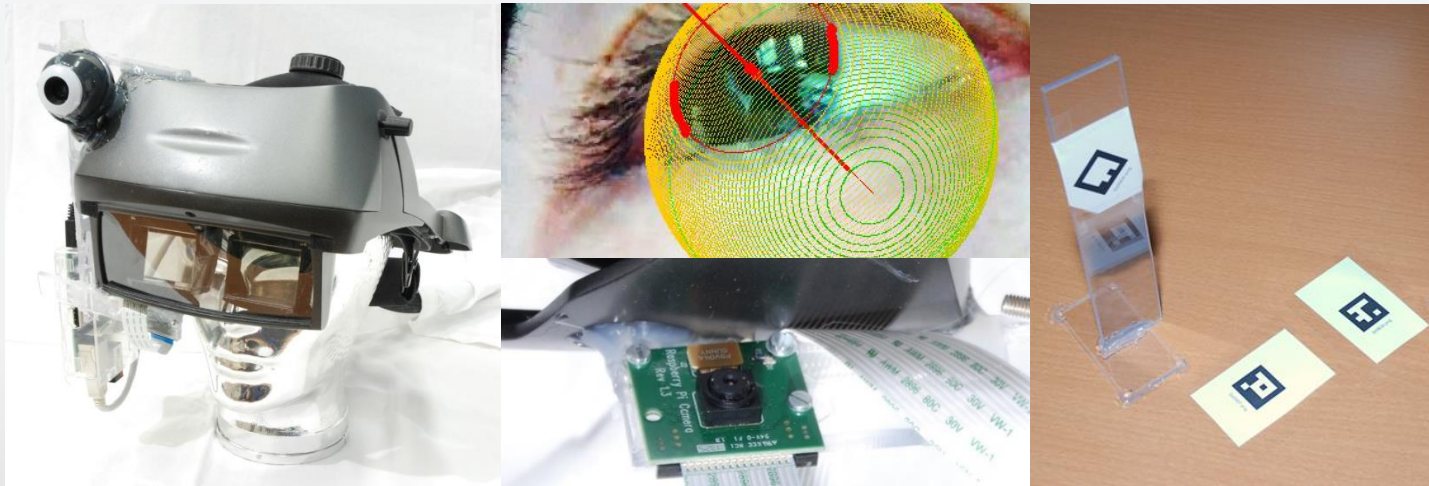


# Interaction-Free Calibration for Optical See-Through Head-Mounted Displays based on 3D Eye Localization

Yuta Itoh and Gudrun Klinker

TU München

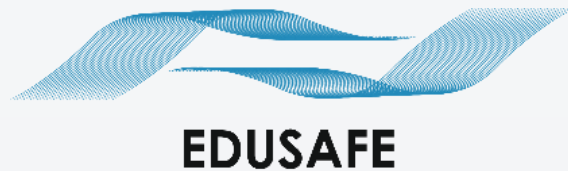


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# Information

- This work is
  - a part of EDUSAFE project



- and funded by



This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under PITN-GA-2012-316919-EDUSAFE.

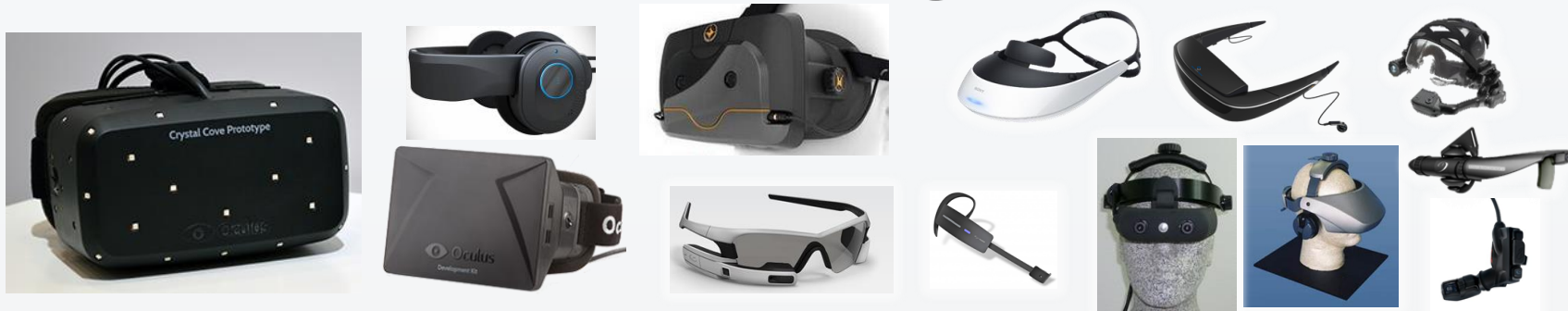


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# Head Mounted Displays (HMD)

- Non Optical See-Through



- Optical See-Through (OST)



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# Why I CAN'T Recommend OST-HMDs?

- Latency
- Depth cues
- Field of View
- Weight
- ...

and....



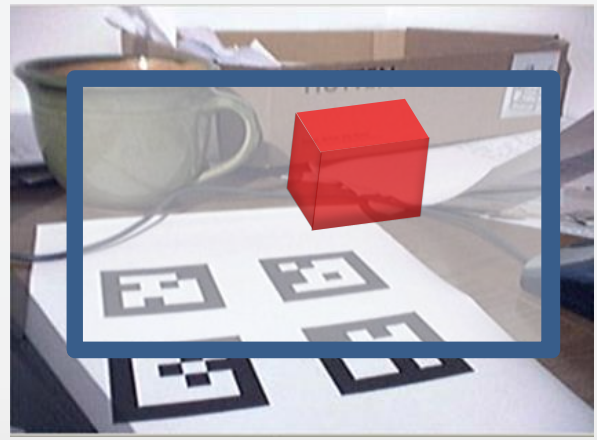
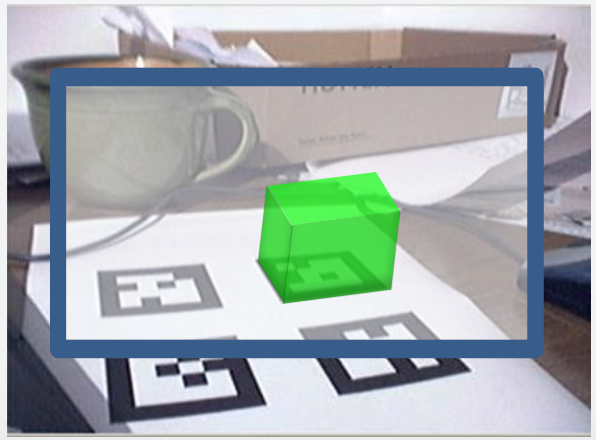
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# Why I CAN'T Recommend OST-HMDs?

