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Gaze Calibration of Eye Trackers for Head-Mounted Displays Using Eye-Frontalization Process

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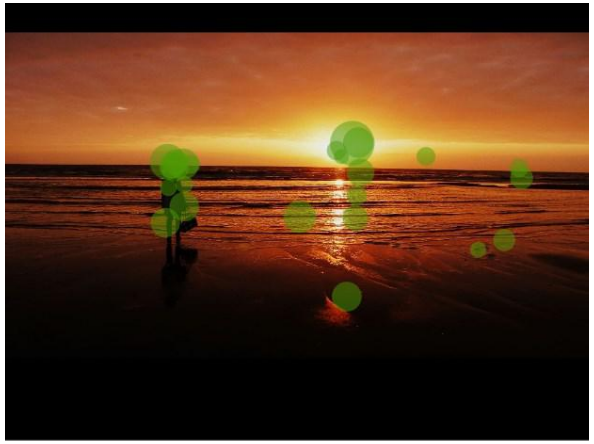
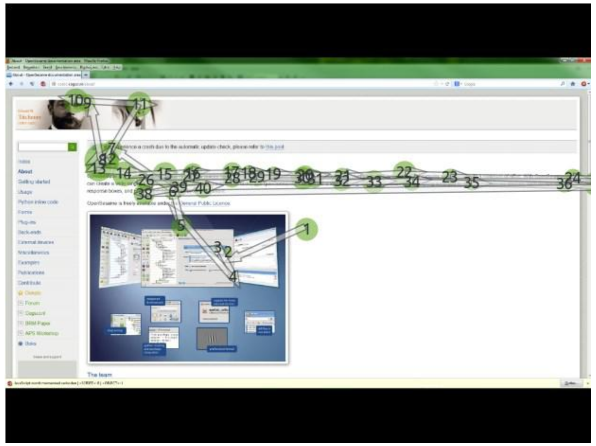
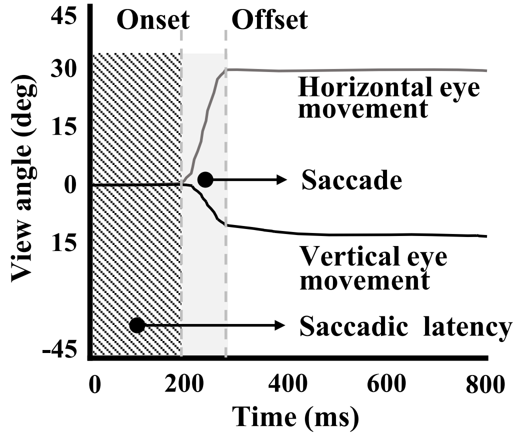
2. Background







Scan path | **Fixation points** | **Sequence** | **Eye movements**

↓

Gaze Information

2. Background

Voluntary

Measured value
- Fixation point

Utilization
- User interface
- Face tracking

Involuntary

Measured value
- Scanpath
- Sequence
- Eyemovemnt

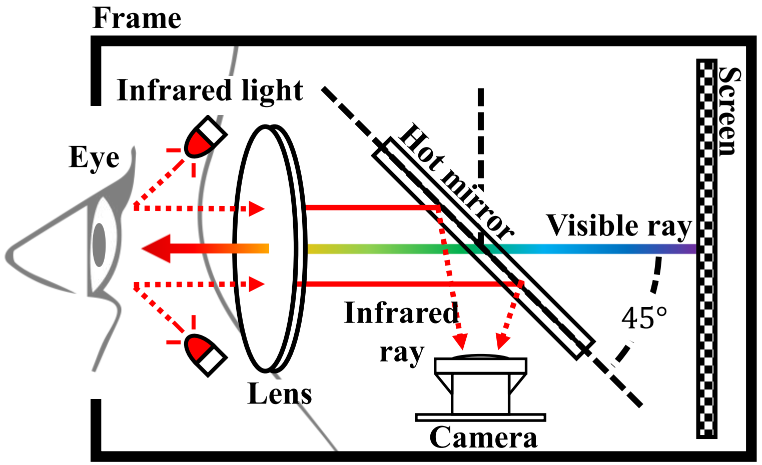
Utilization
- Psychology
- Neuroscience
- Medicine

Gaze information is used for a variety of tasks.

