INTERACTION-FREE CALIBRATION FOR OPTICAL SEE-THROUGH HEAD-MOUNTED DISPLAYS BASED ON 3D EYE LOCALIZATION

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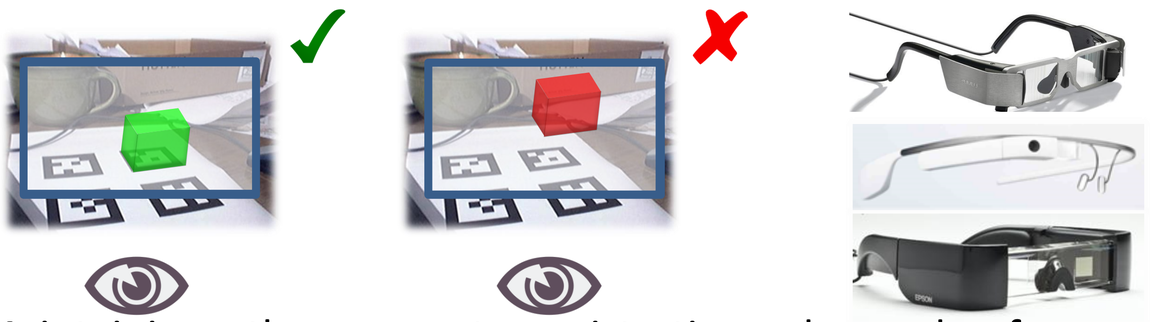
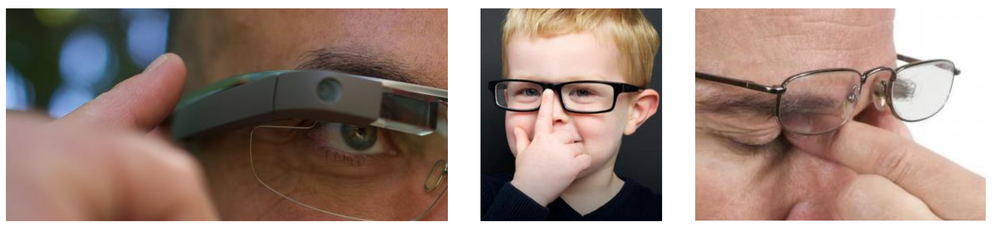
Abstract & Motivation

A correct spatial registration of **Optical See-Through** Head-Mounted Displays (**OST-HMD**) w.r.t. a user's eye(s) is an essential problem for any AR application using the such HMDs.

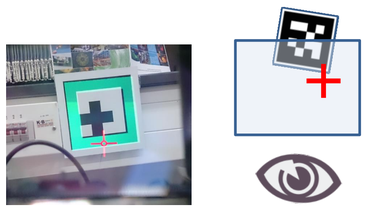


Maintaining the correct registration demands frequent **(re)calibrations** for the end-users whenever they move the HMD on their head (Touching, rubbing eyes etc.).



Our method utilizes dynamic **3D eye position** from an eye tracker in combination with pre-computed, static display parameters.

The result shows that our calibration with eye tracking is more stable than repeated **SPAAM calibrations**.



Problem Statement

Estimate a world-to-eye projection, a 3x4 matrix, of an **Eye-HMD camera**:

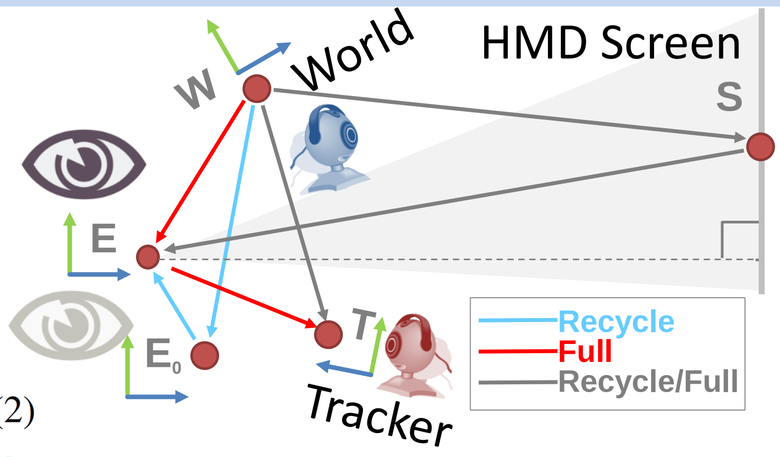
$$\mathbf{P}_{WE}(\mathbf{t}_{WE}) := \mathbf{K}_E \begin{bmatrix} \mathbf{R}_{WE} & \mathbf{t}_{WE} \end{bmatrix} \quad (1)$$

The intrinsic parameter of the camera has the following 2 representations:

$$\mathbf{K}_E = \begin{bmatrix} \alpha_x & & c_x \\ & \alpha_y & c_y \\ & & 1 \end{bmatrix} \begin{bmatrix} [\mathbf{t}_{SE}]_z & & -[\mathbf{t}_{SE}]_x \\ & [\mathbf{t}_{SE}]_z & -[\mathbf{t}_{SE}]_y \\ & & 1 \end{bmatrix} \quad \text{Full} \quad (2)$$

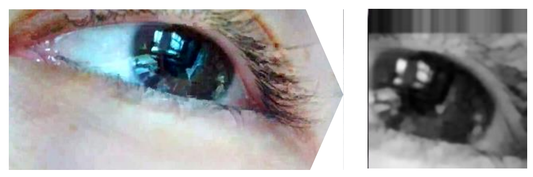
$$= \mathbf{K}_{E_0} \begin{bmatrix} 1+[\mathbf{t}_{E_0E}]_z/[\mathbf{t}_{SE}]_z & & -[\mathbf{t}_{E_0E}]_x/[\mathbf{t}_{SE}]_z \\ & 1+[\mathbf{t}_{E_0E}]_z/[\mathbf{t}_{SE}]_z & -[\mathbf{t}_{E_0E}]_y/[\mathbf{t}_{SE}]_z \\ & & 1 \end{bmatrix} \quad \text{Recycle} \quad (3)$$

(2) requires whole information about the display, while (3) recycles a previous calibration parameter set. Both need 3D eye position $\mathbf{t}_{WE}$. We evaluate (3) this time.