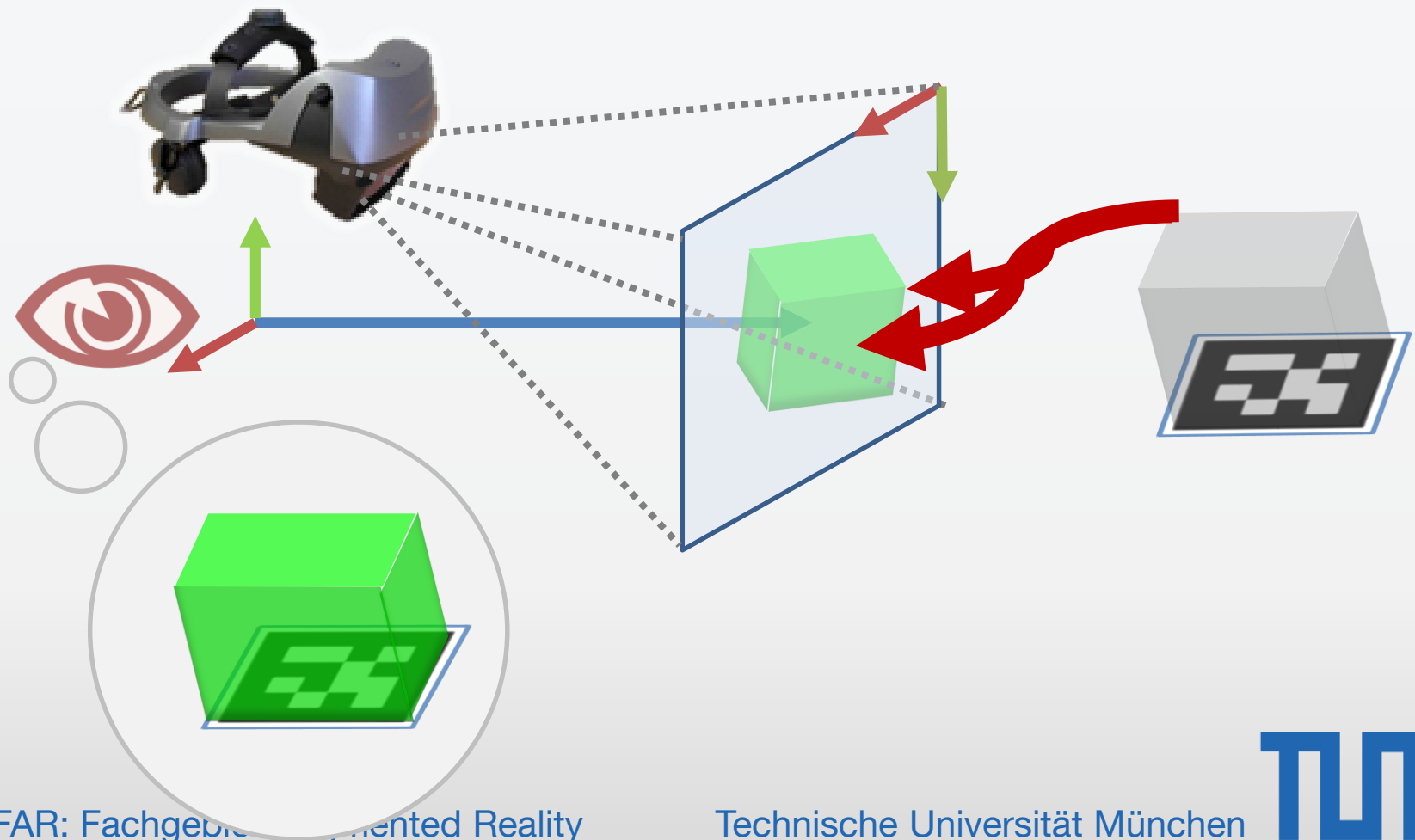
- Latency
- Depth cues
- Field of View
- Weight
- ...

- **Spatial** registration  
– Calibration



# Calibration of **Eye&OST-HMD**

- HMD moves on one's head  
-> frequent **recalibration**



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# Calibration of **Eye&OST-HMD**

- HMD moves on one's head  
-> frequent **recalibration**

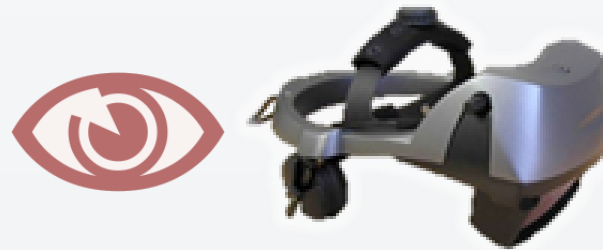


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# Ideal Eye-HMD Calibration

- Should be **Simple & Accurate**



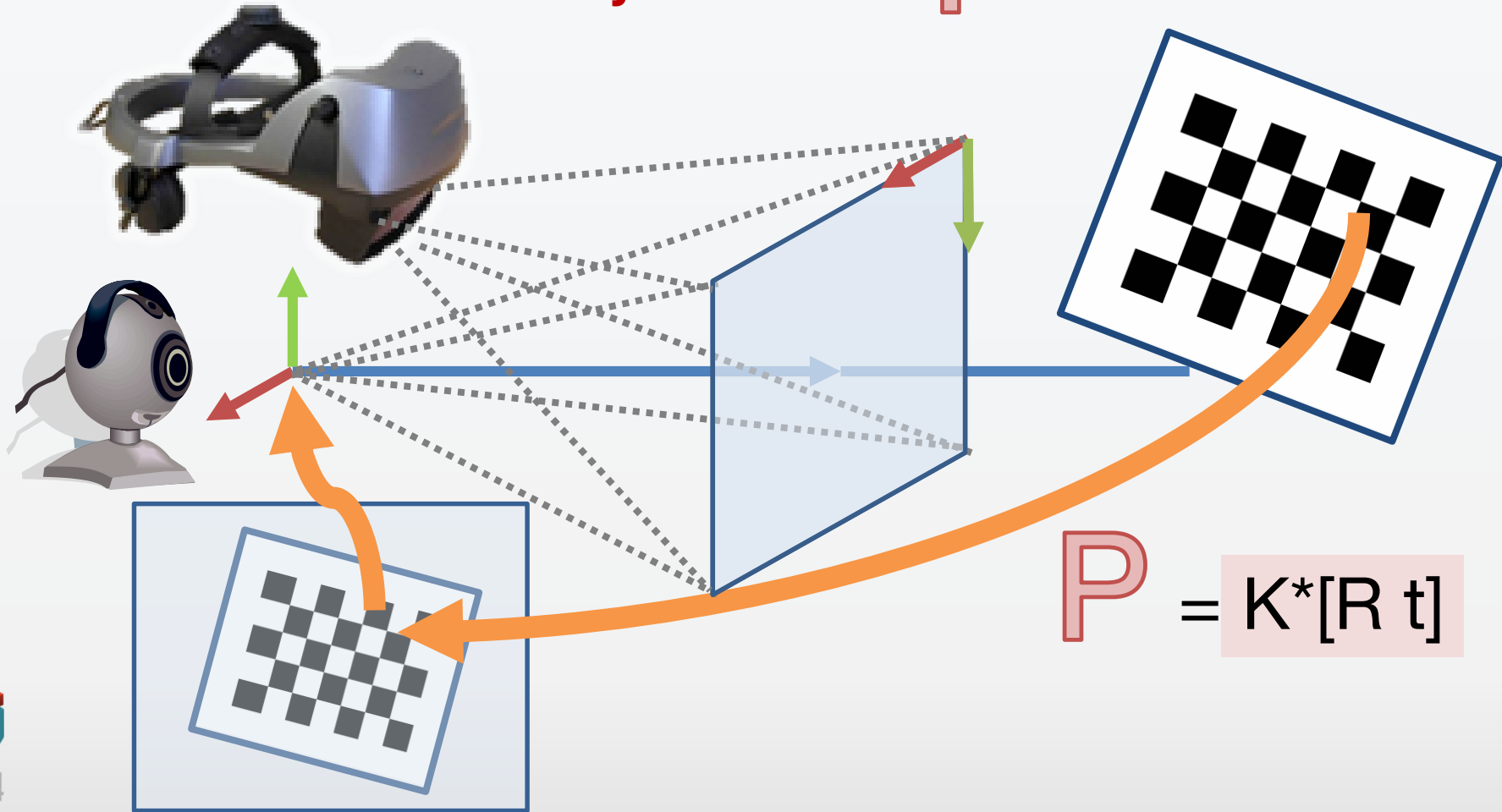
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# Camera Calibration Analogy

