



The Journey Towards Better 3D Gaze Estimation

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Nikola Popovic
Xi Wang

Supervisor: Prof. Dr. Luc van Gool

Mathis Lindner
16.06.2023, Zürich



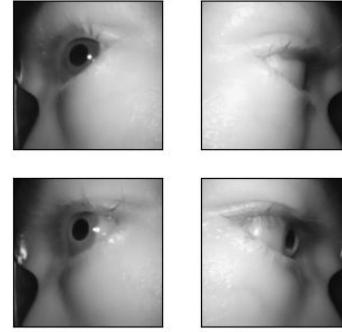
Motivation



Related Work

types are annotated (Mov.). The subtypes stand for $I = \text{Iris}$, $P = \text{Pupil}$, $Sc = \text{Sclera}$, $Lid = \text{Eyelid}$, $F = \text{Fixation}$, $S = \text{Saccade}$, $SP = \text{Smooth Pursuits}$, and $B = \text{Blinks}$.

Data	Sub.	Tracker	FRQ	Res.	Num. Annot	Seg 2D P I Sc	Seg 3D P I Sc	PC	LM 2D P I Lid	LM 3D P I Lid	Eye	Ga	Mov. F S SP B	
	VR	AR	HM											
POG[75]	20	-	-	1	30Hz	768 × 480	-	-	-	-	-	Y	-	-
NNVEC[31]	20	-	-	1	25Hz	384 × 288	866,069	-	-	-	-	Y	Y	-
NVGaze[70]	35	1	1	-	120Hz	640 × 480	2,500,000	-	-	-	-	Y	Y	-
Casia.v1[77, 92]	108	-	-	1	-	320 × 280	756	- Y	-	-	-	-	-	-
Casia.v2[77, 92]	60	-	-	2	-	640 × 480	2,400	- Y	-	-	-	-	-	-
Casia.v3[77, 92]	≈700	-	-	3	-	Multiple	22,034	- Y	-	-	-	-	-	-
Casia.v4[77, 92]	≈1,800	-	-	4	-	Multiple	54,601	- Y	-	-	-	-	-	-
Casia.test[77, 92]	1,000	-	-	1	-	640 × 480	10,000	- Y	-	-	-	-	-	-
Casia.age[94, 3]	50	-	-	2	-	Multiple	≈160,000	- Y	-	-	-	-	-	-
Ubiris.v1[78]	241	-	-	Y	30Hz	Multiple	877	- Y	-	-	-	-	-	-
Ubiris.v2[79]	261	-	-	Y	200Hz	400 × 300	≈11,000	- Y	-	-	-	-	-	-
MASD[12, 11, 10]	82	-	-	Y	-	Multiple	2,624	- Y	-	-	-	-	-	-
GAN[33]	22	-	-	1	120Hz	640 × 480	130,856	Y - Y	-	-	-	-	-	-
500k[49]	20	-	-	1	25Hz	384 × 288	866,069	Y - Y	-	-	-	-	-	-
OpenEDS[61]	152	1	-	-	200Hz	400 × 640	356,649	Y Y Y	-	-	-	-	-	-
GIW[72]	19	-	-	1	120Hz	640 × 480	≈2,016,000	-	-	-	-	Y Y Y Y	-	-
BAY[86]	6	-	-	1	30Hz	640 × 480	27,022	-	-	-	-	Y Y Y	-	-
HEV[13]	57	1	-	-	24-30Hz	-	no images	-	-	-	-	Y Y	-	-
HEI[82]	63	1	-	-	60Hz	-	no images	-	-	-	-	Y Y	-	-
LPW[93]	22	-	-	1	120Hz	640 × 480	130,856	-	-	-	Y	-	-	-
Swi[89]	2	-	-	1	-	620 × 460	600	-	-	-	Y	-	-	-
ExCuSe[46]	7	-	-	1	25Hz	384 × 288	39,001	-	-	-	Y	-	-	-
Else[56]	17	-	-	1	25Hz	384 × 288	55,712	-	-	-	Y	-	-	-
PNET[55, 54]	5	-	-	1	25Hz	384 × 288	41,217	-	-	-	Y	-	-	-
EWO[51]	11	-	-	1	25Hz	384 × 288	1,100	-	-	-	Y	-	-	-
FRE[52]	11	-	-	1	25Hz	384 × 288	4,000	-	-	-	Y	-	-	-
TüEyeD	39	-	-	1	25Hz	384 × 288	5,665,053	Y Y Y	Y Y Y	Y	Y Y Y	Y Y Y	Y Y Y Y	-
	1	-	-	1	60Hz	320 × 240	12,184	Y Y Y	Y Y Y	Y	Y Y Y	Y Y Y	Y Y Y Y	-
	22	-	-	1	95Hz	640 × 480	130,856	Y Y Y	Y Y Y	Y	Y Y Y	Y Y Y	Y Y Y Y	-
	54	1	1	1	120Hz	640 × 480	8,691,764	Y Y Y	Y Y Y	Y	Y Y Y	Y Y Y	Y Y Y Y	-
	16	-	-	1	60Hz	640 × 360	6,367,216	Y Y Y	Y Y Y	Y	Y Y Y	Y Y Y	Y Y Y Y	-



