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Eye Gesture Recognition on Portable Devices

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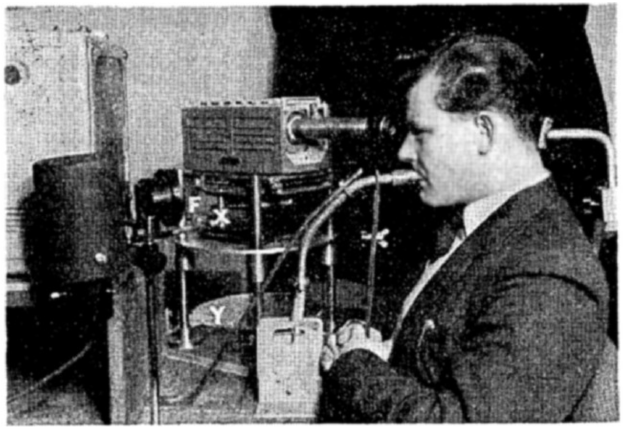
September 9, 2012

Introduction: Brief history of eye tracking

Delabarre 1898

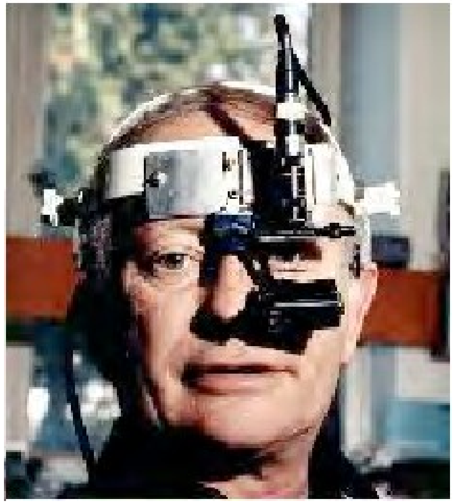
Buswell 1935



Mackworth 1958

Shackel 1960

Merchant 1969



Land 1997

Mobile eye trackers

tobii Glasses
IR markers for object tracking

SMI Eye Tracking Glasses
pupil/CR, binocular

Ergoneers Dikablis

ASL MobileEye XG

Introduction: Remote eye trackers

mirametrix S2

seeingmachines faceLAB 5

tobii X120

SMI iViewX Hi-Speed

tobii eye tracking laptop

Still missing...

- Portable devices have become an integral part of people's everyday life
- Previous device generations limited in sensing capabilities and processing power
- Powerful smartphones with high-resolution front-facing cameras

→ **Gaze-based interfaces that will be pervasively usable in daily life** [1]

Samsung Galaxy S3
1.9MP front-facing camera
1.4GHz quad-core CPU

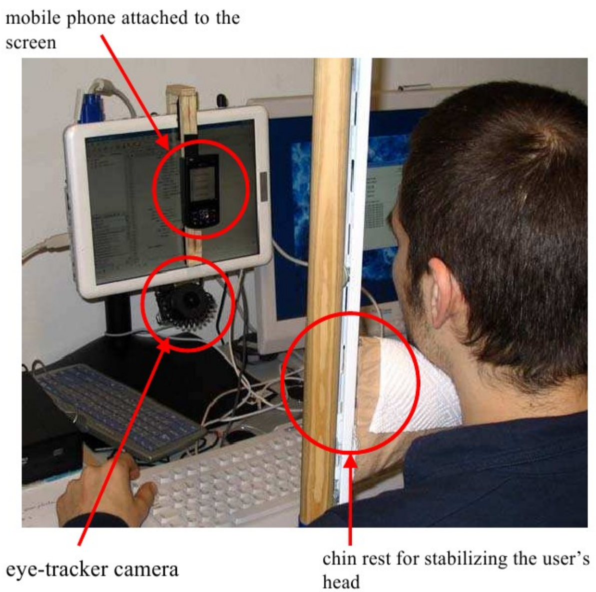
Challenges

- No infrared illumination
- Real-time, embedded head pose and gaze estimation
- Highly dynamic interaction styles