- Find **3D-2D Projection**:  $P$



$$P = K*[R t]$$

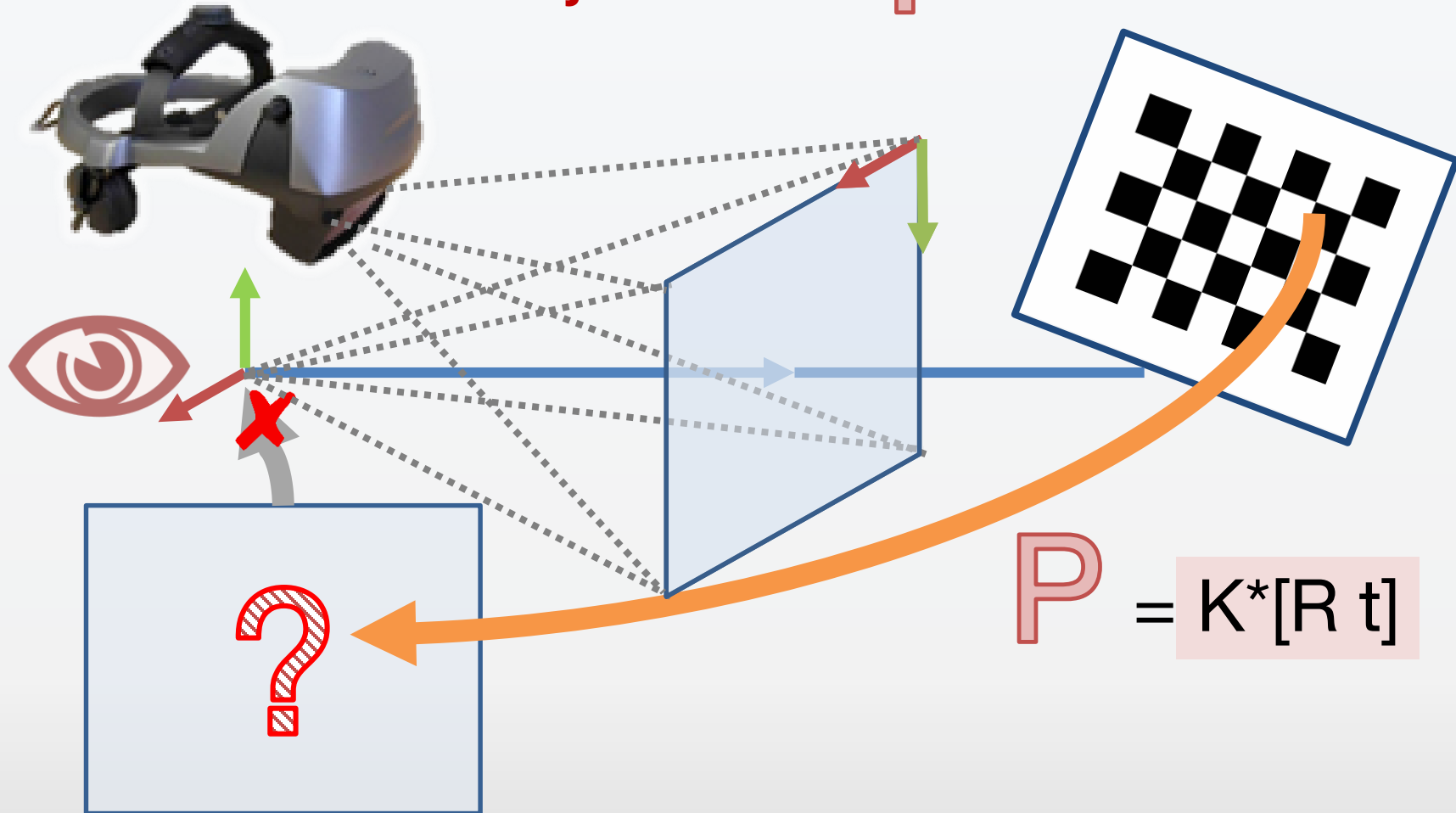


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# In the Eye of the Beholder...

- Find 3D-2D Projection:  $P$

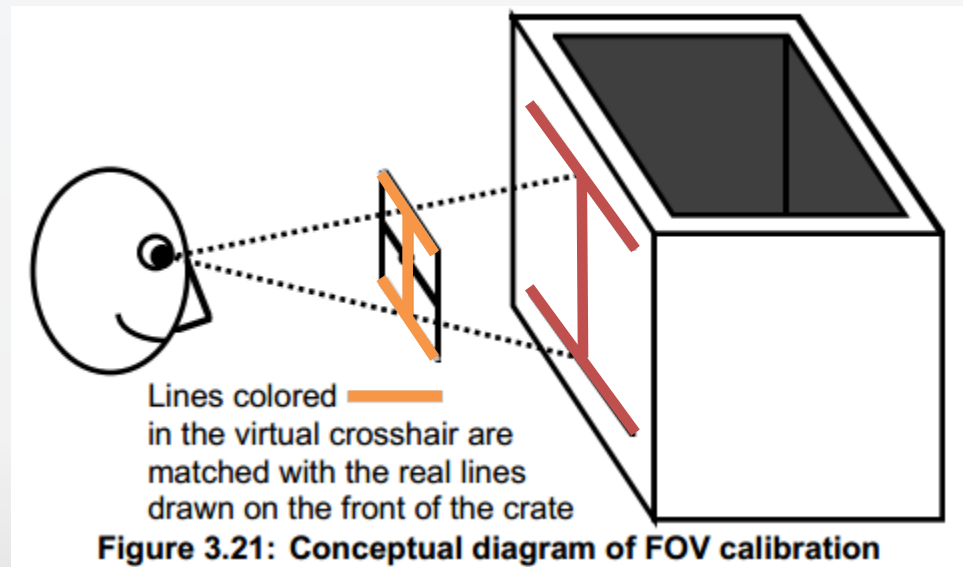


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# Related Work

- Manual alignment
  - **Intensive** user interaction
  - **User-dependent** noise



