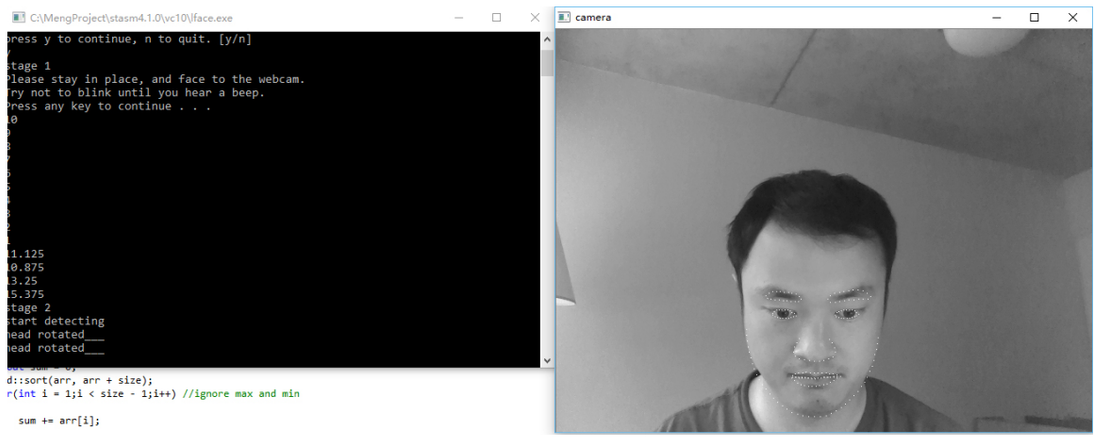
Working Process

demo video: https://www.youtube.com/watch?v=oV8cXvIca2Q

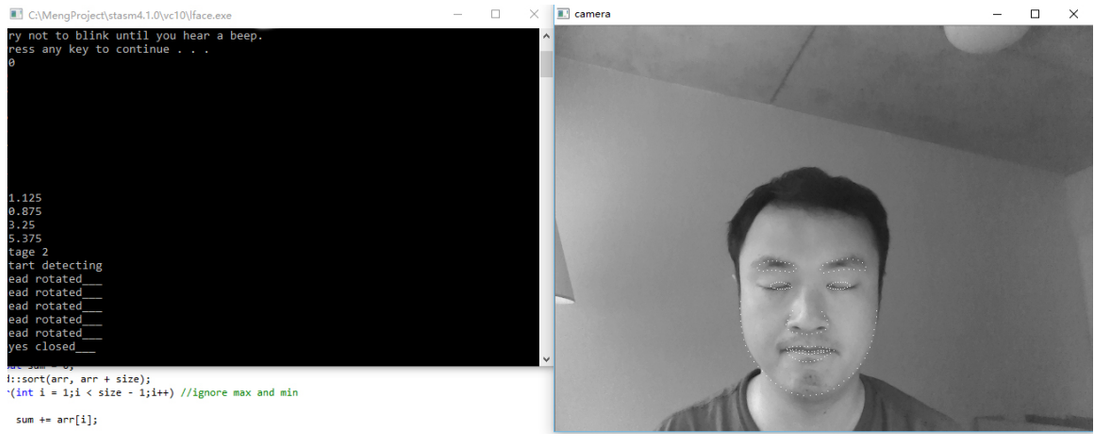
- The application locates 194 landmarks and compares the distance between key landmarks with the standard values



- When the rotated head is detected the reminders are two short beeps and a literal reminder displayed on the console