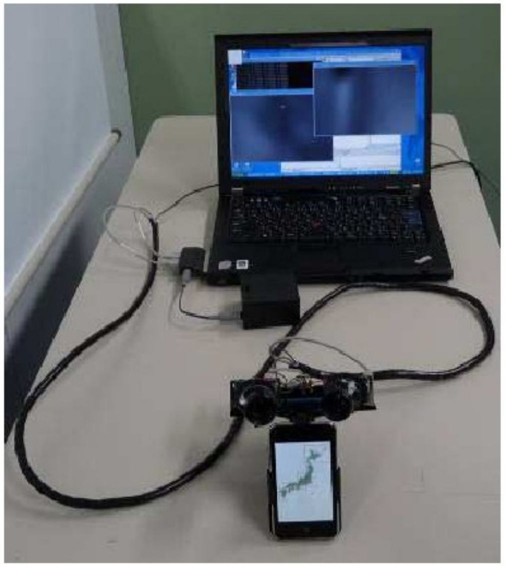
[1] Bulling et al., IEEE Pervasive Computing 9(4), 2010

Related work

- Eye-gaze interaction for mobile phones [1]
  remote eye tracker, chin rest



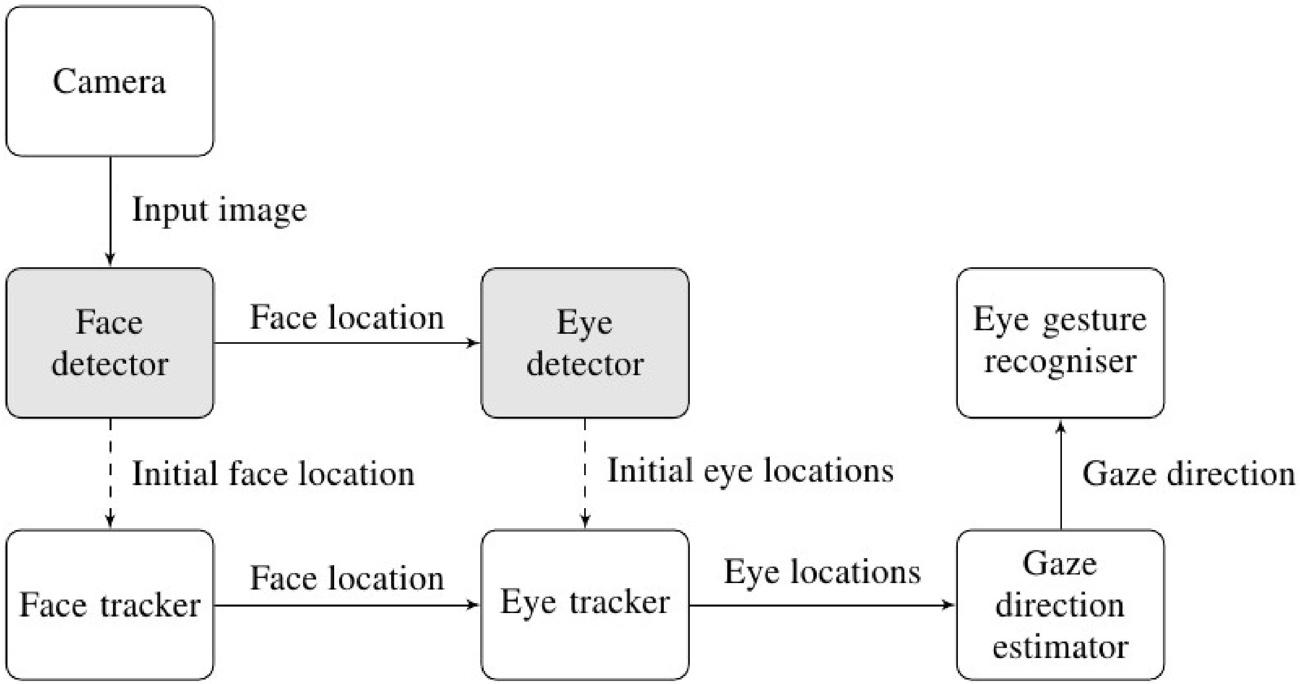
- Gaze interface for mobile devices [2]
  two external CV cameras, IR illumination, laptop



- EyePhone: Activating mobile phones with the eyes [3]
  on-device processing, only eye position

[1] Drewes et al., Proc. Mobility 2007 / [2] Nagamatsu et al., Proc. CHI 2010 / [3] Miluzzo et al., Proc. MobiHeld 2010

Eye gesture recognition (I)

