A Blink Detection Algorithm for Eye-Tracking Applications Based on Facial Geometry

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Blink Detection

Blinking as a feature

- Indicator of eye strain/dry eye
- Drowsiness detection
- Face liveness
- Concussion diagnosis

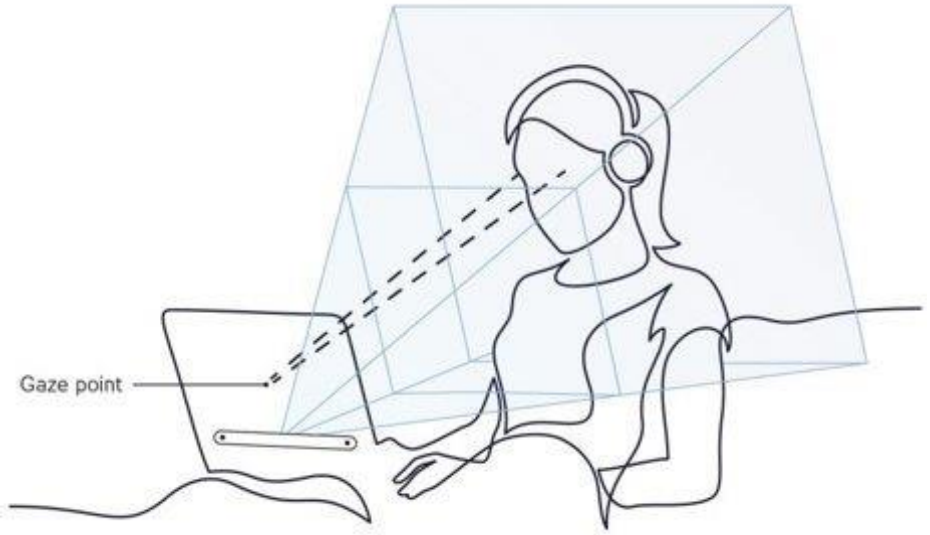
Blinking as an artifact

- Noise/disruptions
  - EEG VS EOG
- Negative impact on tasks
  - Facial recognition
  - Gaze tracking

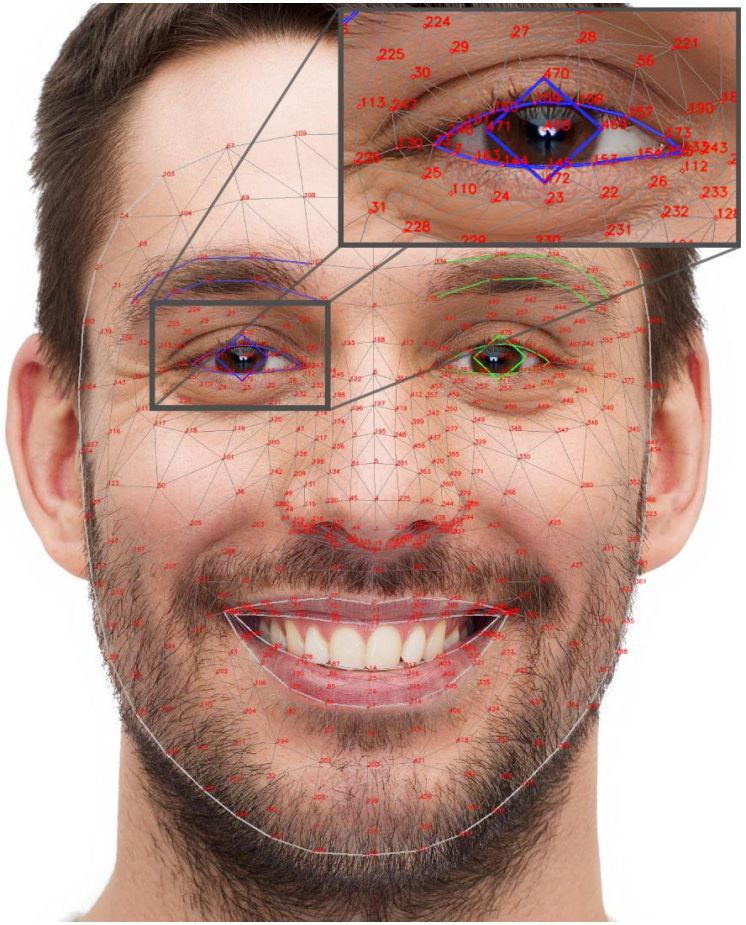
Eye Tracking

Eye tracking is a key feature in applications where the analysis of eye behavior is central.