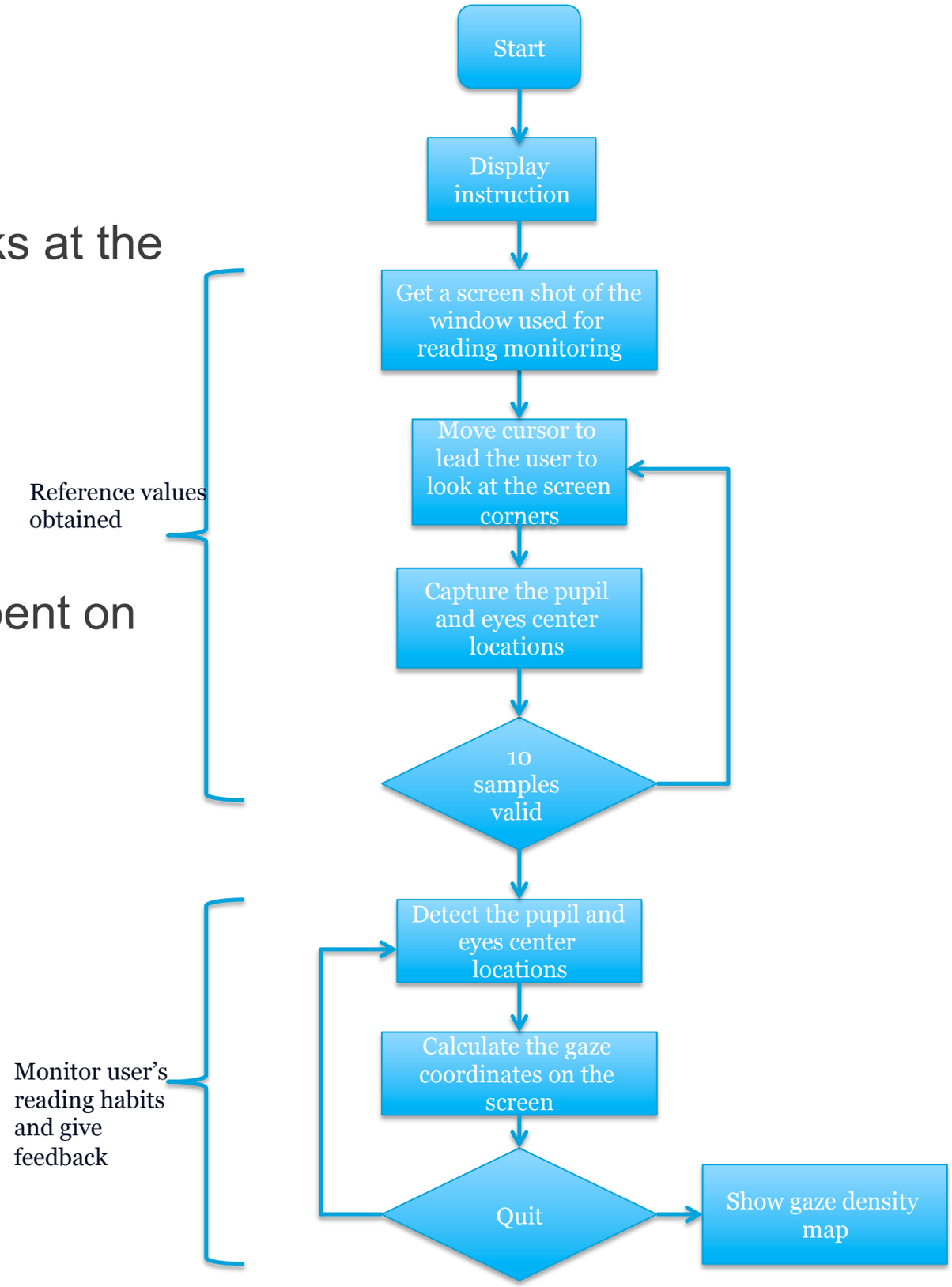
- When the closed eyes are detected, the reminders are a long beep and a corresponding literal reminder on the console



Reading Habits Monitor

Overview

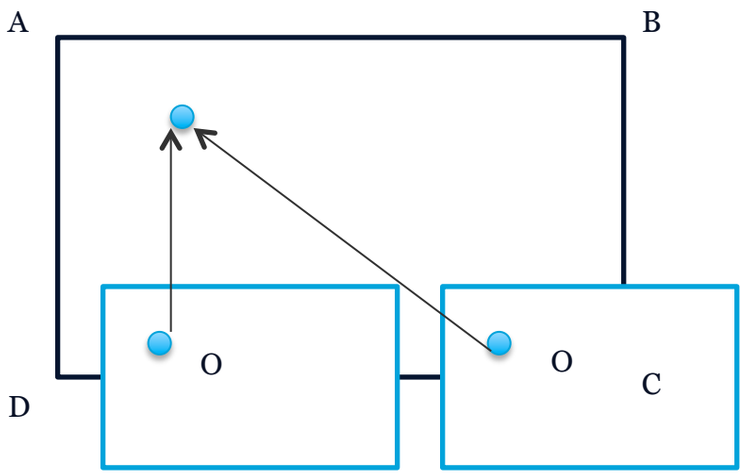
- Captures pupils location when the user looks at the 4 corners
- Locates key landmarks on each frame
- Estimates gaze direction on the screen
- Calculates gaze direction residence time spent on 1 of 100 blocks of the screen.
- Outputs a gaze density map