- Data-sets not public
- Pseudo Labels
- Synthetic Data
- Not Real 3D
- Missing Intrinsic

The Goal?

Introducing Pupil Invisible



Pupil
Labs



- Fully functioning product
- 3 Cameras
 - World RGB 30HZ
 - Left Eye IR 200HZ
 - Right Eye IR 200HZ
- IMU 200HZ

Pupil Invisible

Connecting the Pupil Invisible to the PC

Dear ISG staff,

I am working on my semester thesis with the CVL,
There are commands that I need to execute in order to make a library work, unfortunately they need sudo rights:
<https://github.com/pupil-labs/pyuvc#running-as-a-non-root-user>

"

One needs to setup udev rules and add the target user to the plugdev group to avoid the privileged access req

```
echo 'SUBSYSTEM=="usb", ENV{DEVTYPE}=="usb_device", GROUP="plugdev", MODE="0664"' | sudo tee /etc/udev/rules.d/99-pupil-invisible.rules
sudo udevadm trigger
sudo usermod -a -G plugdev $USER
# logout and back in
```

"

How can I go from there? what are my options?

thank you for your help,

Mathis Lindner

It is a video capturing device

(<https://pupil-labs.com/products/invisible/tech-specs/>) which includes 3 cameras.

- I am guessing those are the product/vendor id's, but the device is plugged in so you may check it.

Bus 001 Device 075: ID 0c45:6366 Microdia

Bus 001 Device 074: ID 0c45:64ab Microdia

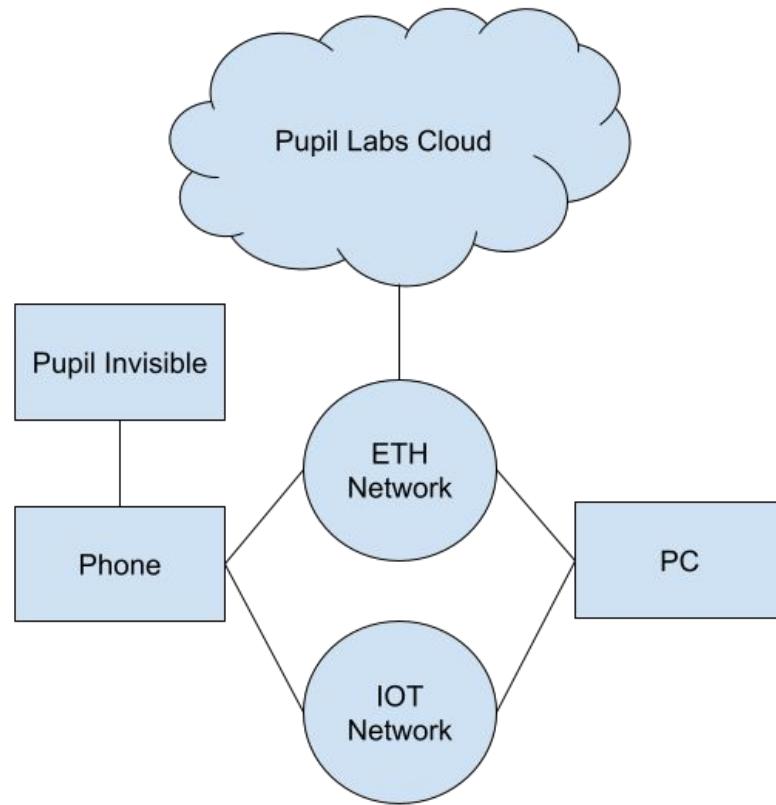
Bus 001 Device 073: ID 0c45:64ab Microdia