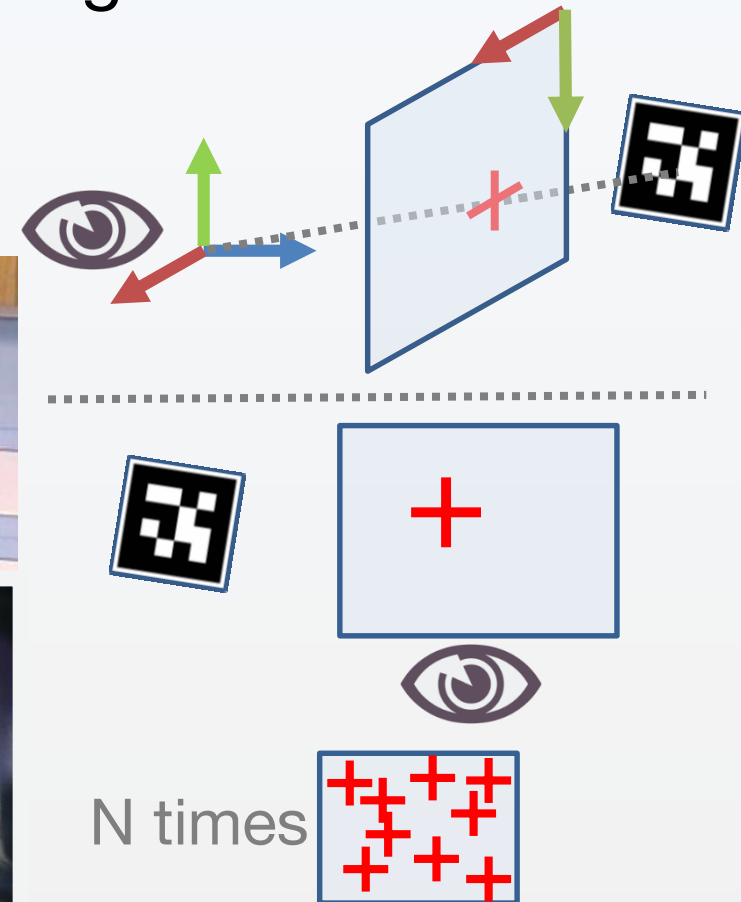
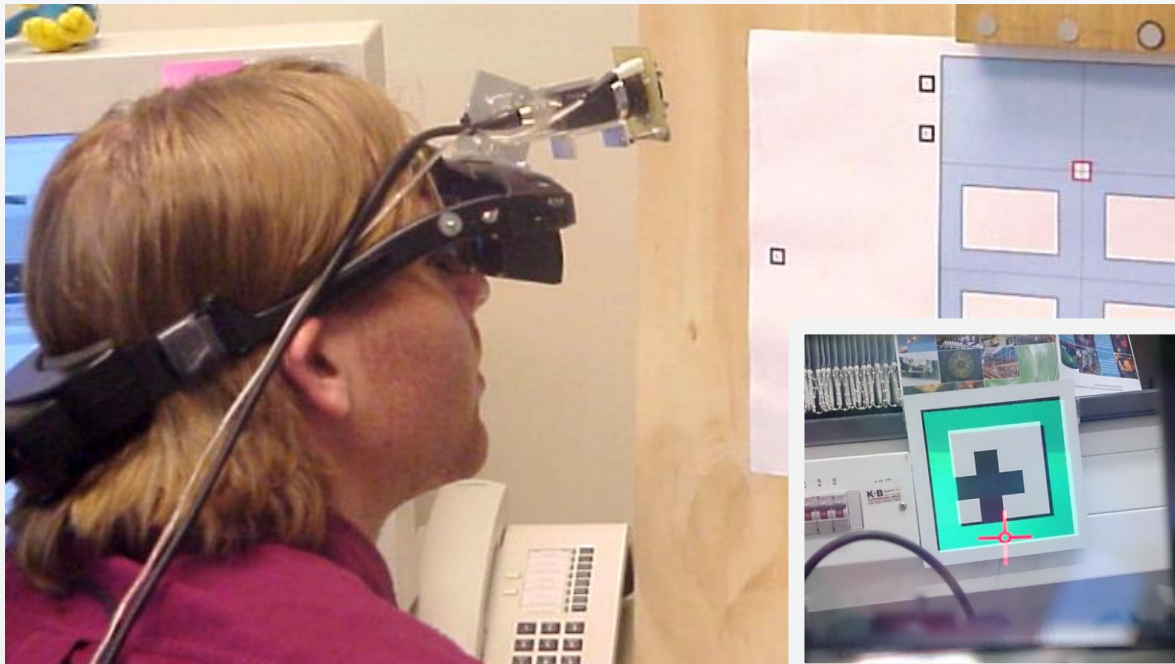
2014 Figure 1: Wooden frame for calibration and registration

[Predictive tracking for augmented reality](#)

RT Azuma - 1995 - [ronaldazuma.com](http://ronaldazuma.com)

# Related Work

- **SPAAM**: Single Point Active Alignment Method
  - **Medium** user interaction
  - **User-dependent** noise



Single point active alignment method (**SPAAM**) for optical see-through HMD calibration for AR

M Tuceryan, N Navab - Augmented Reality, 2000.(ISAR 2000). ..., 2000 - [ieeexplore.ieee.org](http://ieeexplore.ieee.org)

**Practical solutions for calibration of optical see-through devices**

Y Genc, M Tuceryan, N Navab - ... of the 1st International Symposium on ..., 2002 - [dl.acm.org](http://dl.acm.org)

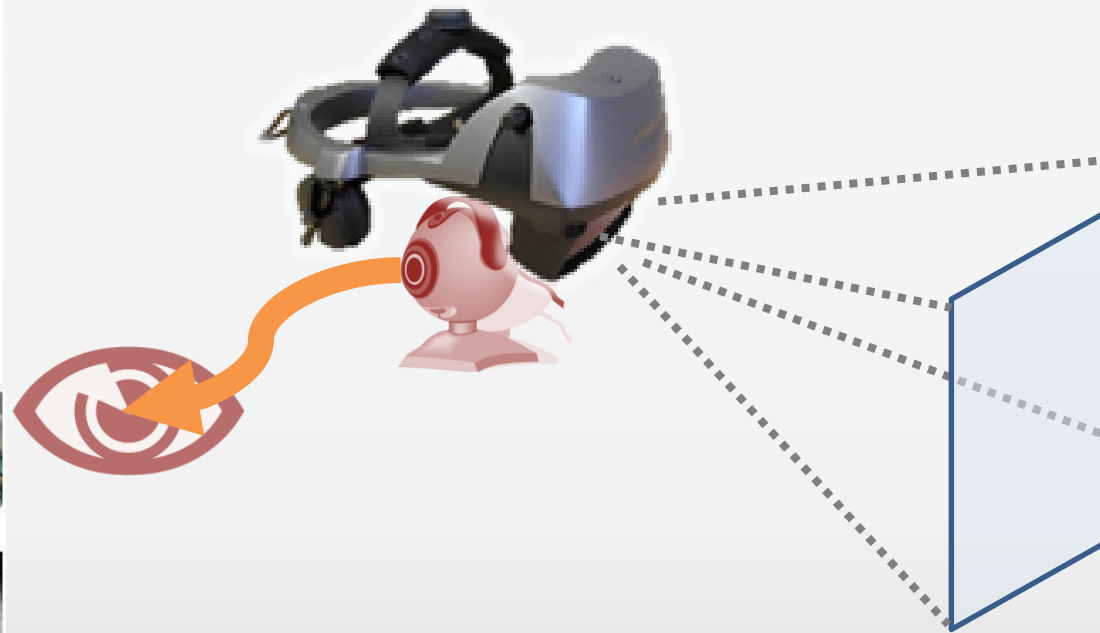


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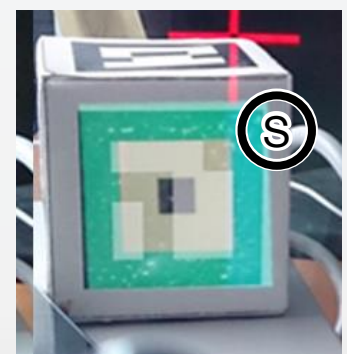
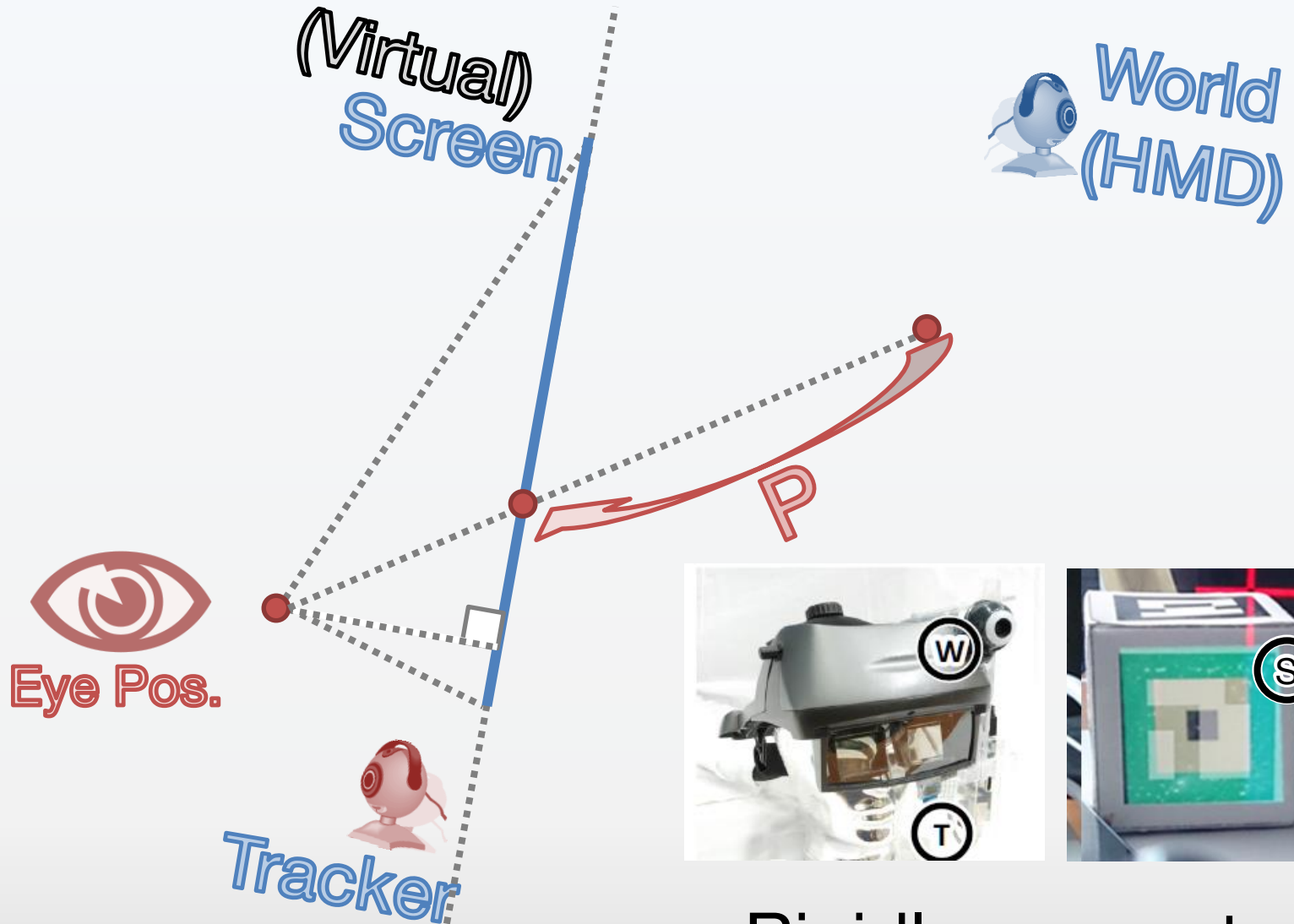