- Concussion diagnosis
- Cognitive load
- Online attention/engagement
- Drowsiness detection
- Increased accessibility



MediaPipe

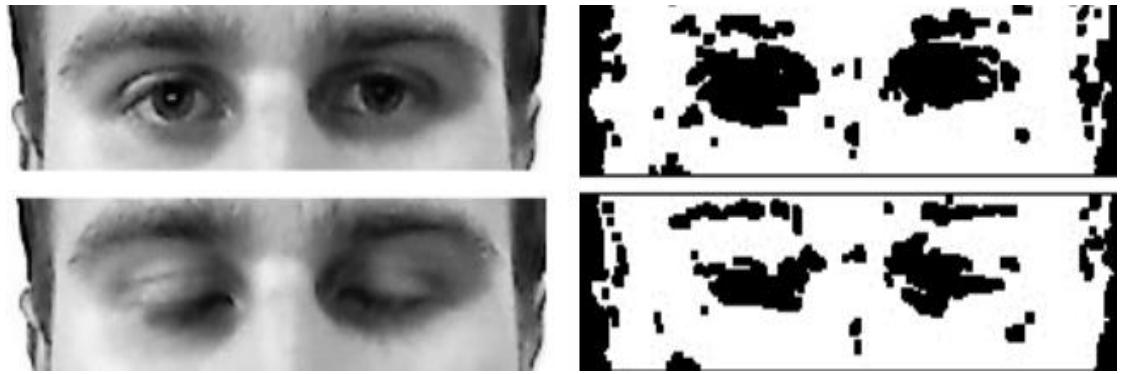


- In 2019 Google released MediaPipe
- MediaPipe: machine learning framework that enables facial landmark detection
- Developed web application for extracting 478 facial landmarks for each frame of video stream
  - 5 landmarks for each pupil
- Output 3D coordinates to extract and analyze various features
- Platform independent with no proprietary software