- I am working on the snapo machine.

Best,

- Pupil Invisible With USB
- Driver Issues
- Back and Forth with ISG support
- Solution: Through the network

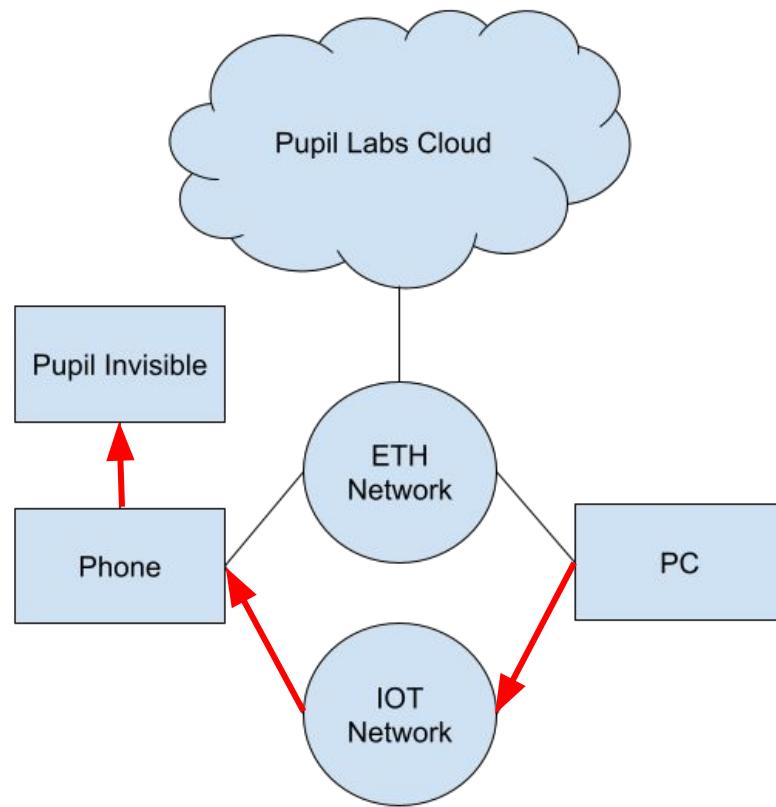
Network Approach:



ISG Team efforts

- ink-E-Mail | ▾ Aufräumen Verschieben ▾ Kategorien ▾ ...
Harry Angen via RT <support@ee.ethz.ch>
Hi Mathis Wann bis du denn im ETF/B/2.1 (soviel ich weiss, ist dort dein Arbeitsplatz)? Dann werd ich vorbei kommen, damit du mir zeigen kannst, was d
- Aleksandar Djordjevic via RT <support@ee.ethz.ch>
Dear Mathias and Nikola, Network Entry created. PSK Key sent seprate by email
- Nikola Popovic via RT <support@ee.ethz.ch>
Dear Aleks, This project will run until mid-September 2023 (might end earlier, but safe to assume the mentioned date). Best, Nikola
- Nikola Popovic <nipopovic@vision.ee.ethz.ch>
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Dear Mathias and Nikola, As your phone is only able to connect over WiFi, can you tell me how long this Project is going to be running? Regards Aleks
- Stephan Roth via RT <support@ee.ethz.ch>
Dear Mathis, Our recommendation is to place the phone in our IoT-Network without internet access, with a fixed IP there. My colleague Harry will test a
- Mathis Lindner <mlindner@student.ethz.ch>
Dear Stephan, We have already tried to connect directly with the right ip and port yesterday. I now have managed to communicate with the phone with i
- Mathis Lindner <mlindner@ethz.ch>
(Kein Nachrichtentext)
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Dear Mathis (cc: to Nikola), Looking at the documentation it looks to me like you can set the base port for the REST API yourself: <https://pupil-labs-realti>
- support@ee.ethz.ch
Hi (deutsch unten) This message has been automatically generated in response to your message regarding "Accessing an android phone over the local i