# Our Method

- Utilizes 3D Eye Localization
  - **Interaction-free**, thus do not bother users
  - **More accurate** than a realistic SPAAM setup



# Off-axis Pinhole Camera



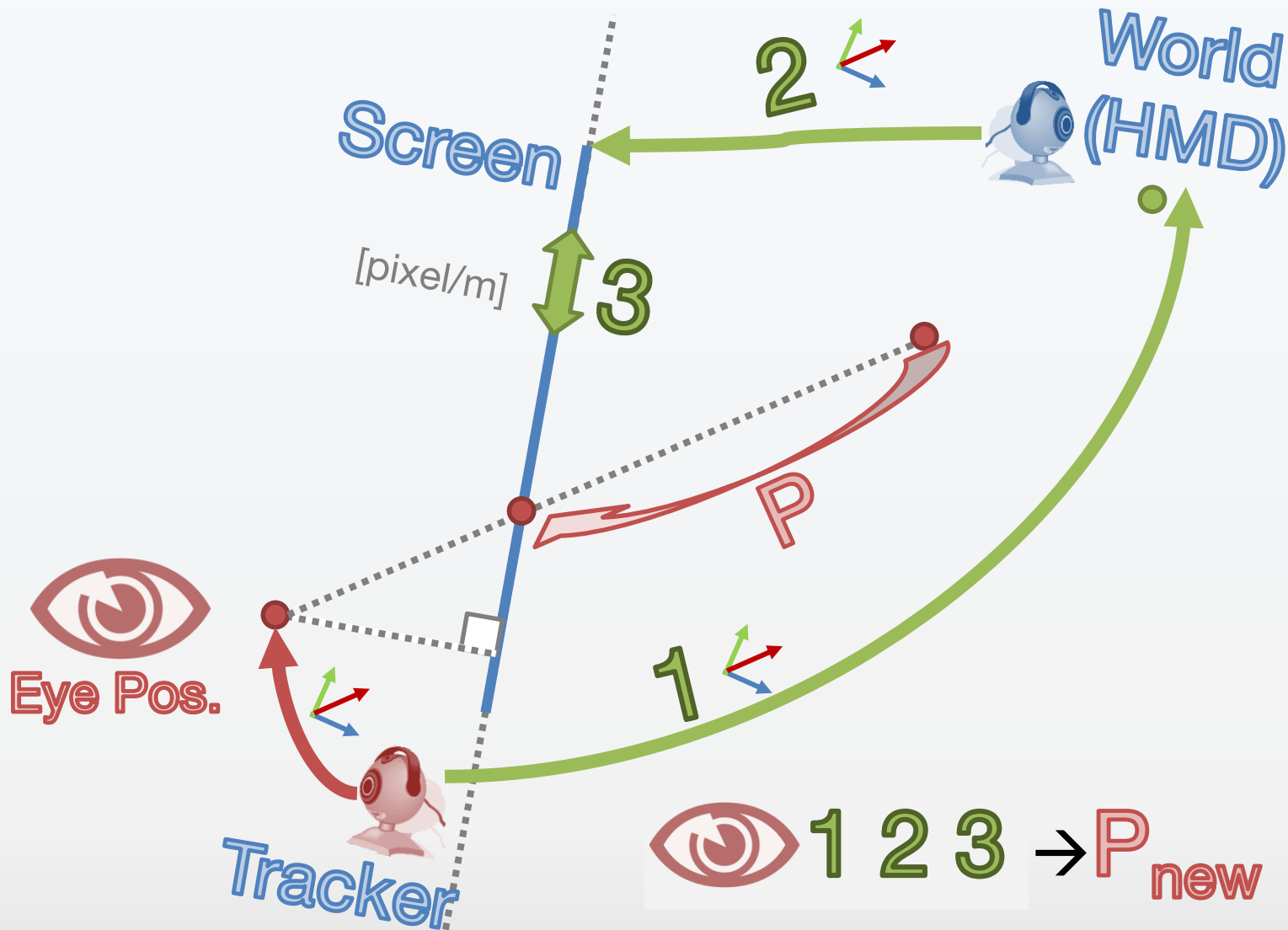
Rigidly connected



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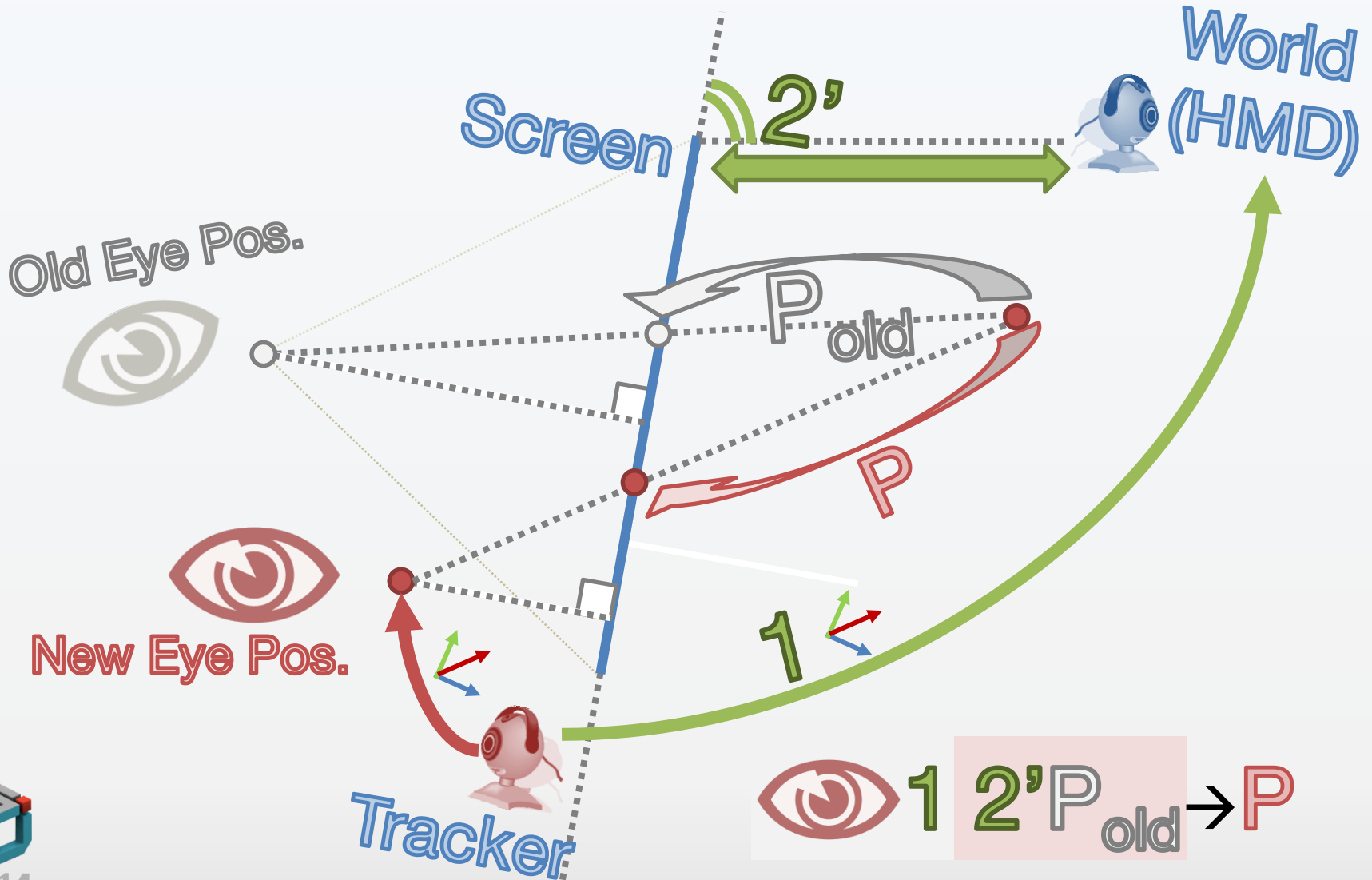
# Projection by Full Display Parameters



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# Projection with Old Projection (Recycle)



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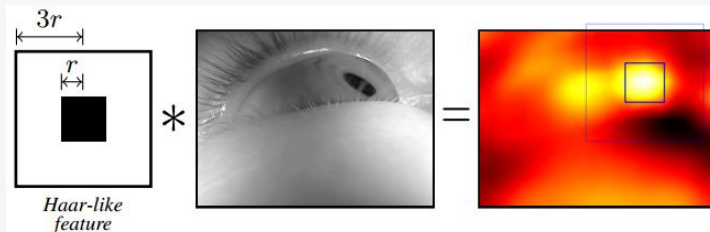




# 3D Eye Position Estimation

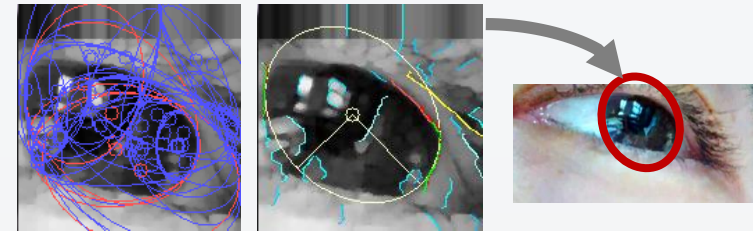
## 1. Estimate a **2D** iris ellipse

– Iris detector

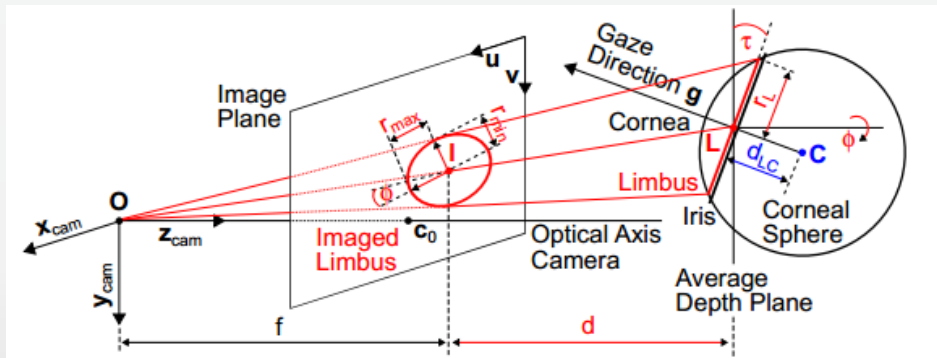


[Robust real-time pupil tracking in highly off-axis images](#)  