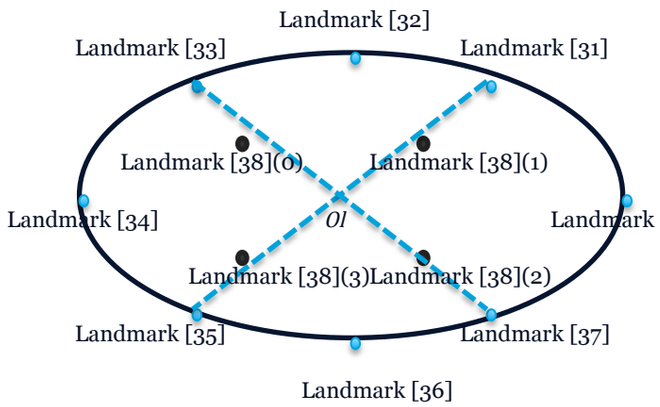


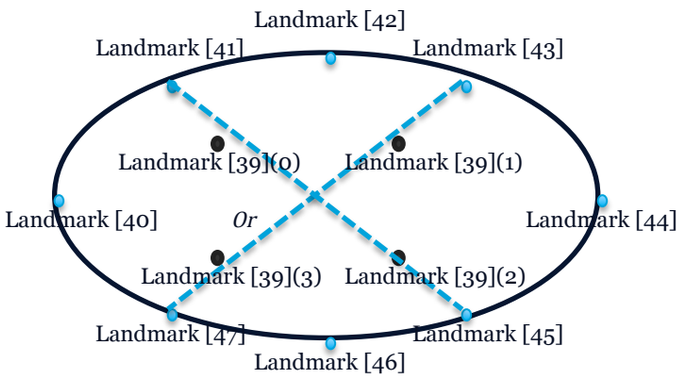
Gaze Direction Estimation

- Five landmarks used for gaze estimation around each eye. The four landmarks on the eye border are used to calculate the geometric center of the eye.

- Representation of the gaze mapping principle. The pupils' movements in a particular area in the eyes could be mapped to the gaze location on the screen.



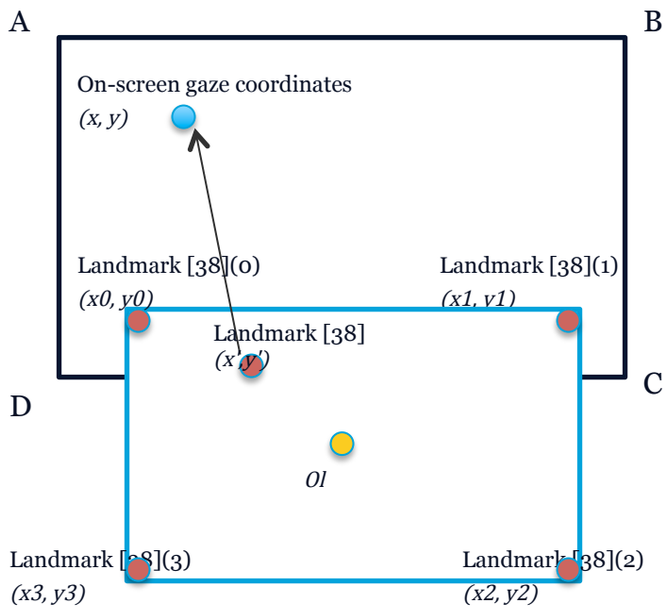




Gaze Direction Estimation

- The location of the left pupil is mapped to the estimated gaze coordinates on the screen.

- The same thing happens to the right pupil.