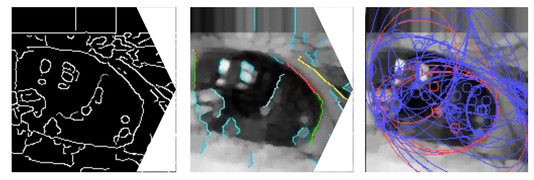


3D Eye Localization

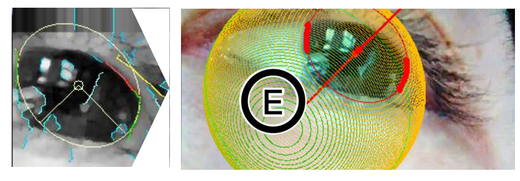
1. Estimate a 2D iris ellipse
   - Iris detector [3]



   - Ellipse fitting by RANSAC

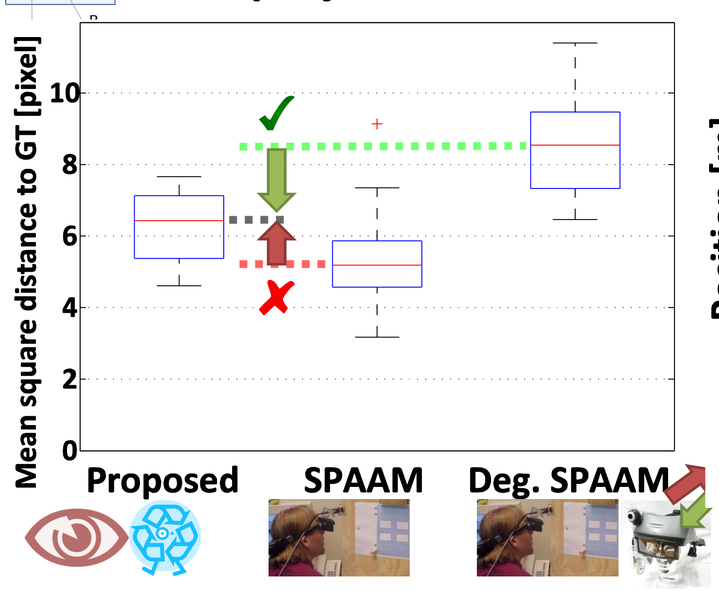


2. 3D backprojection [2]

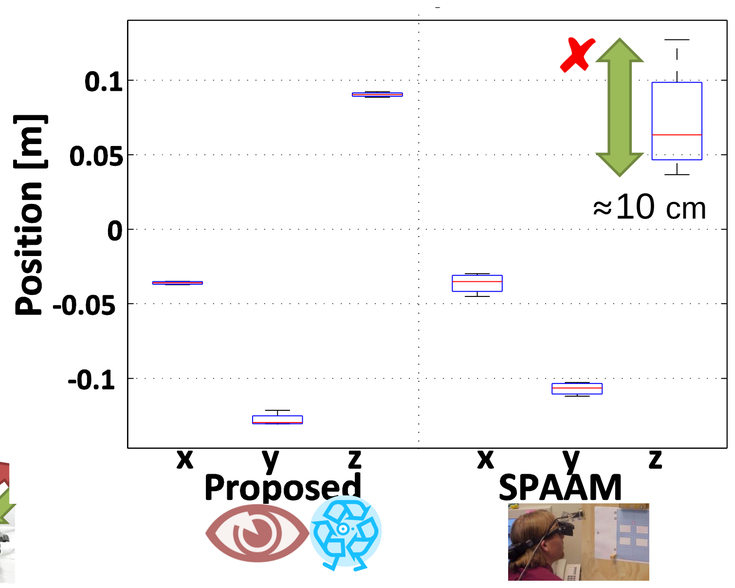


Experiments

2D Reprojection Errors



3D Eye Position Estimates



Comparison with Single Point Active-Alignment Method (SPPAM [4]), a standard calibration method relying on **user-interaction**. The proposed method outperforms **Degraded SPAAM** with stable eye position estimates.

Conclusion

Calibration of OST-HMD using 3D eye position

- Simple:
No user interaction required

- Accurate:
More accurate than a conventional approach

References

[1] Y. Itoh, G. Klinker, "Interaction-Free Calibration for Optical See-Through Head-Mounted Displays based on 3D Eye Localization," 3D User Interfaces (3DUI), 2014,IEEE

[2] C. Nitschke, A. Nakazawa, H. Takemura, "Image-based Eye Pose and Reflection Analysis for Advanced Interaction Techniques and Scene Understanding," SIG, 2011, IPSJ

[3] L. Świrski, A Bulling, N. Dodgson, "Robust real-time pupil tracking in highly off-axis images," ETRA, 2012, ACM

[4] M. Tuceryan, N. Navab, "Single point active alignment method (SPAAM) for optical see-through HMD calibration for AR," ISAR, 2000, IEEE

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