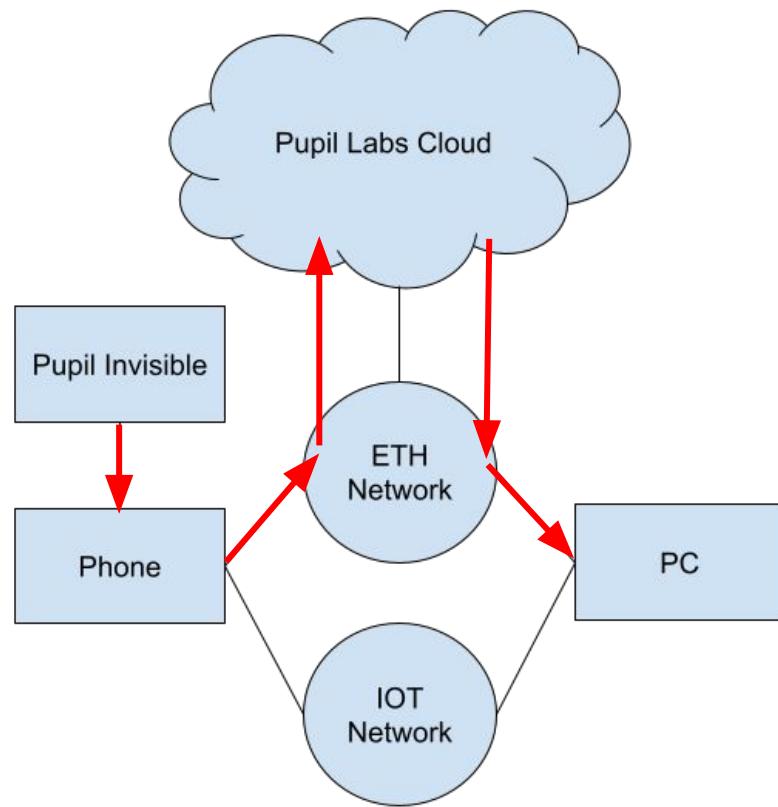
Network Approach:



ISG Team efforts

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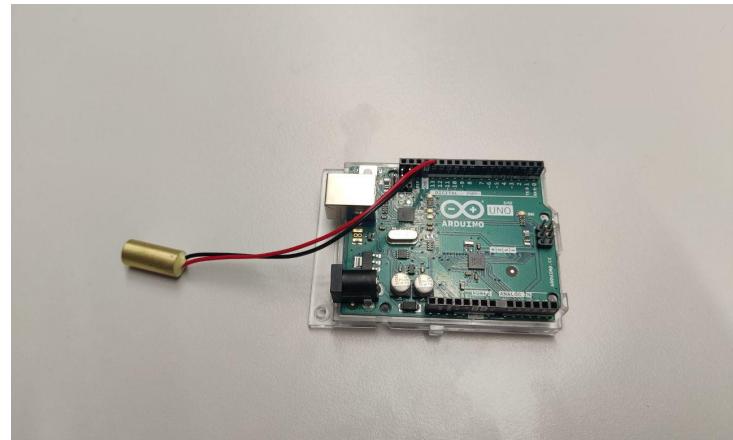
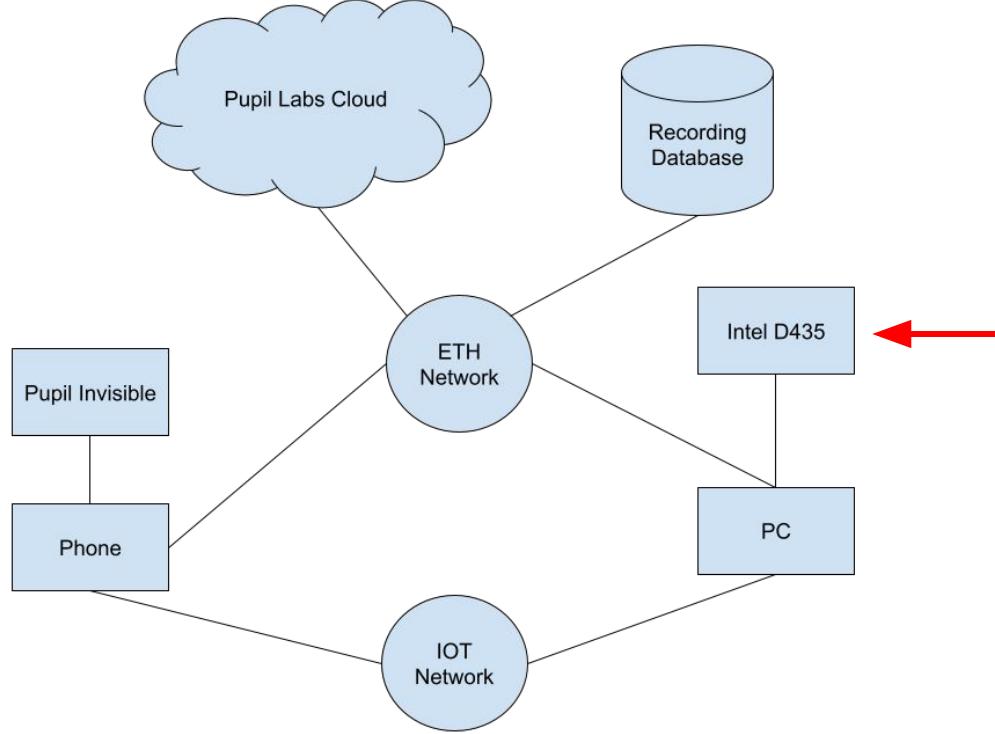
Network Approach:



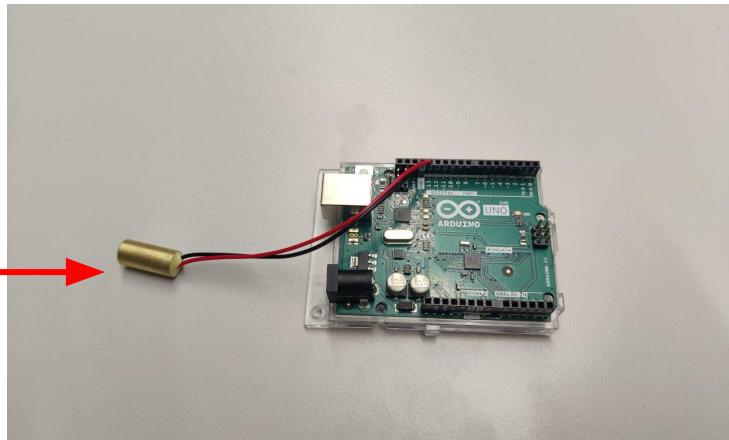
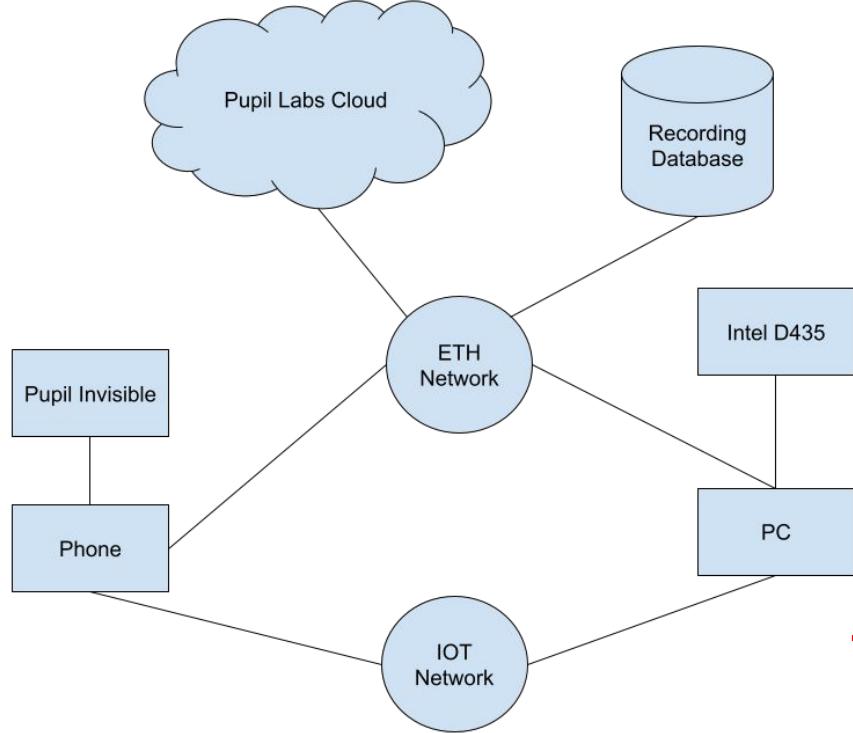
ISG Team efforts

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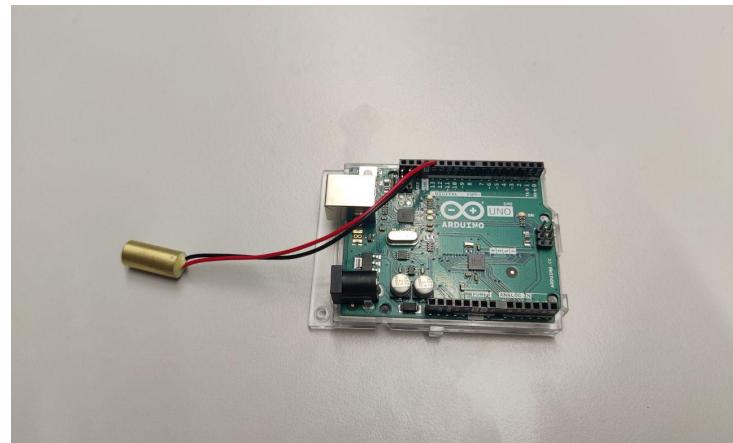
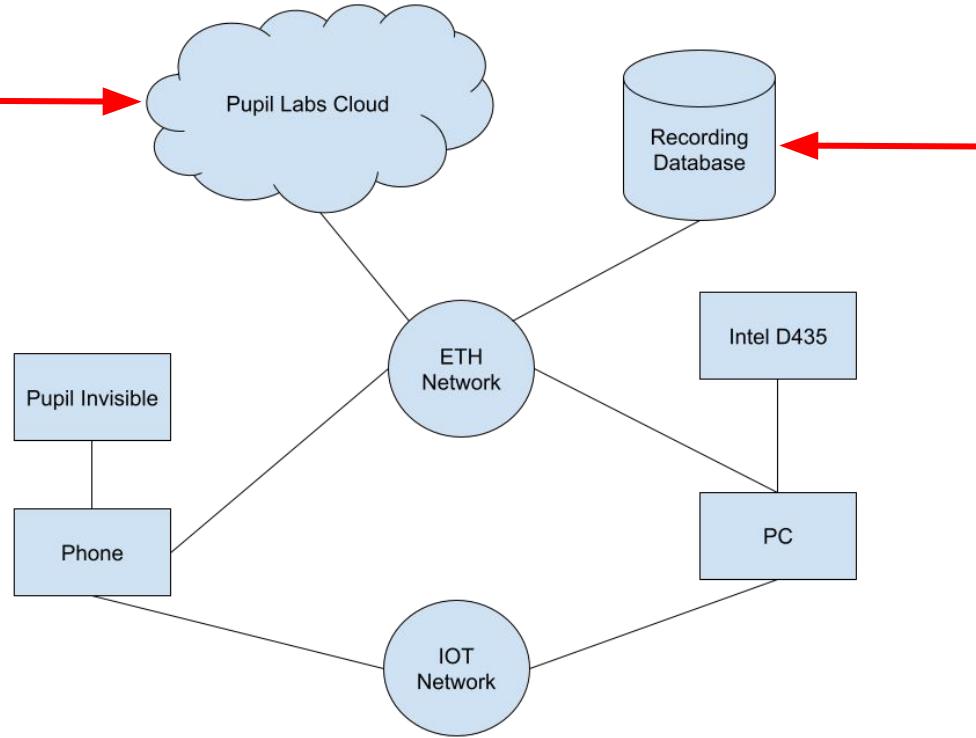
The Complete Setup