The on-screen gaze coordinates *(x, y)*

$$\frac{x}{l_{AB}} = \frac{x' - x_{ol} - x_{0'}}{(x_1 - x_0) \div 2 + (x_2 - x_3) \div 2}$$

$$Where\ x_{0'} = x_0 - x_{ol}, x_{ol}\ is\ a\ constant\ value\ obtained\ with\ x_0$$

$$l_{AB}\ is\ the\ width\ of\ the\ user's\ screen$$

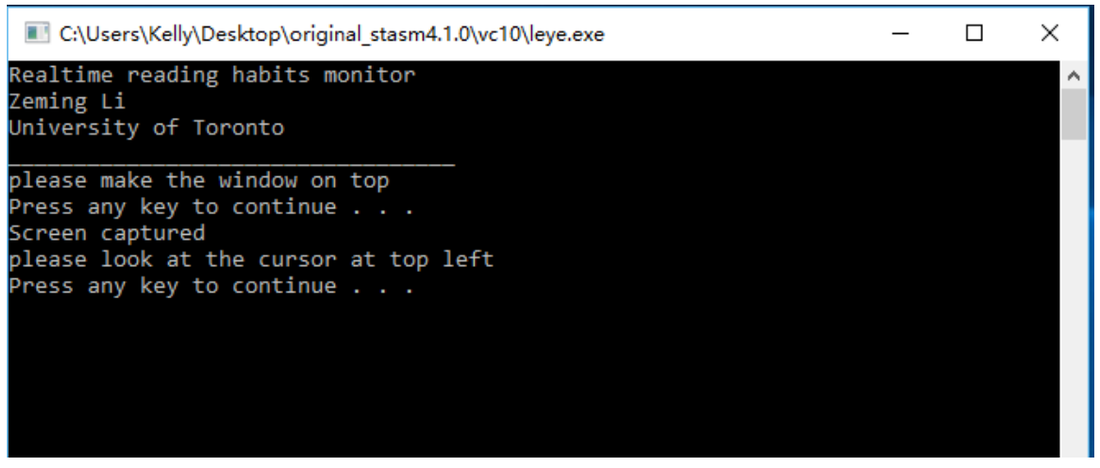
$$\frac{y}{l_{AD}} = \frac{y' - y_{ol} - y_{0'}}{(y_1 - y_0) \div 2 + (y_2 - y_3) \div 2}$$

$$Where\ y_{0'} = y_0 - y_{ol}, y_{ol}\ is\ a\ constant\ value\ obtained\ with\ y_0$$

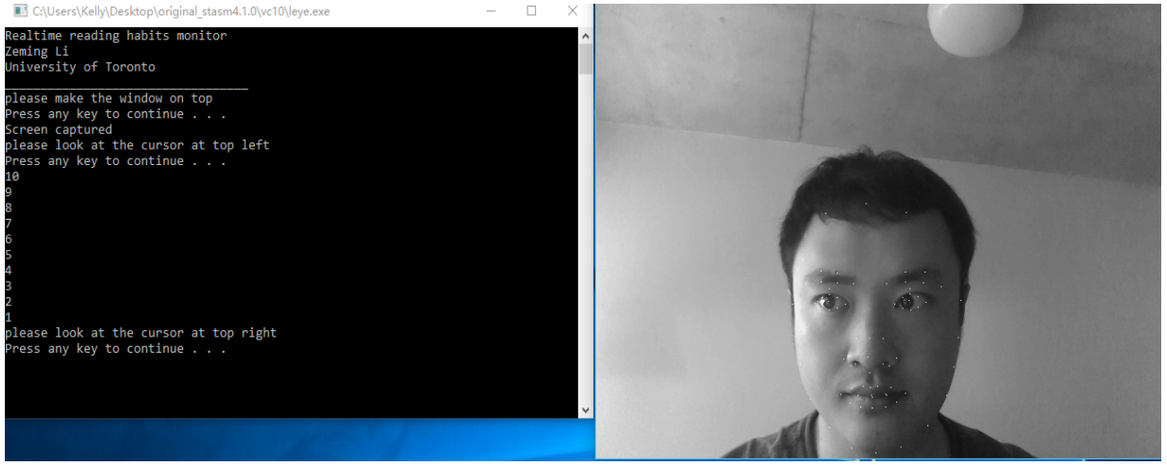
$$l_{AD}\ is\ the\ height\ of\ the\ user's\ screen$$