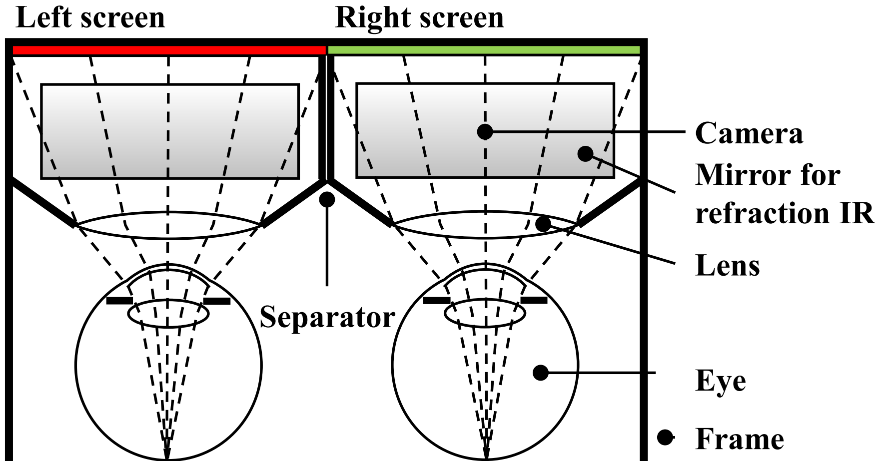
2. Background

- **Features of Virtual Really Head Mounted display Eye Tracker (VRHMD-ET)**

VRHMD-ET



Side view



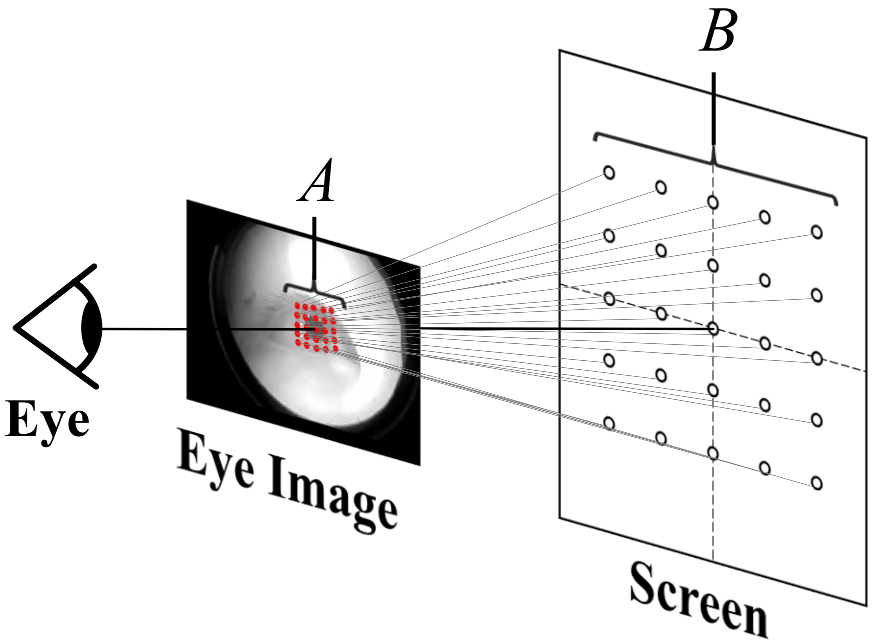
Top view

Internal structure of the VRHMD-ET

- Less affected by ambient light
- Visual stimuli can be presented at a high visual angle area

2. Background

- **Point of Regard (PoR) Calibration in VRHMD-ET**



Degree of a polynomial

$$\begin{bmatrix} u_R \\ v_R \end{bmatrix} = \begin{bmatrix} \sum_{j=0}^{n} \sum_{k=0}^{j} a_{j,(j-k)} x_i^j y_i^{j-k} \\ \sum_{j=0}^{n} \sum_{k=0}^{j} b_{j,(j-k)} x_i^j y_i^{j-k} \end{bmatrix}$$

$A(x_{0\sim25}, y_{0\sim25})$: Target Points

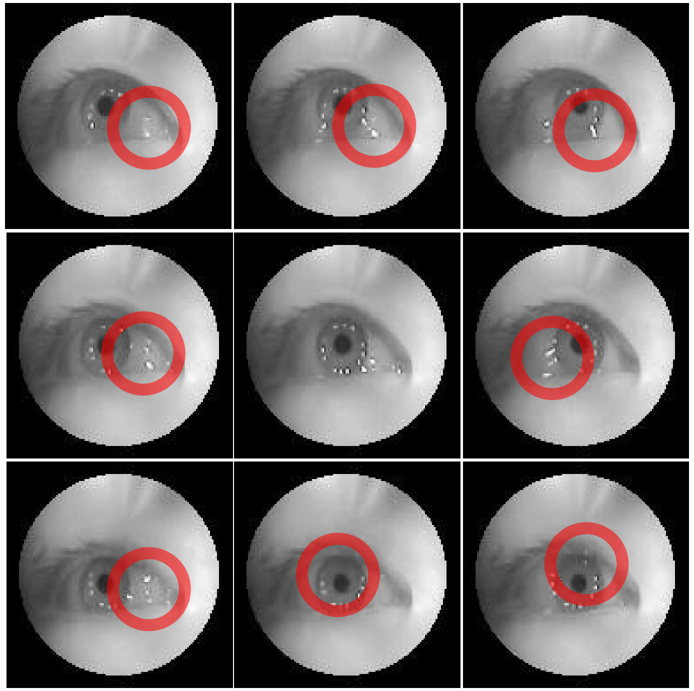
$B(u_R, v_R)$: Point of regard

Coordinate transformation in VRHMD-ET

2. Background

➢ **Gaze Calibration Problem in VR-HMD-ET**

Remote Type



VR-HMD Type

Glint detection is poor in VRMD

3. Research Aim

We propose a new gaze calibration method that can compensate the accuracy of gaze measurement for changes in the position of the VR-HMD relative to the face.

➢ **Approach**

Estimation of Pupil Coordinates

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Semantic Segmentation

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Ensure estimation accuracy of pupil coordinates

Eye Frontalization → **Gaze Redirection**

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Gaze Calibration → **One-Point Calibration**

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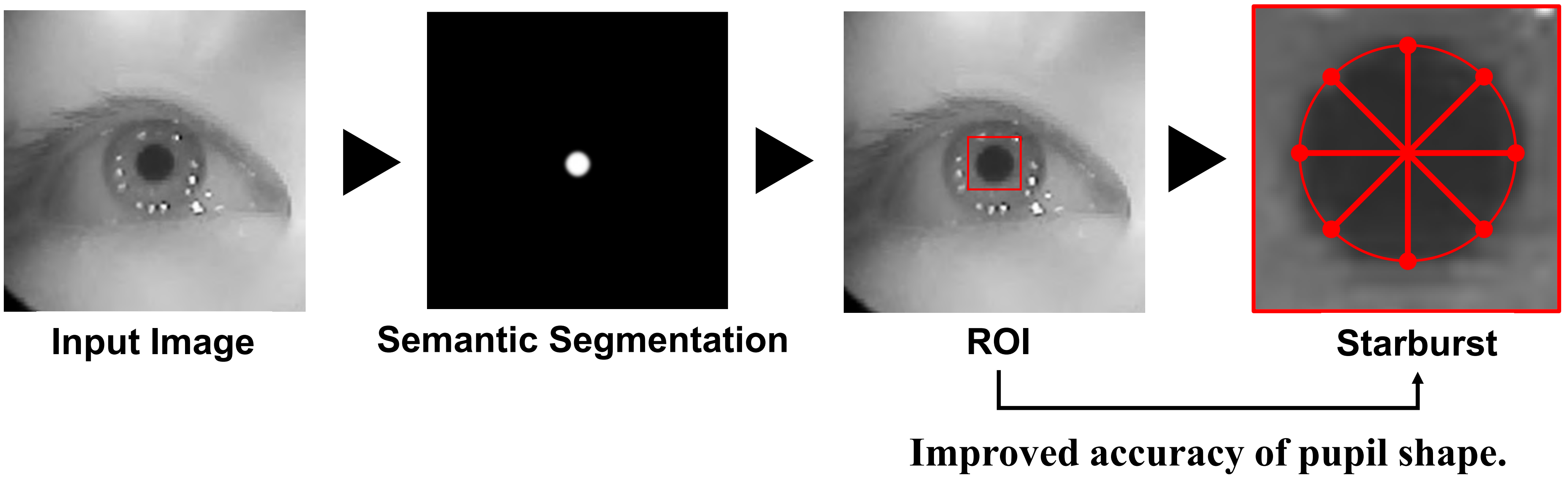
Proposals for new automated calibration

