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Ambient Intelligence

Closed-Eye Gaze Gestures: Detection and Recognition of Closed-Eye Movements with Cameras in Smart Glasses

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Motivation and Goal

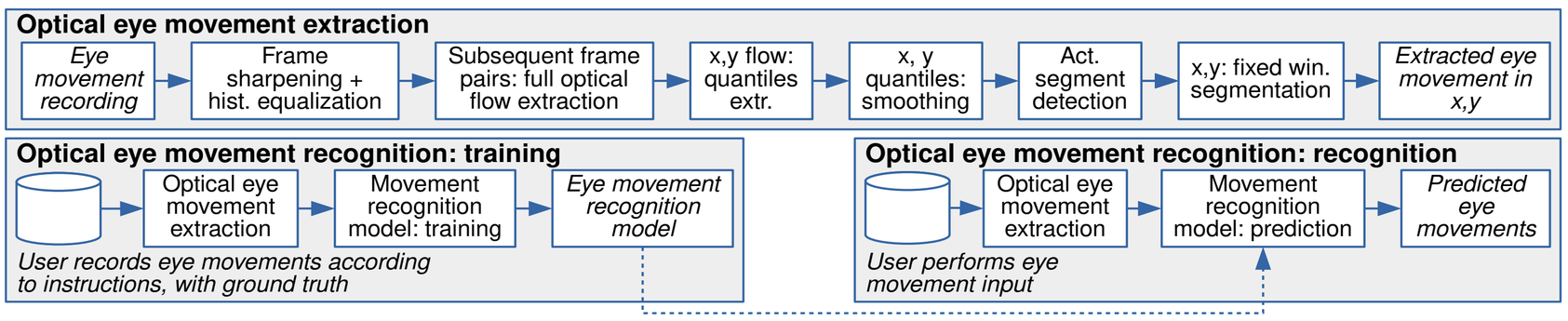
Gaze gesture based graphical passwords, e.g. from smart glasses monitoring a user's eye movements, have potential for quick and unobtrusive mobile authentication. Gaze gestures are hands-free and don't require users to directly look at or focus on the device they are authenticating to. However, similar to PIN and password entry on mobile devices, attackers might easily observe gaze gestures by observing a user's eye and pupil movements. In our research we therefore utilize closed-eye gaze gesture authentication. Our goal is to enable quick, short, and easy gaze-based passwords with closed eyes, which can ideally be shorter than with eyes opened due to effort for successful attacks being higher.
We record data using Pupil, a Pupil Labs eye tracker with the form factor of smart glasses, and which features an eye-facing camera built into the frame of the glasses.