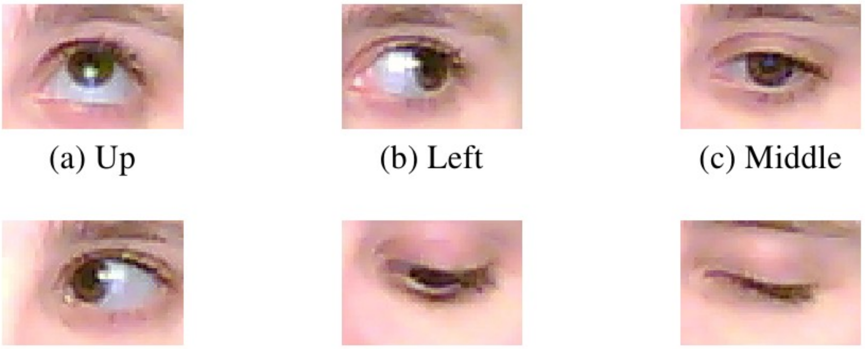


- Implemented as library using OpenCV port for Android [1]
  - Face and eye detectors: Viola-Jones [2,3]
  - Face tracker: mean shift algorithm
  - Eye tracker and gaze estimation: template matching
  - Eye gesture recogniser: string matching

[1] OpenCV for Android, http://code.google.com/p/android-opencv/ / [2] Lienhart and Maydt, Proc. ICIP 2002 / [3] Santana et al., JVCIR 2007

Eye gesture recognition (II)

- Detection of six basic gaze directions
- Filtering and aggregation of gaze directions

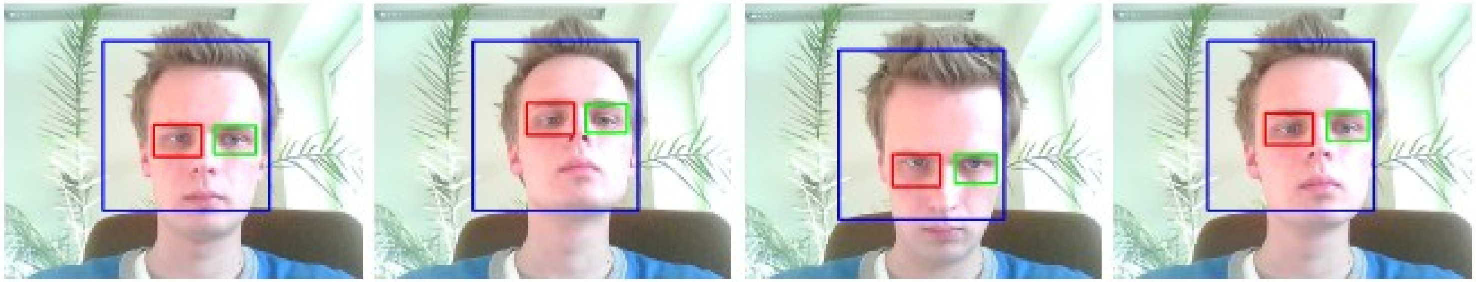


(a) Up (b) Left (c) Middle (d) Right (e) Down (f) Closed

Filtering window →

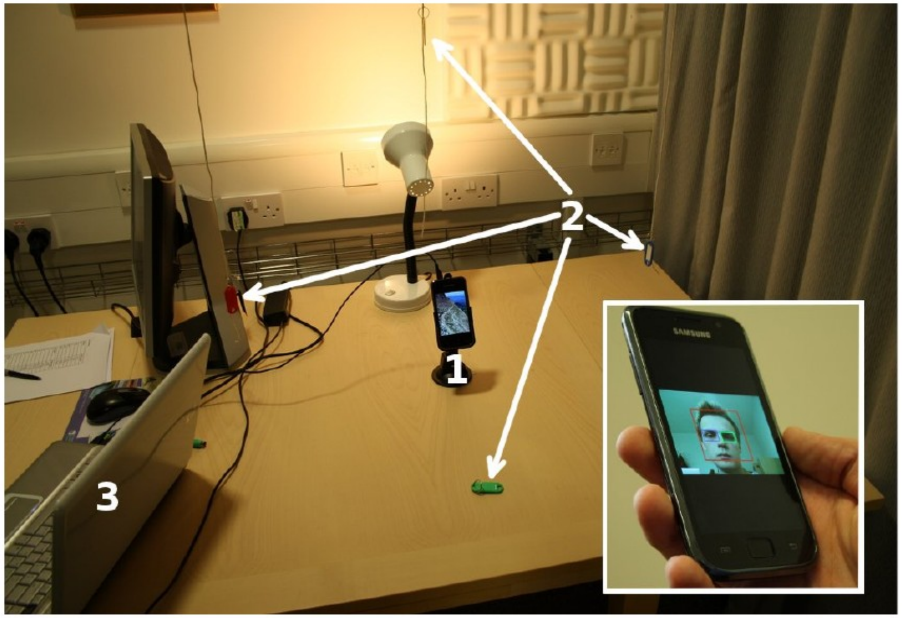
Input	...	M	L	L	M	R	R	R	M	C	D	M	...
Filtered directions	...			L	L		R	R	R		D	D	...
Aggregated directions	...				L				R			D	...