Working Process

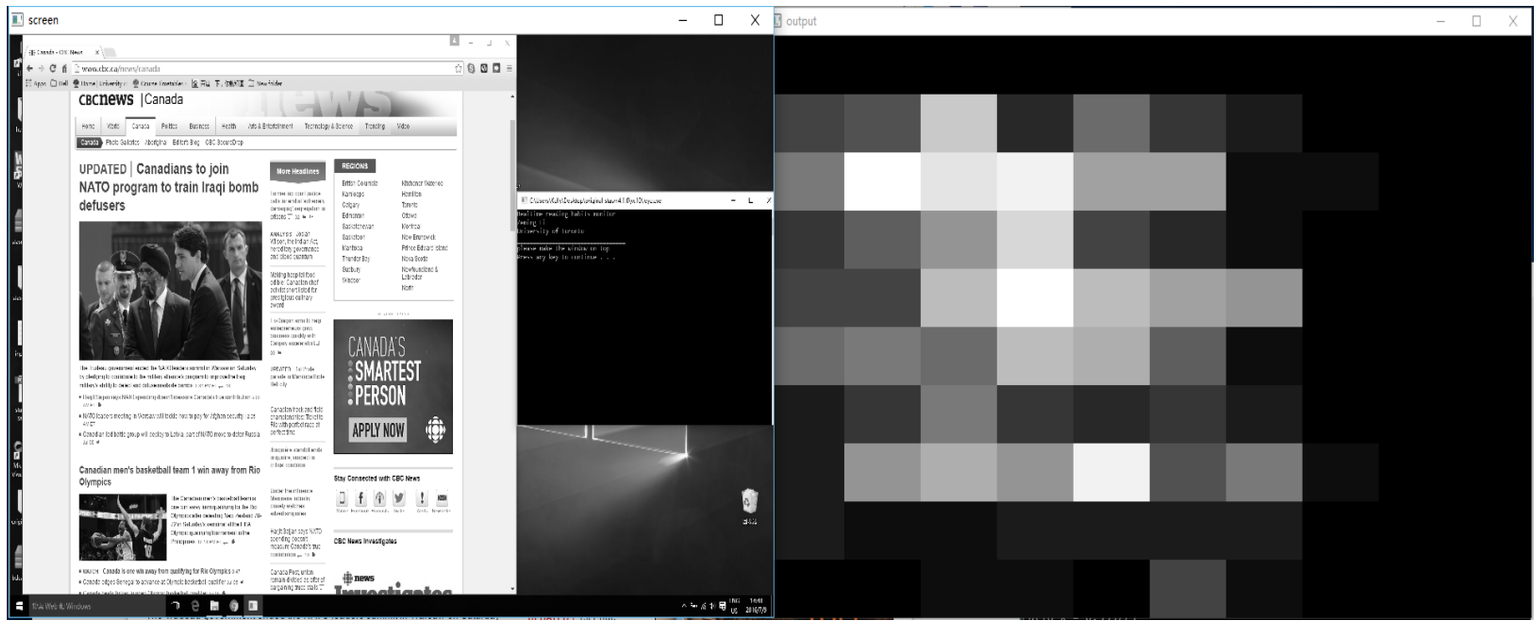
demo video: https://www.youtube.com/watch?v=p7XOMBNL2Jk



- Guides displayed on the console. The window with reading materials on the top is screen-shotted for analysis



- The cursor is set to the top left corner firstly and guides the user to look at the cursor



- Screenshot of the window used for monitoring and gaze density map with the same size
- The color of the blocks in gaze density map reflects the user's reading habits