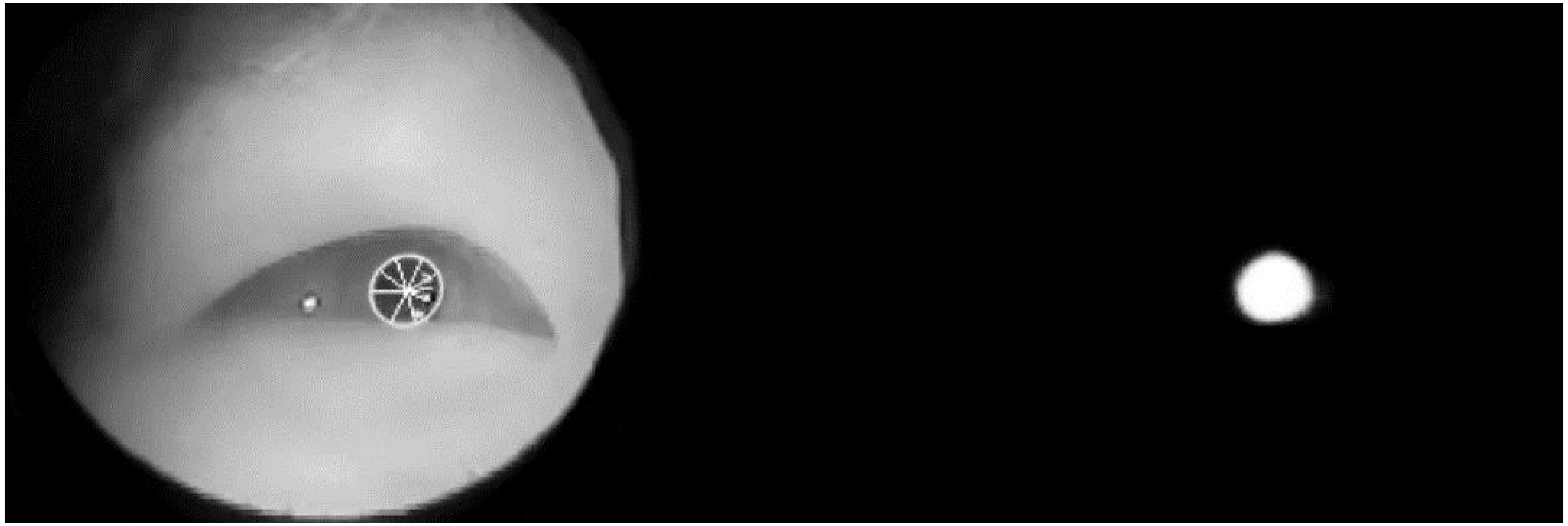
4. Estimation of Pupil Coordinates

➢ **Pipeline for getting pupil coordinates**



4. Estimation of Pupil Coordinates

- **Results of Semantic Segmentation**



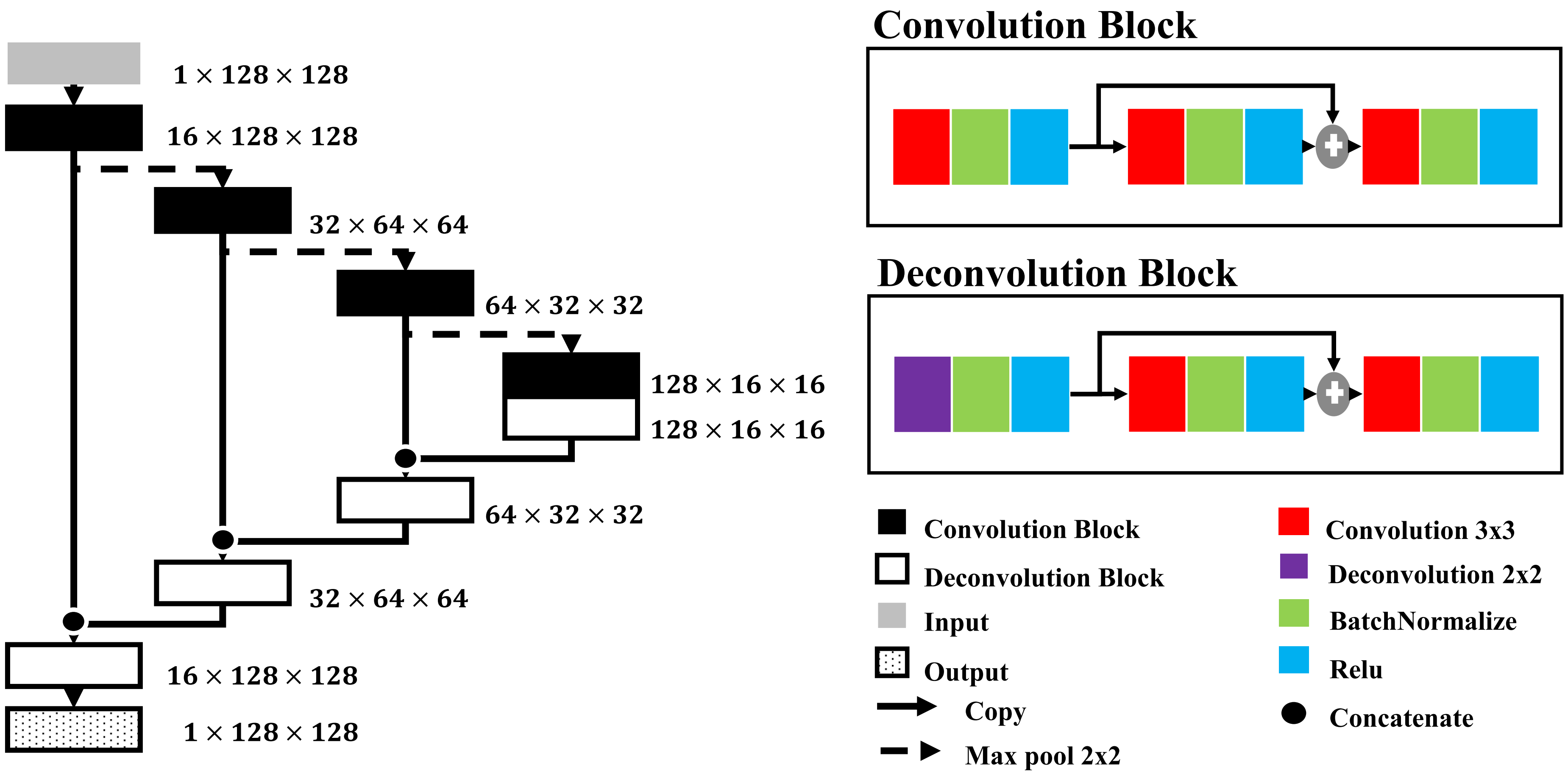
5. Eye Frontalization Process

➢ **Gaze Redirection**

	An Eye for an Eye [8]	GazeDirector [9]	ECC-Net [10]
Result			
Advantage	1. Low calculation cost	1. Photorealistic results	1. Not affected by ambient light 2. Support for occlusion
Problem	1. Eye images need to be taken in advance. 2. Affected by ambient light	1. High calculation cost 2. Affected by ambient light 3. No solution for occlusion	1. Need training data set