Related Works

2D image analysis

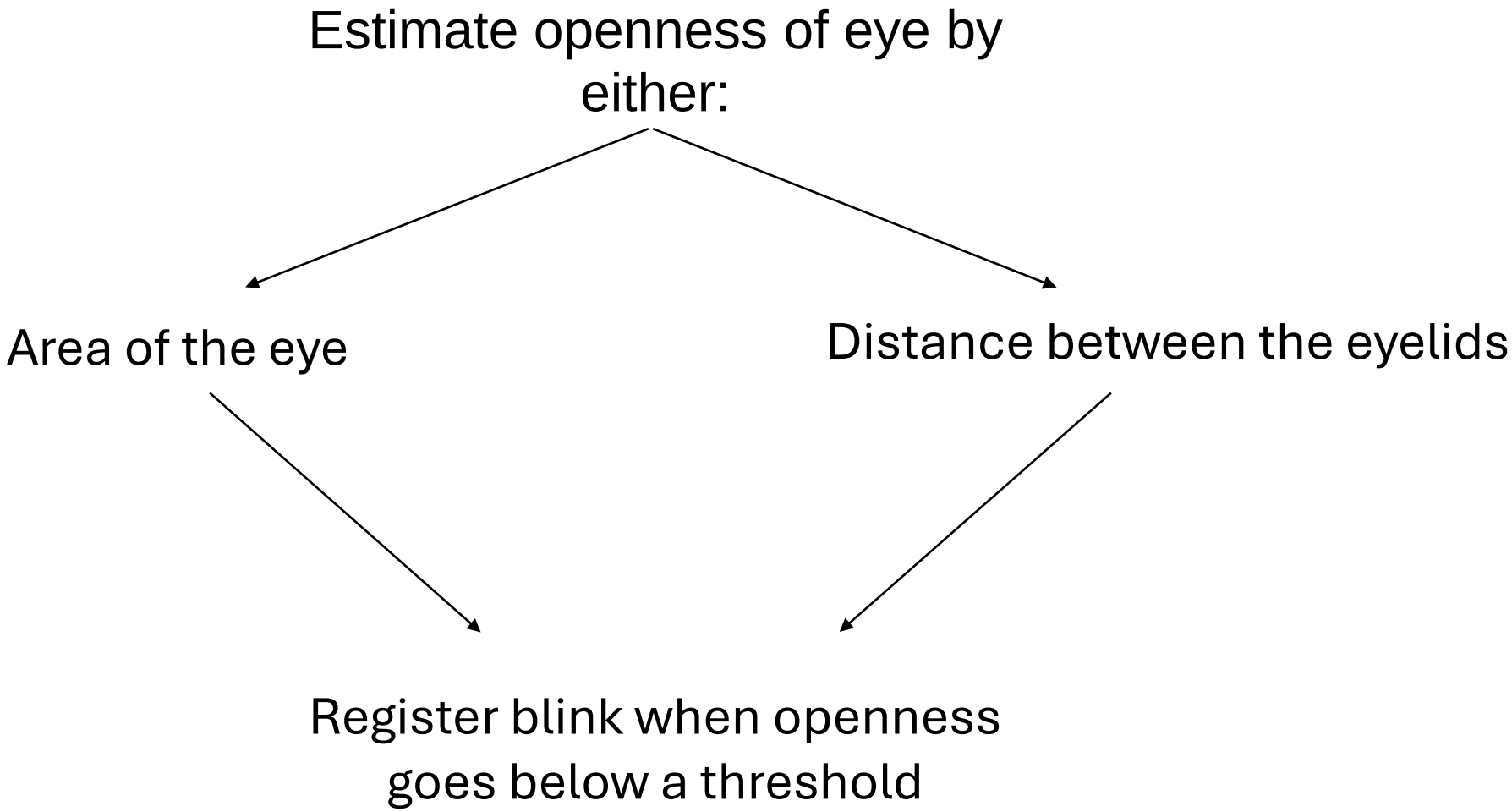
- Use 2D pixels of image
- Which features used effect algorithm accuracy/efficiency
- Performance with eye-patch varies



3D facial geometry

- Use MediaPipe's vision model's eye and pupil landmarks
- More holistic and therefore robust

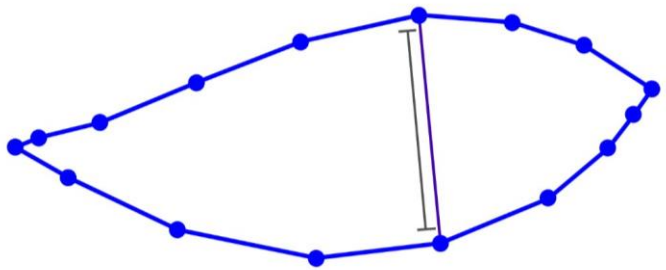
Blink Detection Process



Blink Detection Algorithms

Distance calculation

- Calculate distance between two points on the face:
  - Center of upper eyelid
  - Center of lower eyelid