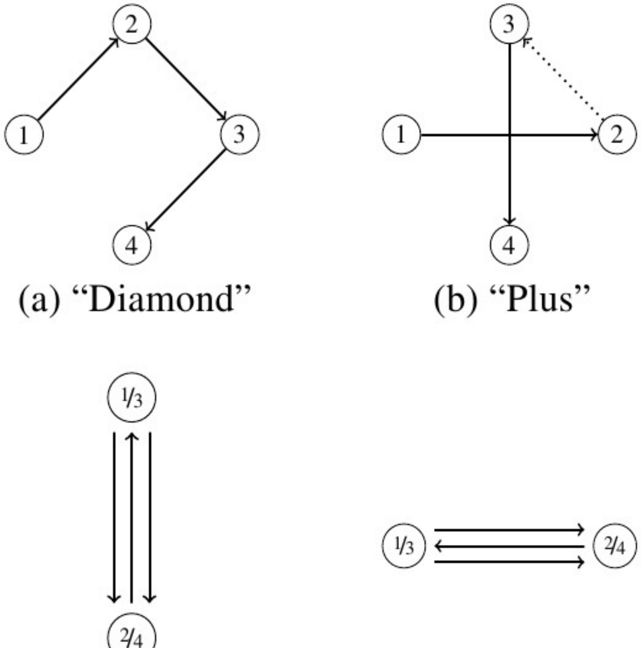
- Additional head gesture detection
  - › based on relative position of the face and left eye



Feasibility study

- 5 participants, 4 male / 1 female, 21 - 25 years
- Two portable devices: Android phone and laptop computer
- Quiet laboratory setting, controlled lighting conditions, no chin rest
- Four tasks: Training, eye gestures on laptop and phone, interaction with photo gallery





(a) "Diamond" (b) "Plus" (c) "Vertical" (d) "Horizontal"

Data analysis and performance evaluation

- Manual post-hoc annotation to identify gestures
- Automatic computation of true positive (TP), true negative (TN), false positive (FP) and false negative (FN) counts
  - TN: number of gestures the algorithm didn't detect but could have detected
- Calculation of false positive rate (FPR), sensitivity/recall and accuracy

$$FPR = \frac{FP}{FP + TN}$$

$$Sensitivity = \frac{TP}{TP + FN}$$

$$Accuracy = \frac{TP + TN}{TP + FN + FP + TN}$$

Results

Real-time performance

- Tracking close to max. frame rate of 30fps
- Recognition state only 0.03% of the time
- Limitation of OpenCV port: video drawing always on

	Laptop	Mobile phone
Tracking	22.73 fps 174 ms	3.95 fps 574 ms
Recognition	13.70 fps 188 ms	4.95 fps 319 ms
Baseline	24.39 fps 108 ms	7.52 fps 298 ms

Recognition performance

- Lower sensitivity on mobile phone
- Large differences between participants

Experiment	Sens. [%]	FPR [%]	Acc. [%]
	Laptop		
Initial training	61.4	7.8	77.4
Recognition	33.8	5.9	67.3
Average	52.9	7.2	74.1
	Mobile phone		
Recognition	28.3	17.6	60.0

Conclusion

Contribution

- First prototype implementation of an eye gesture recognition system that runs entirely on an Android portable device
  - No external cameras or infrared illumination
- Image processing and computer vision system for online head and eye detection and tracking

Future work

- Improve robustness and performance of algorithms
  - Mobile daily life setting (upper body and head movements)
  - Natural lighting conditions and device use
  - Real-time implementation
- True gaze estimation

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