5. Eye Frontalization Process

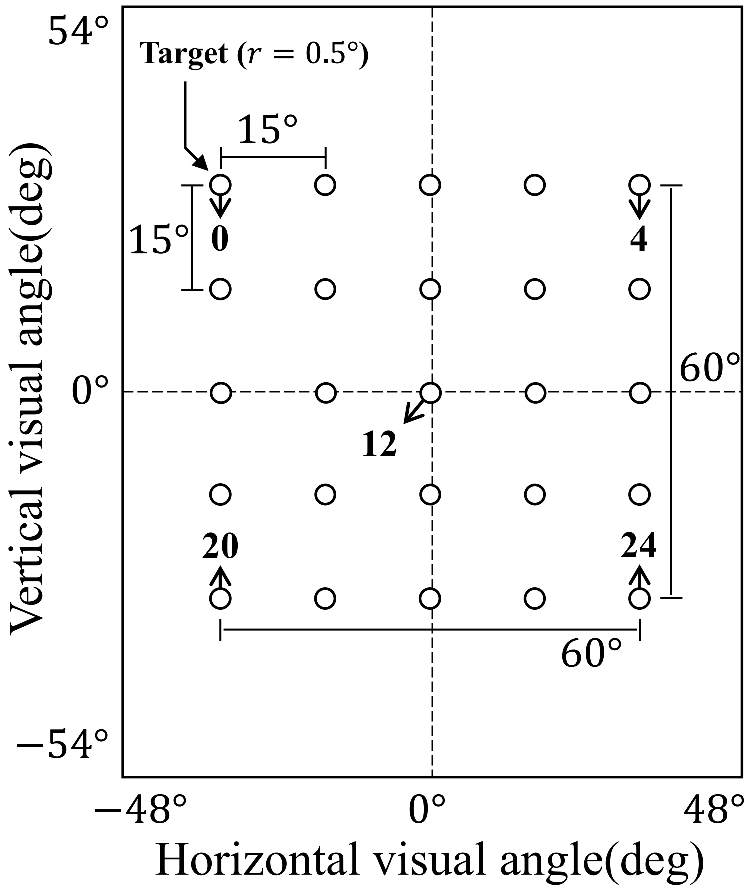
➢ **Our Neural Network**



5. Eye Frontalization Process

➢ **Our dataset**

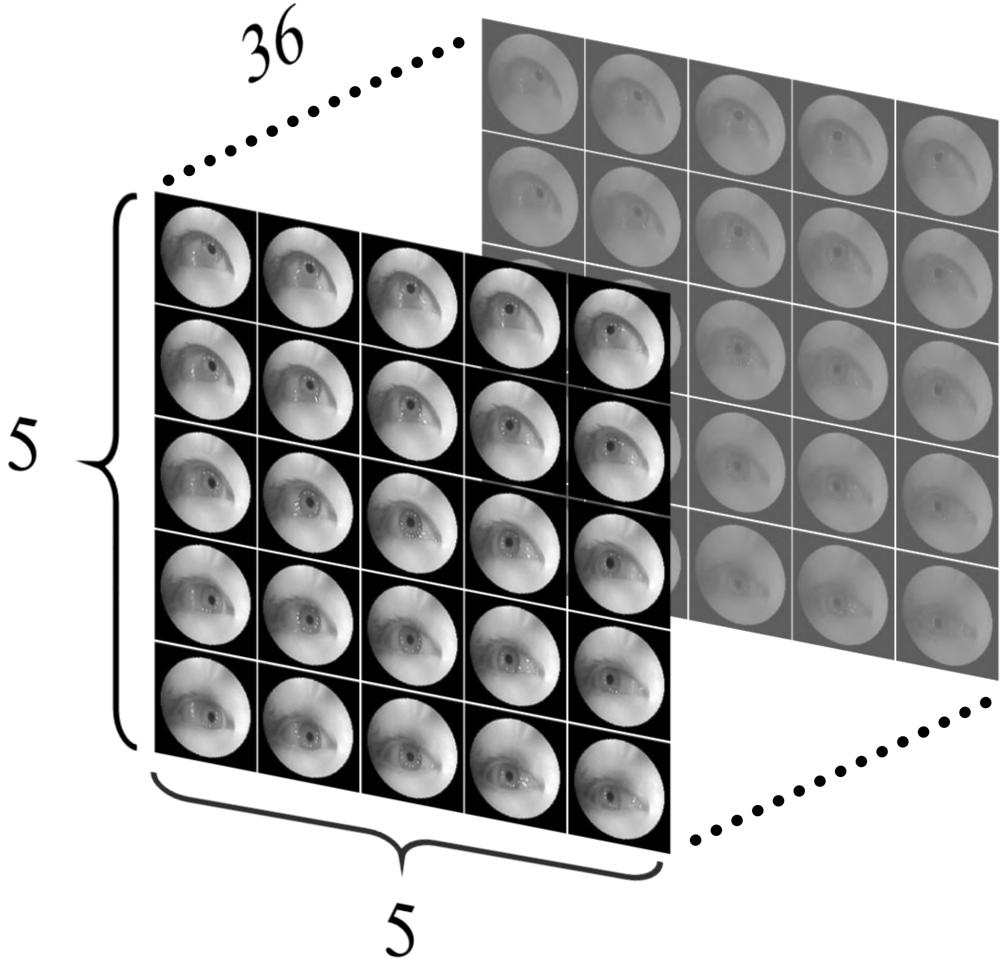
- We collected images of all subjects' eyes gazing at 25 visual targets on the screen, as shown in Figure.



5. Eye Frontalization Process

➢ **Dataset for Developed Networks**

- Each subject was requested to fixate on 25 targets three to four times, resulting 4,000 eye images. These images were used for training.