Extensive Applications

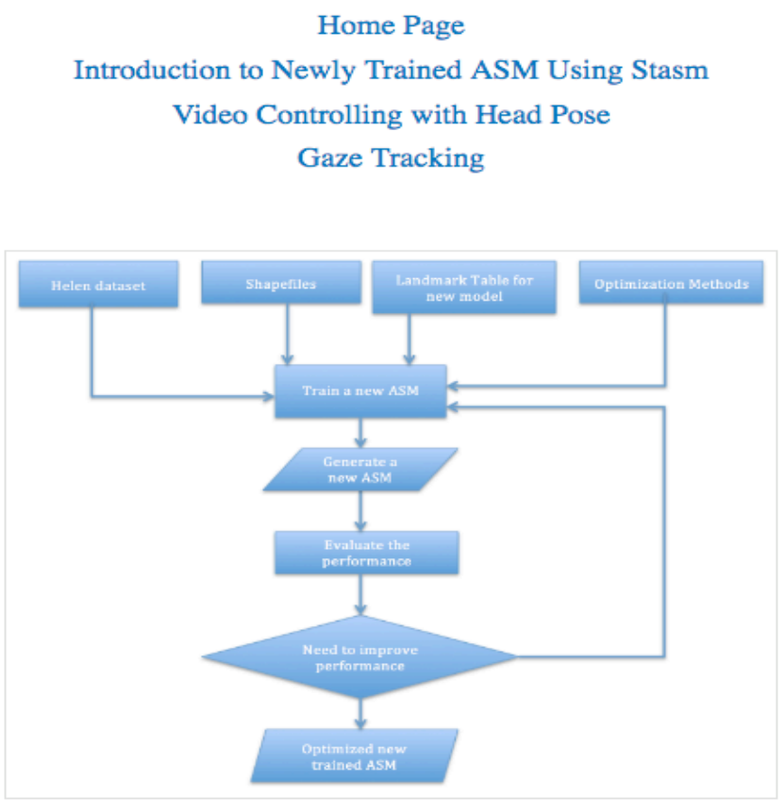
ASM WebApp (xlabs chrome extension api needed)

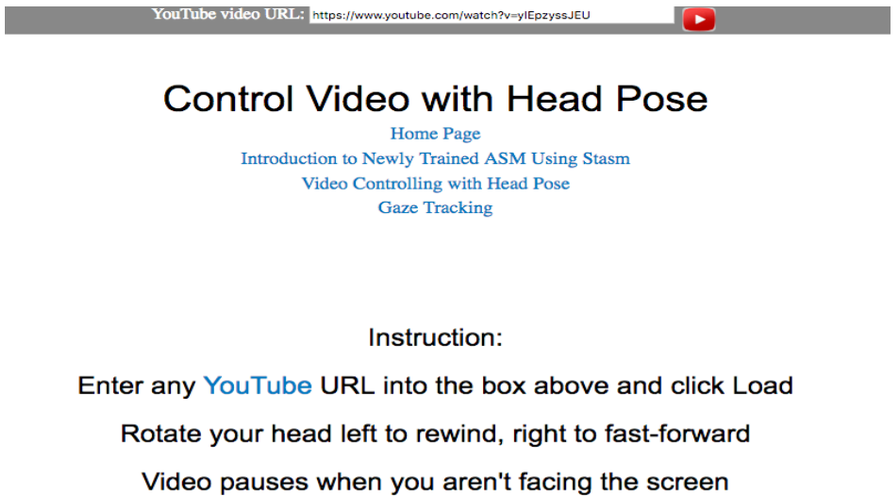
https://asm-webapp.appspot.com/

GitHub: https://github.com/zemli/ASM-WebApp

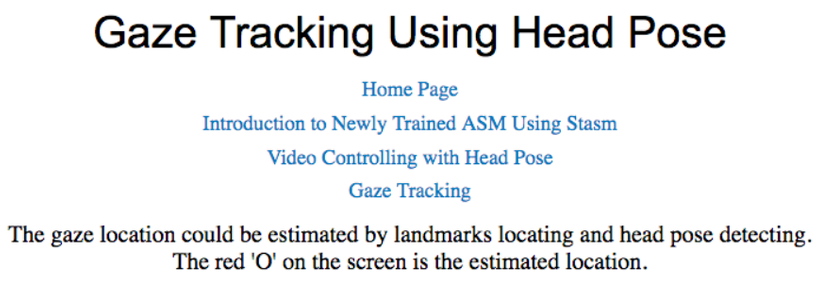
- A web app controls video with the head pose