 L Swirski, A Bulling, N Dodgson - ... of the Symposium on  
 Eye Tracking ..., 2012 - dl.acm.org

+ Fitting by RANSAC



## 2. Back project it to **3D** circle



[Image-based Eye Pose and Reflection Analysis for Advanced Interaction Techniques and Scene Understanding](#)  
 C Nitschke, A. Nakazawa, H. Takemura - CVIM, [ ..., 2011 - ci.nii.ac.jp



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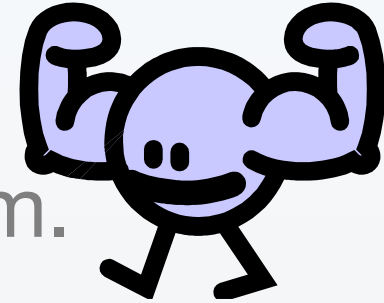


# Formulation Summary

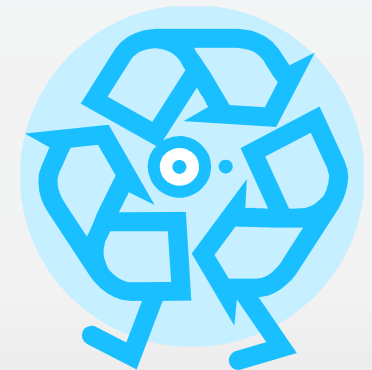


+

- **Full Setup**
  - All display param.



- **Recycle Setup**
  - some display param.
  - + Old projection
  - **Experiment**



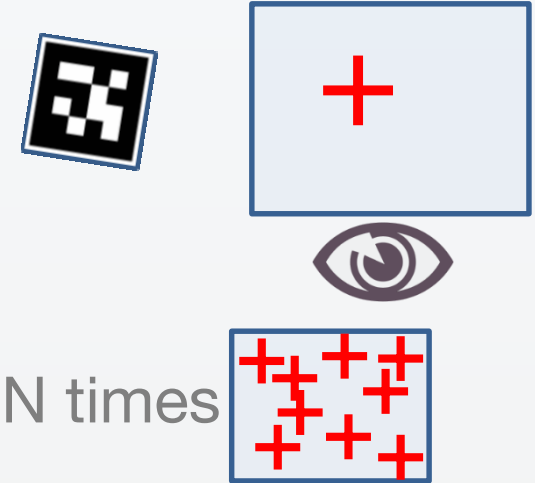
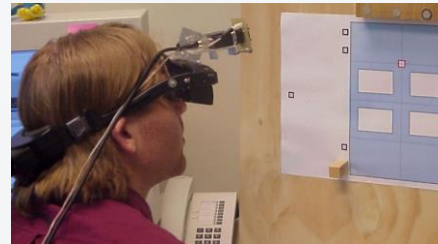
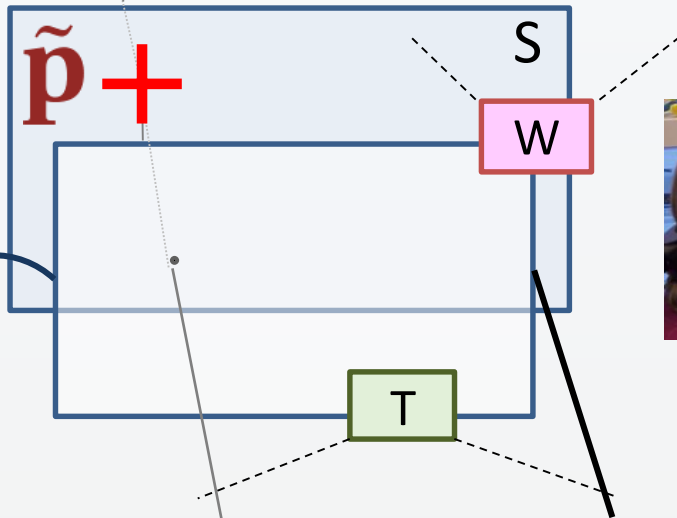
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# “Ground-Truth” Acquisition