5. Eye Frontalization Process

➢ **Training settings**

- This table shows the equipment used to collect data and train the network.

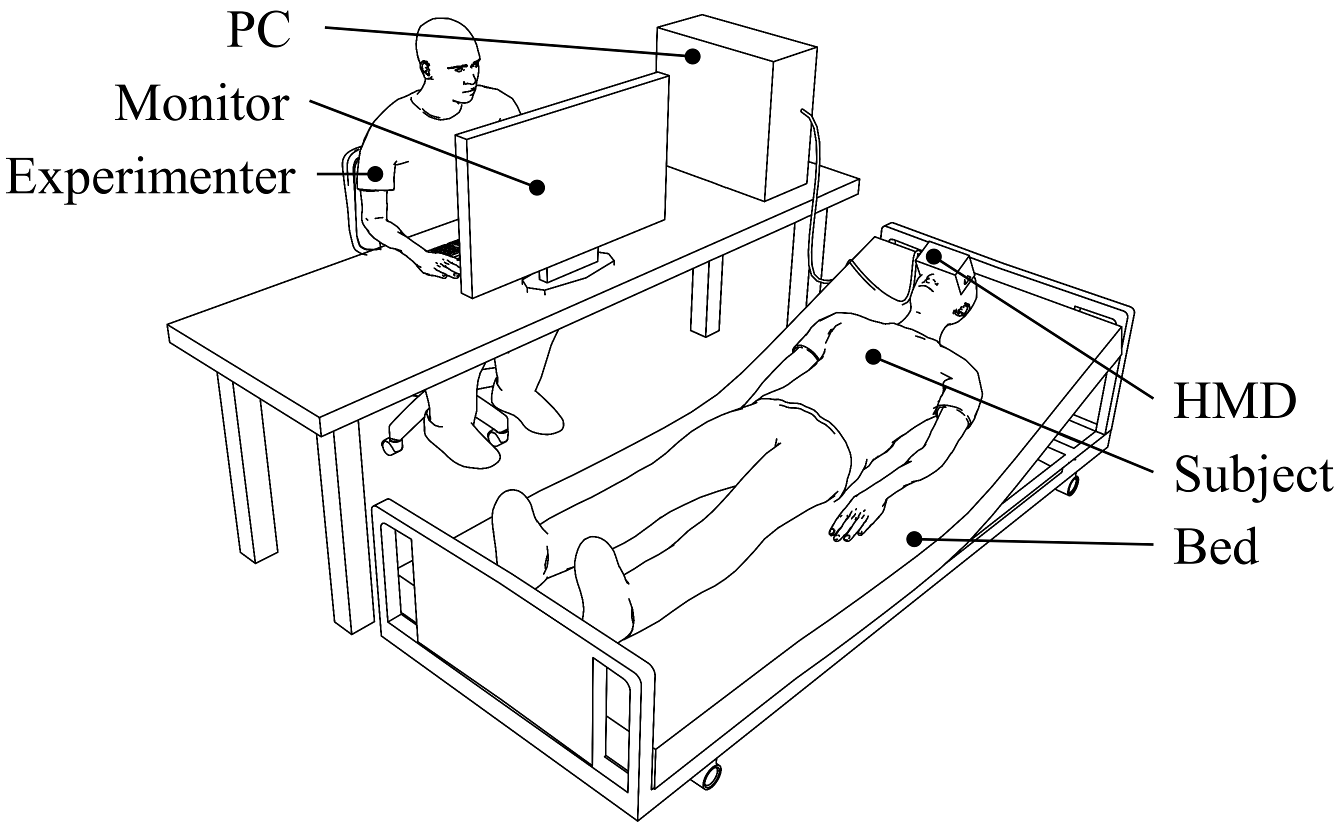
Specifications of experimental equipment

Device	Element	Specification
DIY VRHMD-ET	FoV	90°
	Resolution(Mono)	960 × 1080
	Luminance	250cd/m2
	Sampling Rate	240Hz
Desktop PC	CPU	i7-9700K(3.6GHz)
	GPU	RTX2080(8GB)
	Memory	16GB
	OS	Windows 10 64bit(Ver.2004)