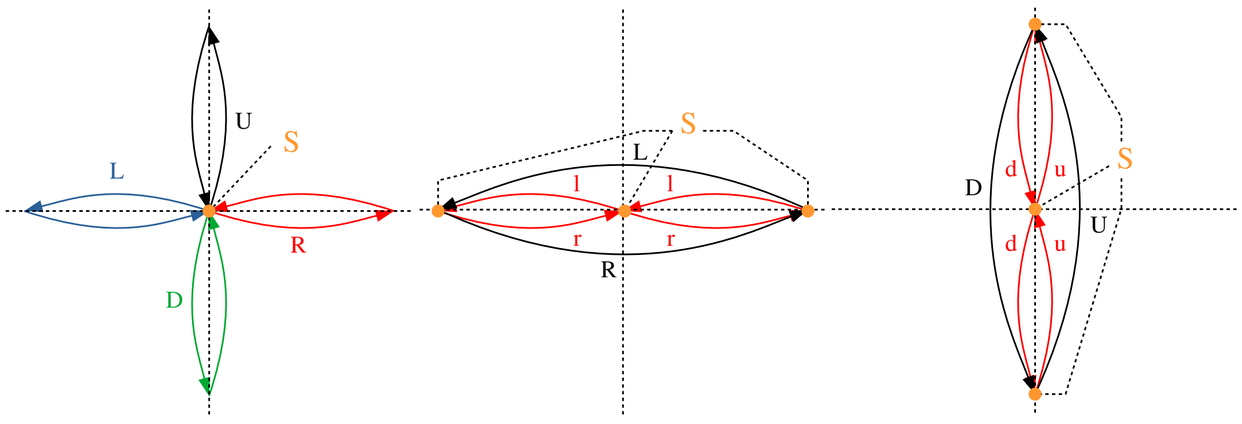

Pupil Labs pupil tracker


Preprocessed pupil video frame

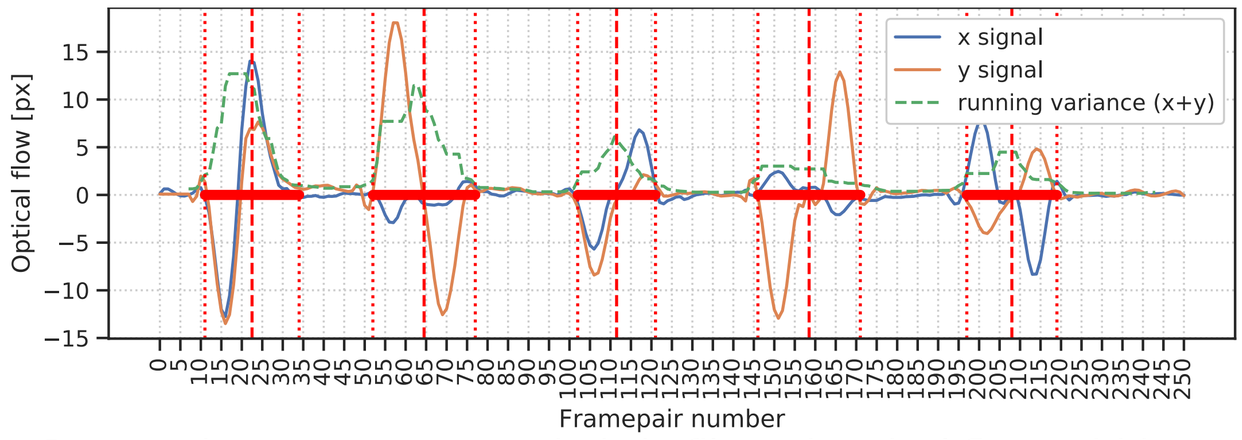
Method

Closed-eye gaze gestures are extracted from optical data with optical flow. Gestures are detected, extracted, and recognized with signal processing and machine learning. We comparatively evaluate the authentication performance and gaze gesture confusion of four closed-eyes gaze gesture password schemes:
LRUDS: 4 bidirectional eye movements, in 4 directions, starting and ending at the center, and 1 squint ("flick") eye movement, which is similar to blinking eyes would eyes be opened.
LlRrUuDdS: 8 unidirectional eye movements of different sizes, in 4 directions, and 1 squint ("flick") eye movement.
lrudS: a subset of the LlRrUuDdS set with 4 unidirectional eye movements in 4 directions, and 1 squint ("flick") eye movement.
LlRrS: a subset of the LlRrUuDdS set with 4 unidirectional eye movements in different sizes in only horizontal directions, and 1 squint ("flick") eye movement.