- 3D-2D pairs:  $(p, \tilde{p})$



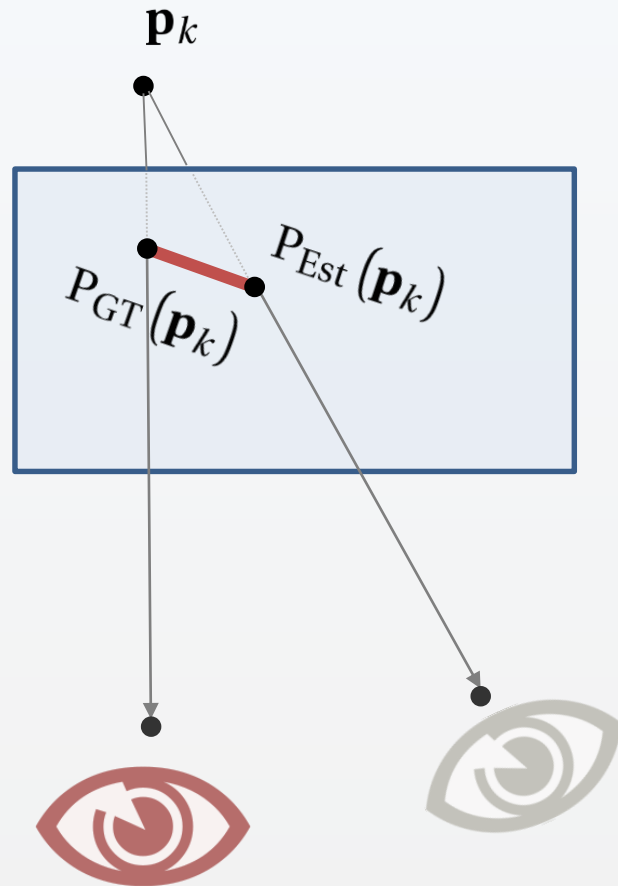
- Eye positions:  $t$



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# Error Measurement



- Estimated projection:  $P_{Est}$
- Reprojection Error:

$$E(P_{Est}) =$$

$$\frac{1}{N} \sum_k \|P_{GT}(\mathbf{p}_k) - P_{Est}(\mathbf{p}_k)\|^2$$

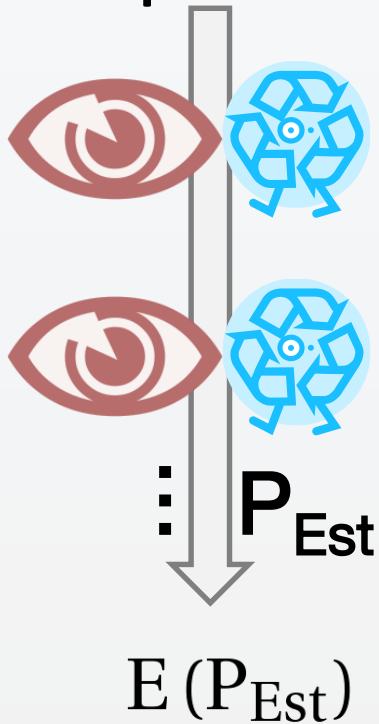


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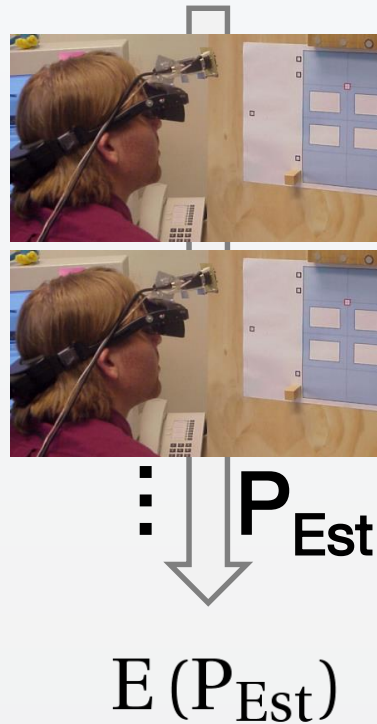