5. Eye Frontalization Process

➢ **Training settings**

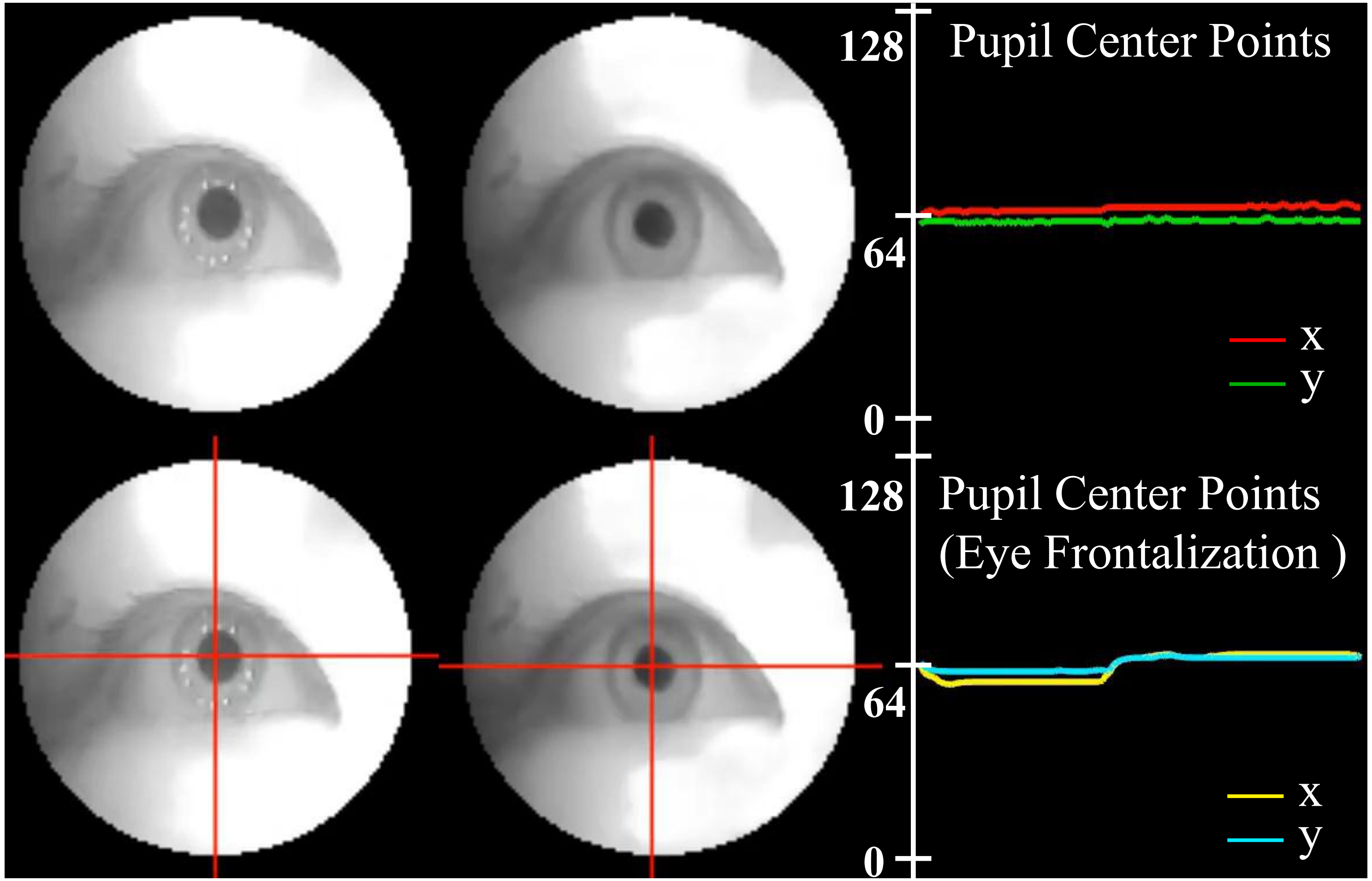
VR-HMD-ET



Experimental environment

5. Eye Frontalization Process

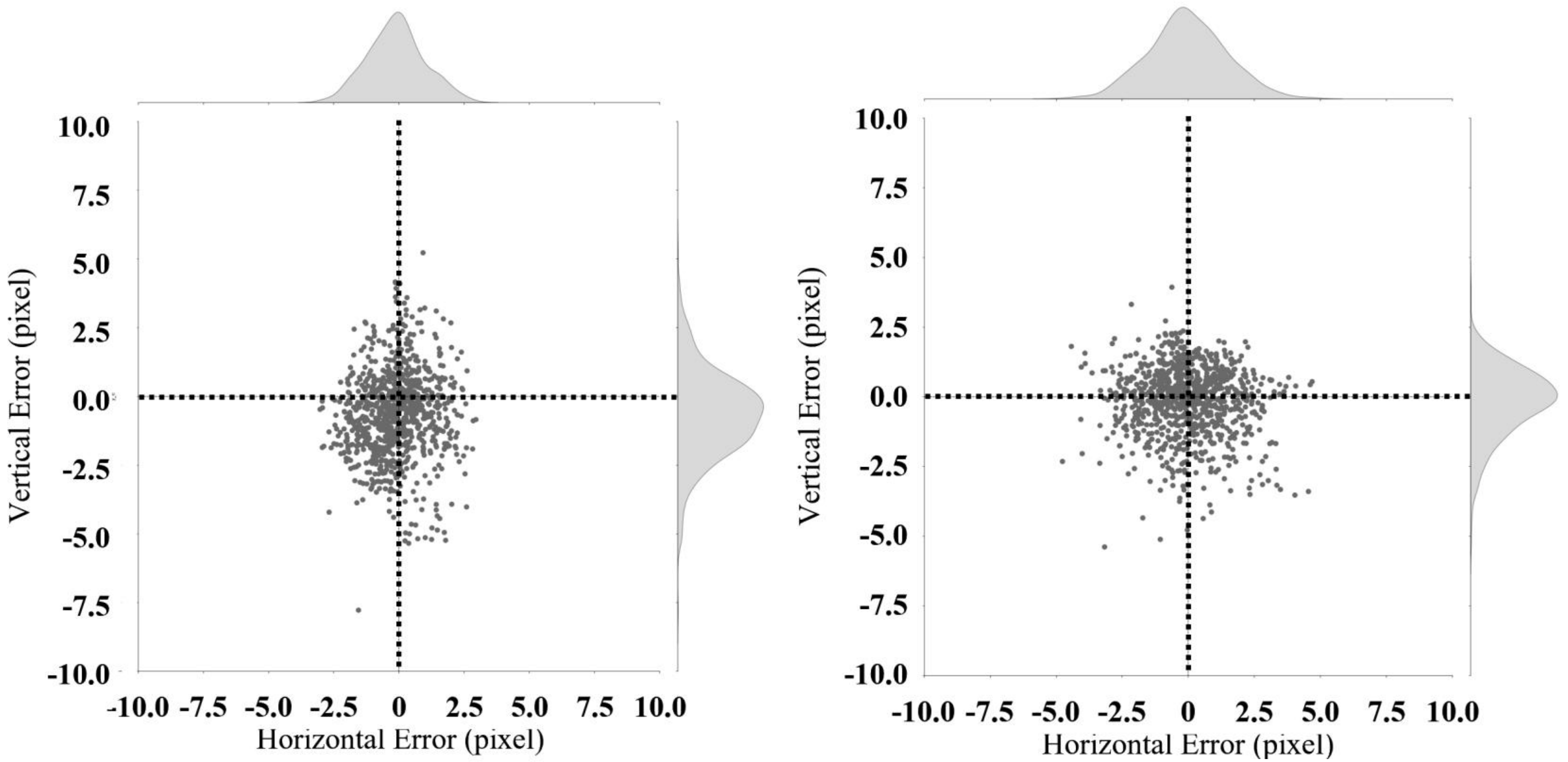
- **Training Result**
  - The video shows that the result of the eyeball straightening process is a small oscillation.



5. Eye Frontalization Process