Blink Detection Algorithms

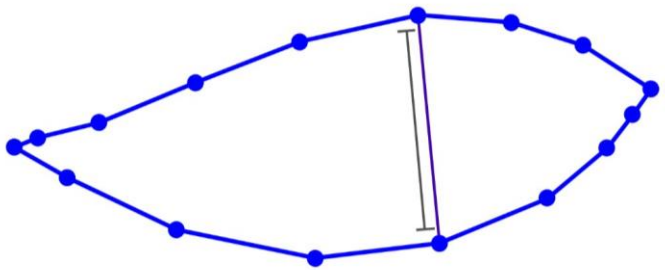
Distance calculation

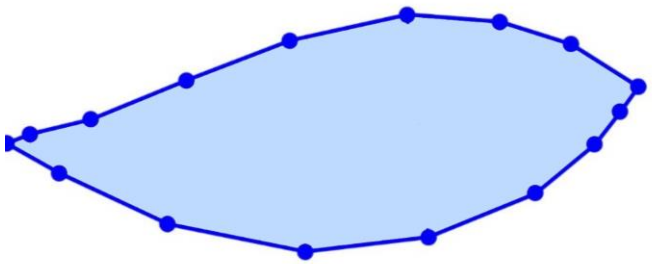
- Calculate distance between two points on the face:
  - Center of upper eyelid
  - Center of lower eyelid

Shoelace theorem

- Use the x and y coordinates of the eyelid's landmarks to calculate area

$$A = \frac{1}{2}\sum_{i=1}^{n}(x_{i+1} + x_i)(y_{i+1} - y_i)$$





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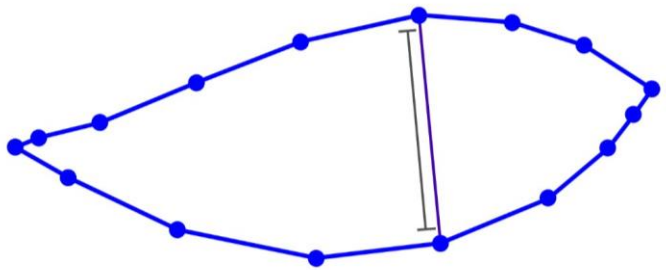

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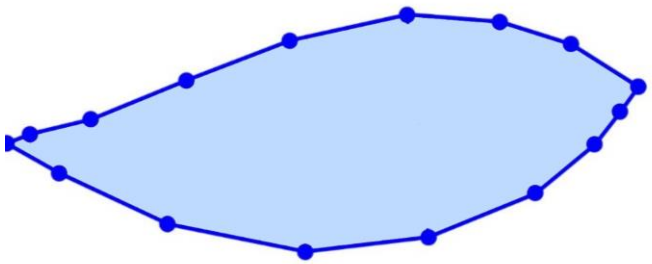
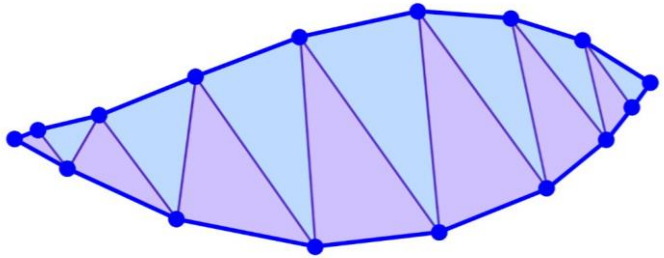


Polygon triangulation

- Divide eye into triangles, form vectors for each triangle.
- Sum area of each triangle