# Three Conditions

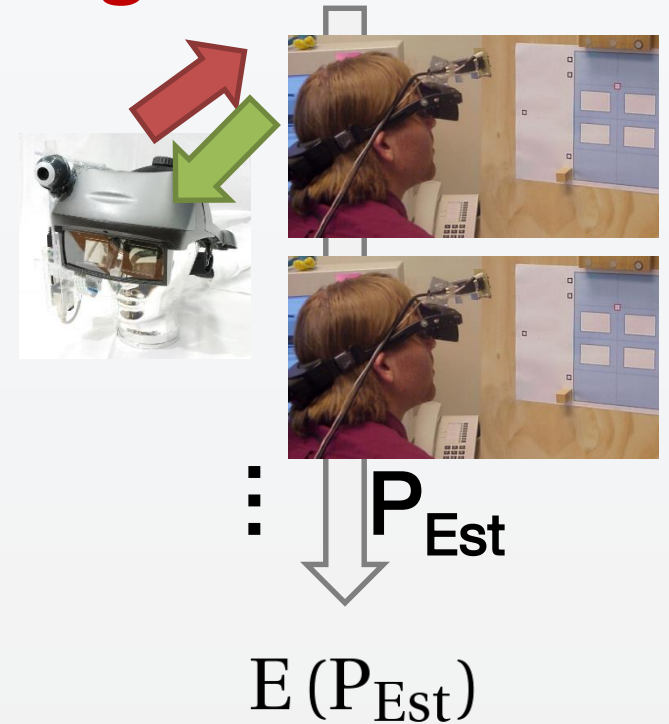
Proposed



SPAAM



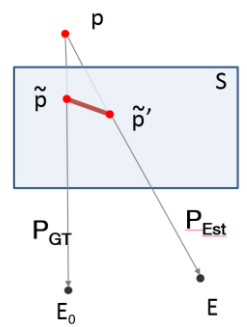
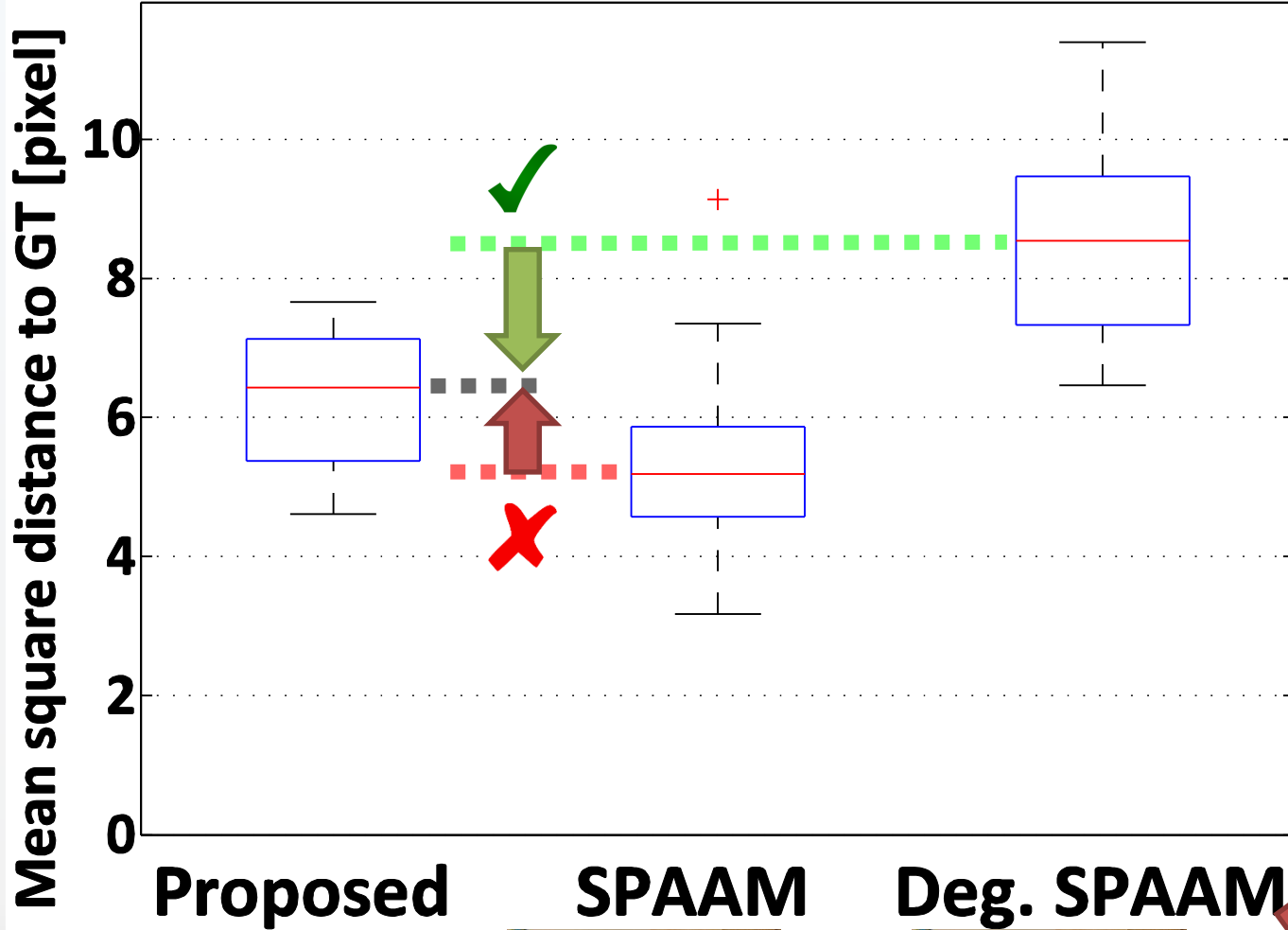
**Degraded** SPAAM



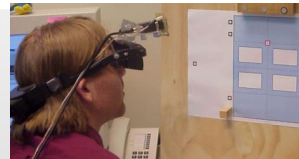
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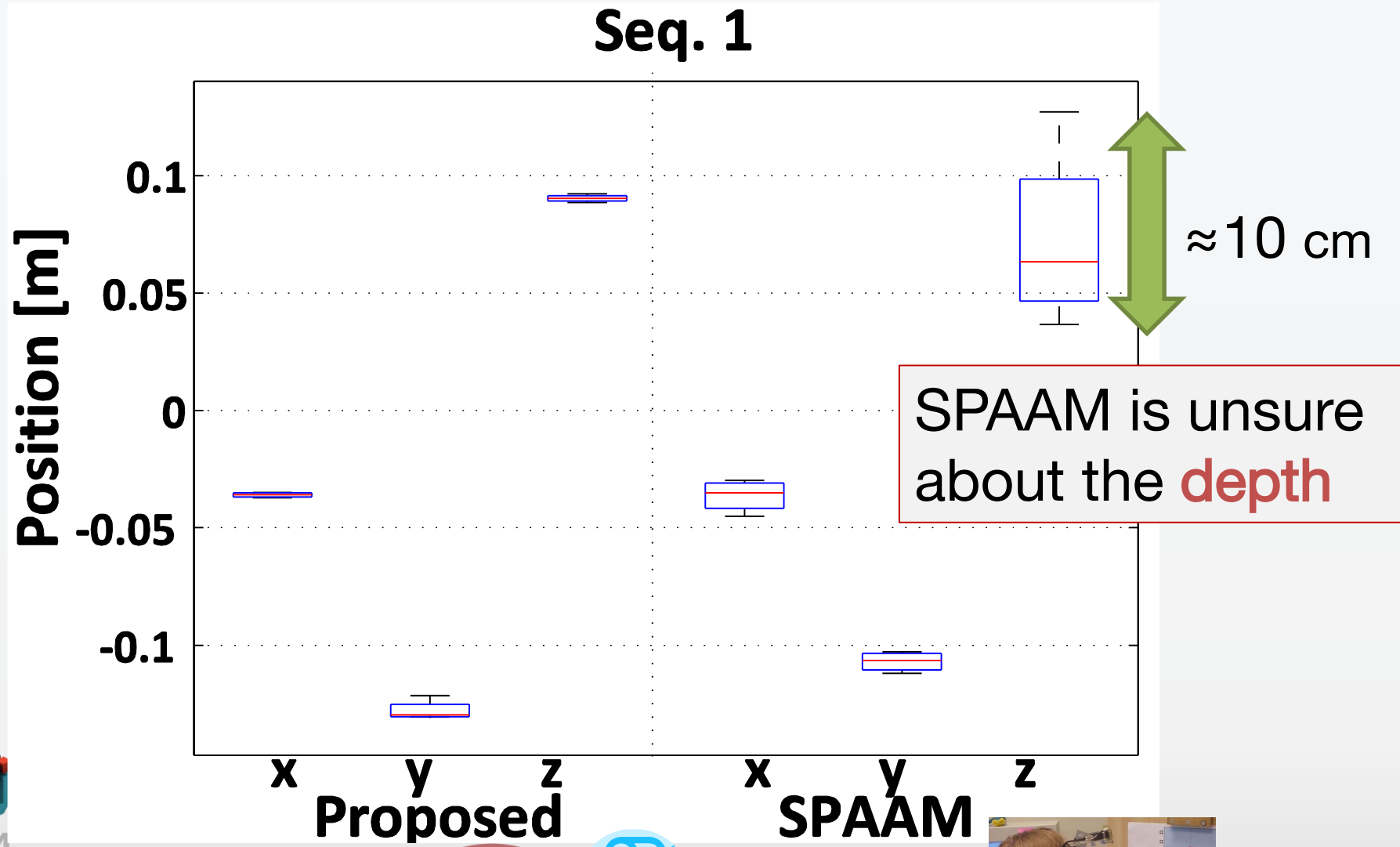
# 2D Projection Errors



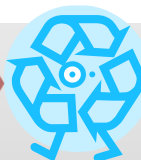
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# 3D Eye Position Estimates

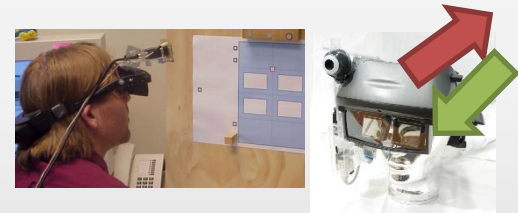
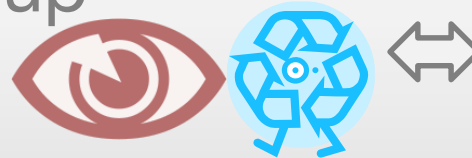


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# Summary

- Calibration of OST-HMDs using  **3D eye position**
  - No user **interaction** required
    - No user-dependent error
  - Two formulations: Recycle & Full  
    - Same mathematically, yet not practically
  - **More accurate** than a **degraded** calibration
    - w/ Recycle Setup



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**Thank you for your attention  
&  
Any questions?**



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