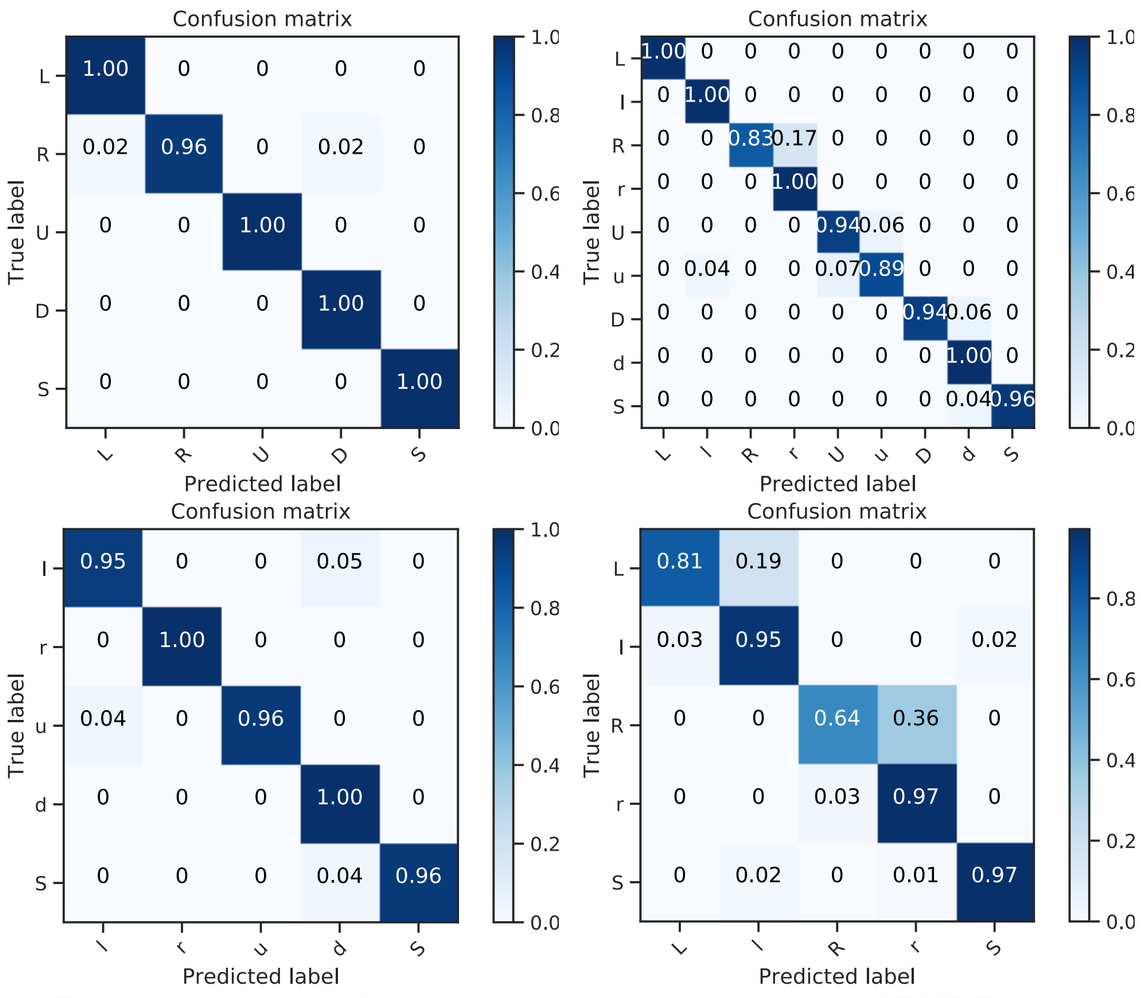
Different gaze gestures for the four gaze gesture protocols (left: bidirectional, center/right: unidirectional horizontal/vertical)



Detected gaze gestures periods in filtered optical flow, within a "SDLRU" gaze gesture password sample from the LRUDS protocol

Dataset

- The evaluation dataset contains a total of 181 closed-eye gaze gesture passwords across the four gaze gesture protocols.
- All passwords together contain a total of 1024 closed-eye gaze gestures.



Gaze gesture confusion matrices per protocol: LRUDS (top left), LlRrUuDdS (top right), lrudS (bottom left), and LlRrS (bottom right)

Results

- Closed-eye gaze gesture detection and segmentation extracts in between 82-92% of gaze gestures correctly, depending on the protocol.
- Gaze can be decomposed into a few main components with PCA: 80%/95% of variance in the data can be captured by 5-7/11-17 components only.

Protocol	Extraction Rate	Recognition Rate
LRUDS	82.2%	99.2%
LlRrUuDdS	89.2%	96.1%
lrudS	85.1%	99.2%
LlRrS	91.6%	93.7%

Conclusions

- Extraction of closed-eyes gaze gestures from optical sources (eye-facing camera embedded in smart glasses) is feasible. Detection rates are between 82%-91%: there is still room for improvement.
- Once closed-eye gaze gestures are extracted they can be distinguished well. Challenges include especially movements of different size (e.g. "R" vs "r").

Future Work

- Comparing optical and capacitive EOG data source with an authentication success evaluation.
- Comparing attackability of open and closed eye gaze gestures with an attack success evaluation.
- Comparing usability of open and closed eye gaze gestures with a usability study.