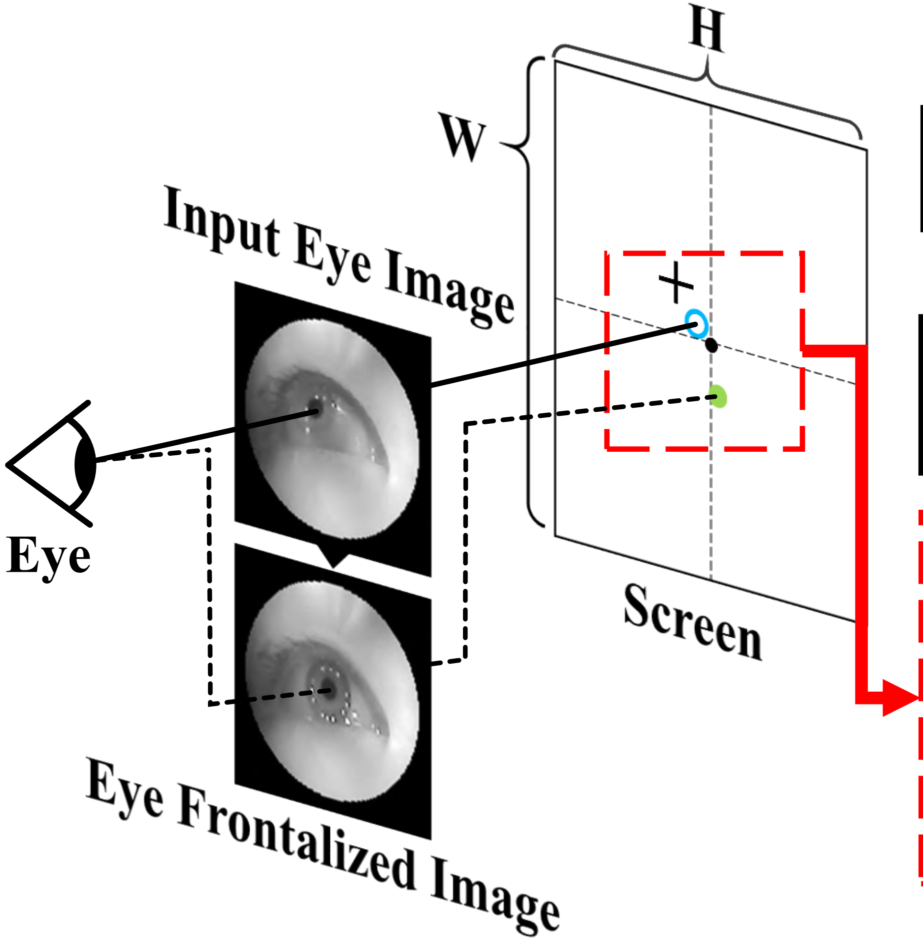
➢ Pupil Coordinate Variation Applying the Eye Frontalization Process

- This figure shows the distribution of horizontal and vertical deviations for the frontalized left and right eyes.
- The mean deviation for this experiment was 1.67 ± 0.98 pixels and 1.74 ± 1.04 pixels for the left and right eyes, respectively.