- The homepage of the website





- A web app estimates the gaze location on the screen



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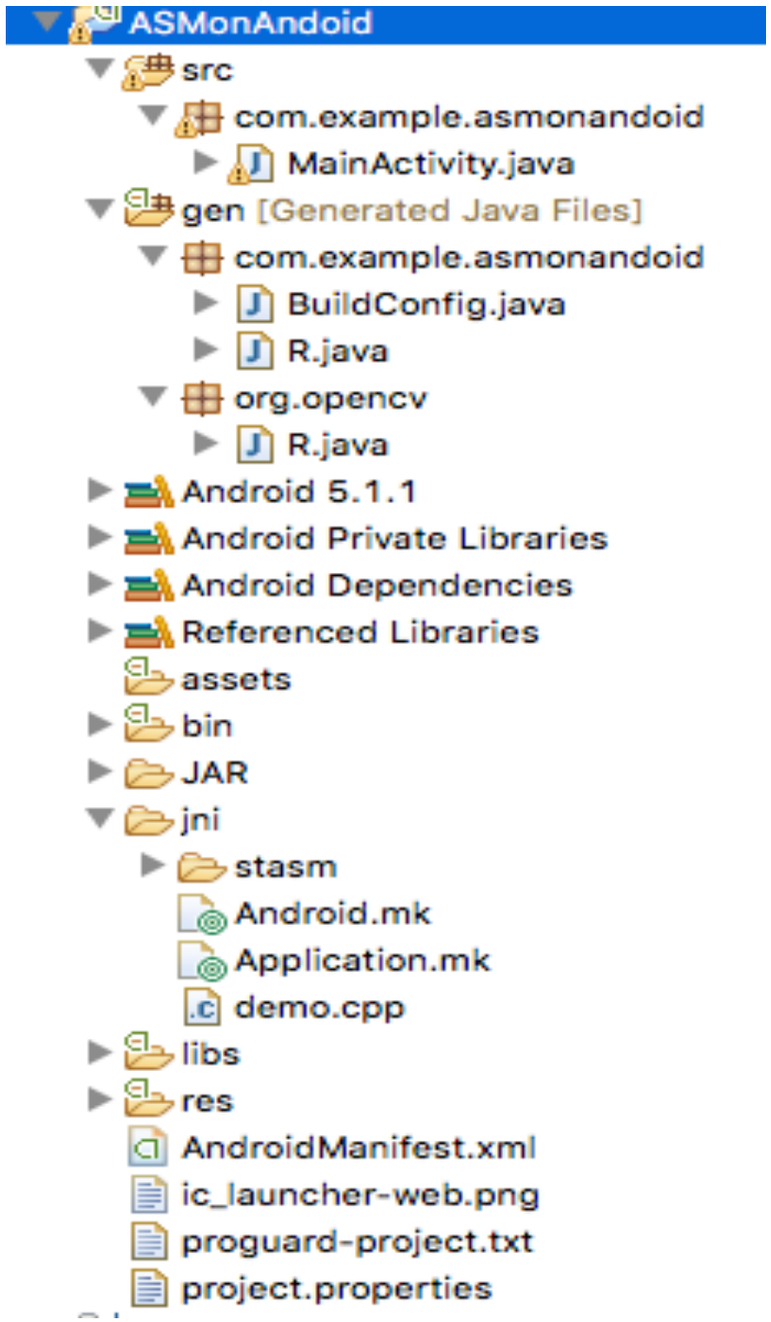
Extensive Applications

ASM on Android

- Facial features locating can be realized by using ASM with OpenCV4Android library