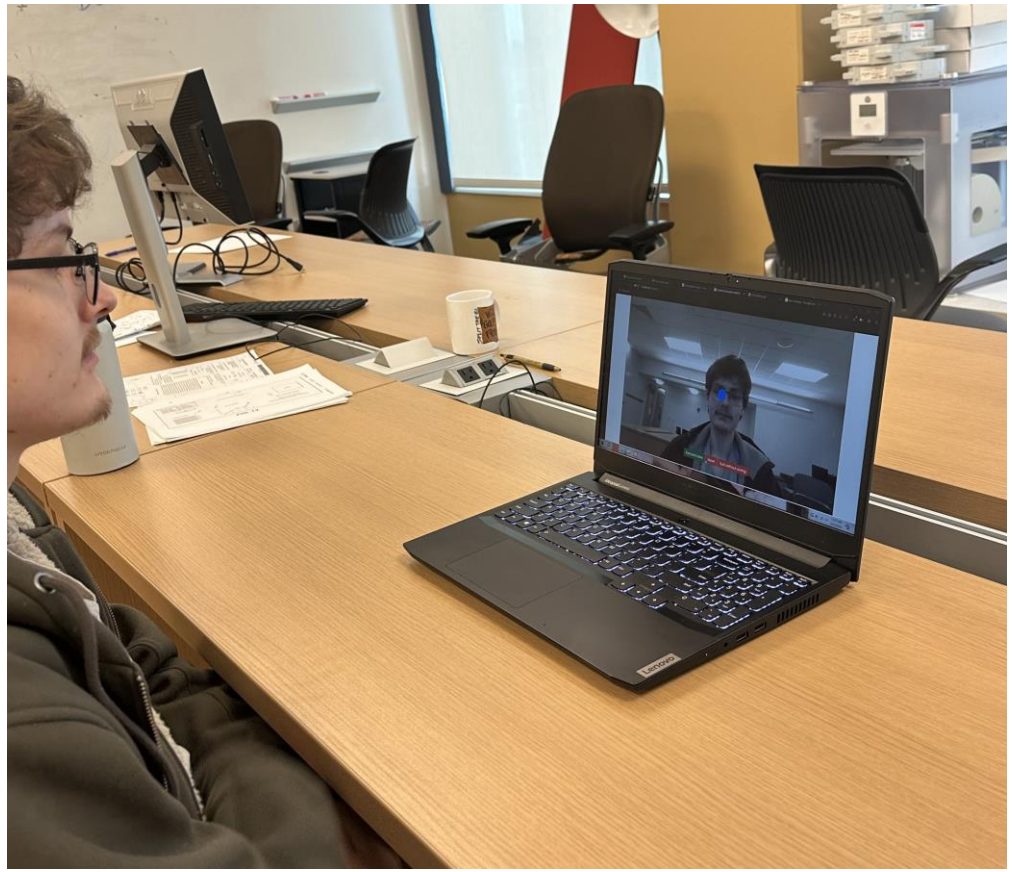
$$A_{t_i} = \frac{1}{2}\|\mathbf{vec1} \times \mathbf{vec2}\|$$

$$A = \sum_{i=1}^{n} A_{t_i}$$



Experimental Setup

- Tests were recorded on consumer-grade webcam
- All test manually observed 20 blinks
- Different testing conditions:
  - Glasses vs. No glasses
  - Movement vs. No movement
  - Movement both horizontal and vertical
  - No movement over 40 degrees
- Approximately 400 frames per recording



Results: Distance Method

Table Legend

NG – No Glasses
G – Glasses
NM- No movement
VM – Vertical Movement
HM – Horizontal Movement

Metrics	NG-NM	G-NM	NG-VM	NG-HM	G-VM	G-HM
# Blinks	20.33	19.33	19.33	19	21.67	12.33
TP	20	19.33	19.33	19	20	12.33
FP	0.33	0	0	0	1.67	0
FN	0	0.67	0.67	1	0	7.67
% Acc	98.4%	96.7%	96.7%	95%	92.3%	61.7%

0.001 ms average compute time

Results: Shoelace Theorem

Metrics	NG-NM	G-NM	NG-VM	NG-HM	G-VM	G-HM
# Blinks	20	19.67	20	19.33	21.67	13.33
TP	20	19.67	20	19.33	20	13.33
FP	0	0	0	0	1.67	0
FN	0	0.33	0	0.67	0	6.67
% Acc	100%	98.4%	100%	96.7%	92.3%	66.7%

0.01 ms average compute time

Results: Polygon Triangulation

Metrics	NG-NM	G-NM	NG-VM	NG-HM	G-VM	G-HM
# Blinks	20	20	20	20	21	14.67
TP	20	20	20	20	20	14.67
FP	0	0	0	0	1	0
FN	0	0.33	0	0	0	5.33
% Acc	100%	100%	100%	100%	95.2%	73.4%

1 ms average compute time

Discussion

- Polygon triangulation: most accurate but takes the longest
- Eyelid Distance: runs that fastest but not as accurate
- Further work quantifying the difference between 3D and traditional 2D blink detection
- Refining threshold calibration

Thank you

- Link to paper:

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