6. Proposals for new automated calibration

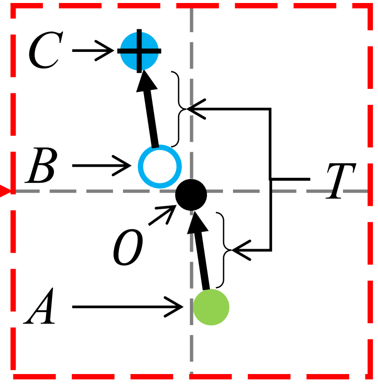
- **Eye Frontalized Process + Single-Point Calibration**



Degree of a polynomial (n)

$$\begin{bmatrix} u_R \\ v_R \end{bmatrix} = \begin{bmatrix} \sum_{j=0}^{n} \sum_{k=0}^{j} a_{j,(j-k)} x_i^{j} y_i^{j-k} \\ \sum_{j=0}^{n} \sum_{k=0}^{j} b_{j,(j-k)} x_i^{j} y_i^{j-k} \end{bmatrix}$$

$$\begin{bmatrix} u'_R \\ v'_R \end{bmatrix} = \begin{bmatrix} u_R \\ v_R \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix}$$



$A(u_G, v_G)$: Eye Frontalized Image of PoR

$B(u_R, v_R)$: Input Eye Image of PoR

$C(u'_R, v'_R)$: Translation of PoR

$O(W/2, H/2)$: Center of screen

$T(t_x, t_y) = O - A$

6. Proposals for new automated calibration

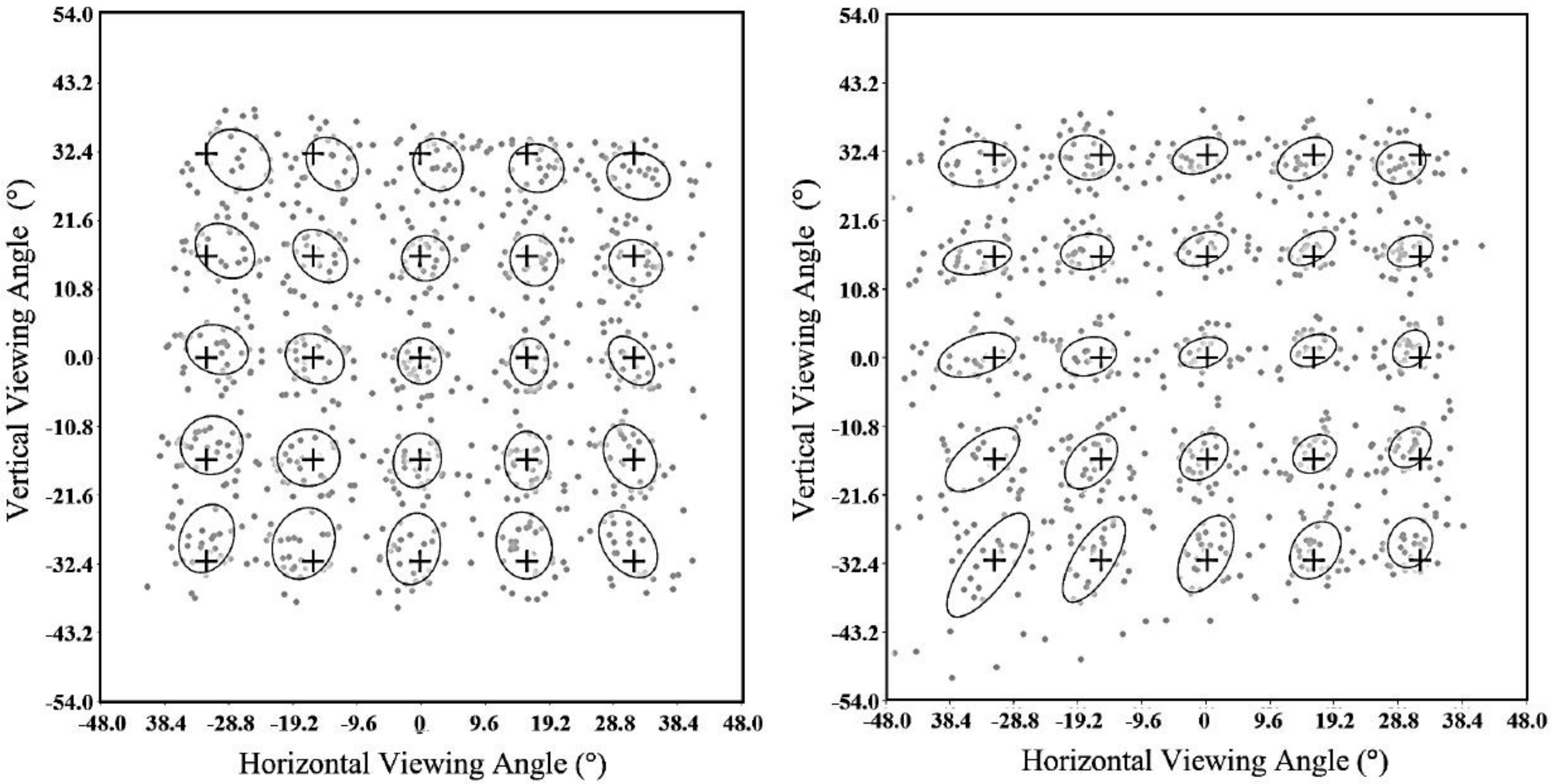
- **Definition of Accuracy**
  - $Target_{x_i}$ and $Target_{y_i}$ are the abscissa and the ordinate of the i-th target, respectively. Likewise, $PoR_{x_{i,j}}$ and $PoR_{y_{i,j}}$ are the abscissa and the ordinate of the i-th PoR, respectively. N is the total number of PoRs.

$$Accuracy = \frac{1}{N}\sum_{i=1}^{N}\sqrt{\left(Target_{x_i} - PoR_{x_{i,j}}\right)^2 + \left(Target_{y_i} - PoR_{y_{i,j}}\right)^2}$$

6. Proposals for new automated calibration

➢ **Result of Accuracy**

- The accuracy of PoR was $5.07 \pm 3.30°$ and $5.50 \pm 3.25°$ for the left and right eyes, respectively.
- This Figure shows the distribution of PoRs for all subjects. As the accuracy of the typical



7. Conclusion

- **We have accomplished**

1. We proposed gaze calibration method can be used to compensate for the accuracy of gaze measurement even when the position of the VR-HMD relative to the face changes.
2. The accuracy of the proposed method is lower than that of common eye measurement devices, but it is acceptable for the first attempt of automatic eye calibration.

In the future, we will continue to improve the calibration method to make the eye tracking system for head-mounted displays easier to use and more accurate.

Thank You, for listening
Any Questions?

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