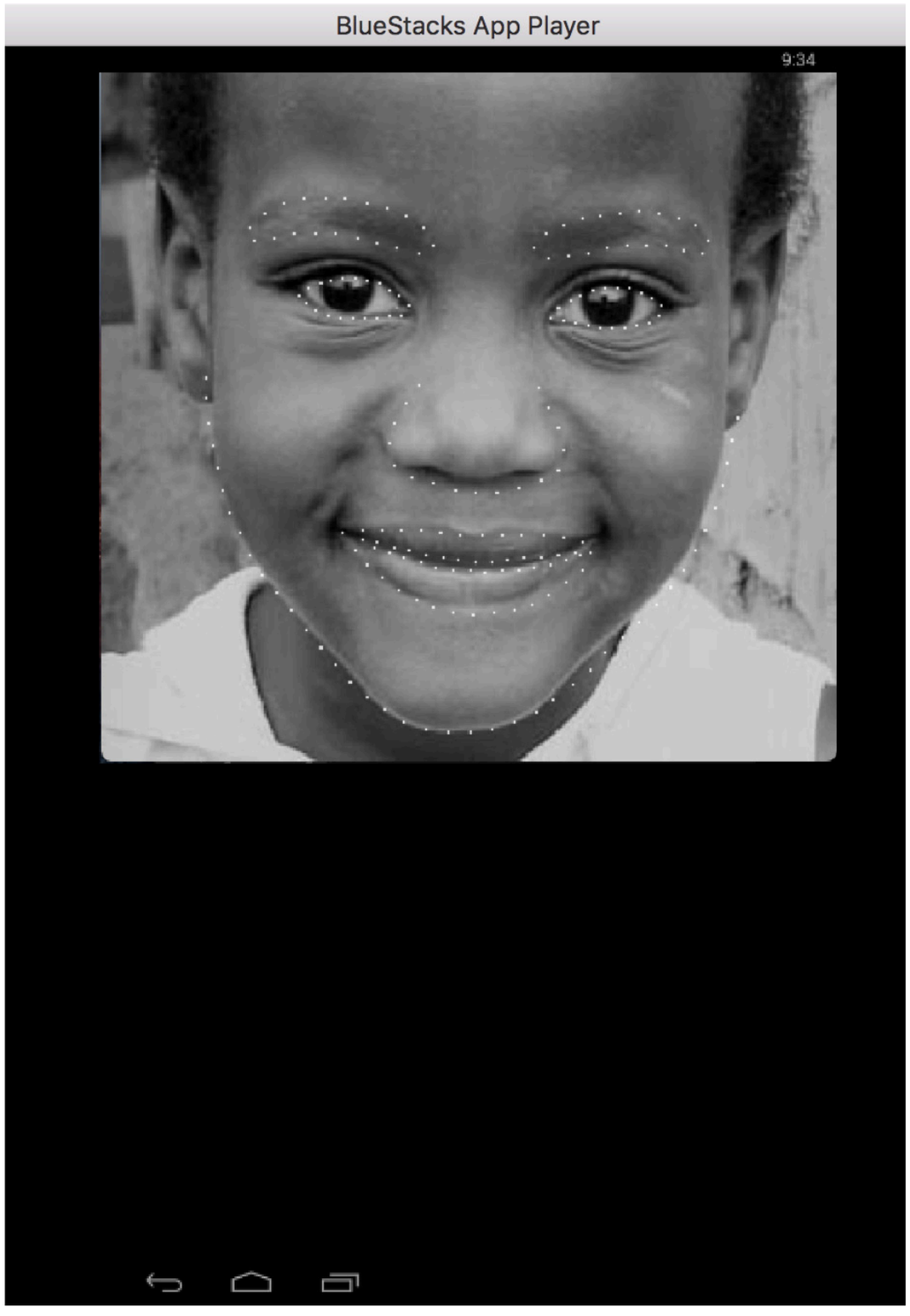
- JNI (Java Native Interface) could use an interface works as a pointer links android application in local reference with ASM source code in global reference.



Extensive Applications

ASM on Android

- Android app running on a virtual machine (BlueStacks) for MacOS. 194 landmarks are accurately located on the face in test image.



Conclusion & Future Work

The new ASM trained on HELEN dataset

- High accuracy under various complications
- Fast processing speed on each landmark
- Detailed shape model (194-landmarks model) for further processing

Real-time Eye and Head Pose Detection System

- Efficient for building real-time applications
- Robustness to different illumination conditions
- Apply to EOR system / monitor users' reading habits

Future Work

- Comprehensive algorithm to estimate gaze direction
- Apply the new model to other biometric applications need detailed shape information (i.e., face verification, facial micro-expression).

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Thanks!

Questions?

Email: zeming.li@mail.utoronto.ca

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