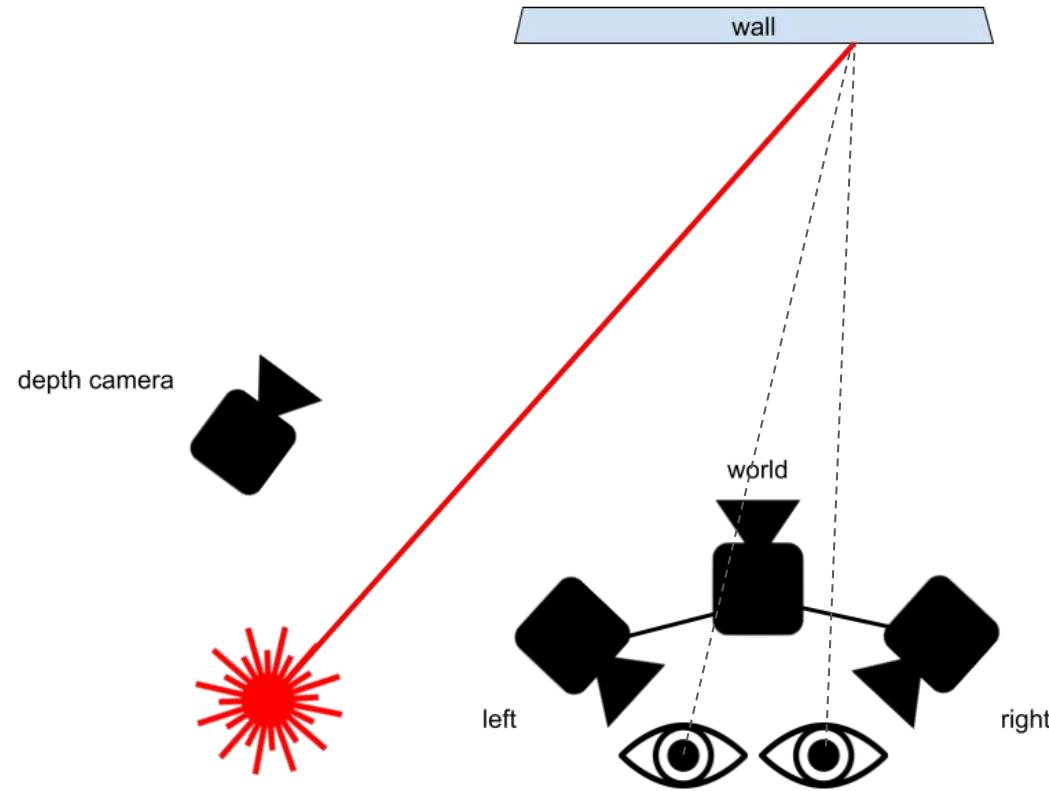
The Complete Setup



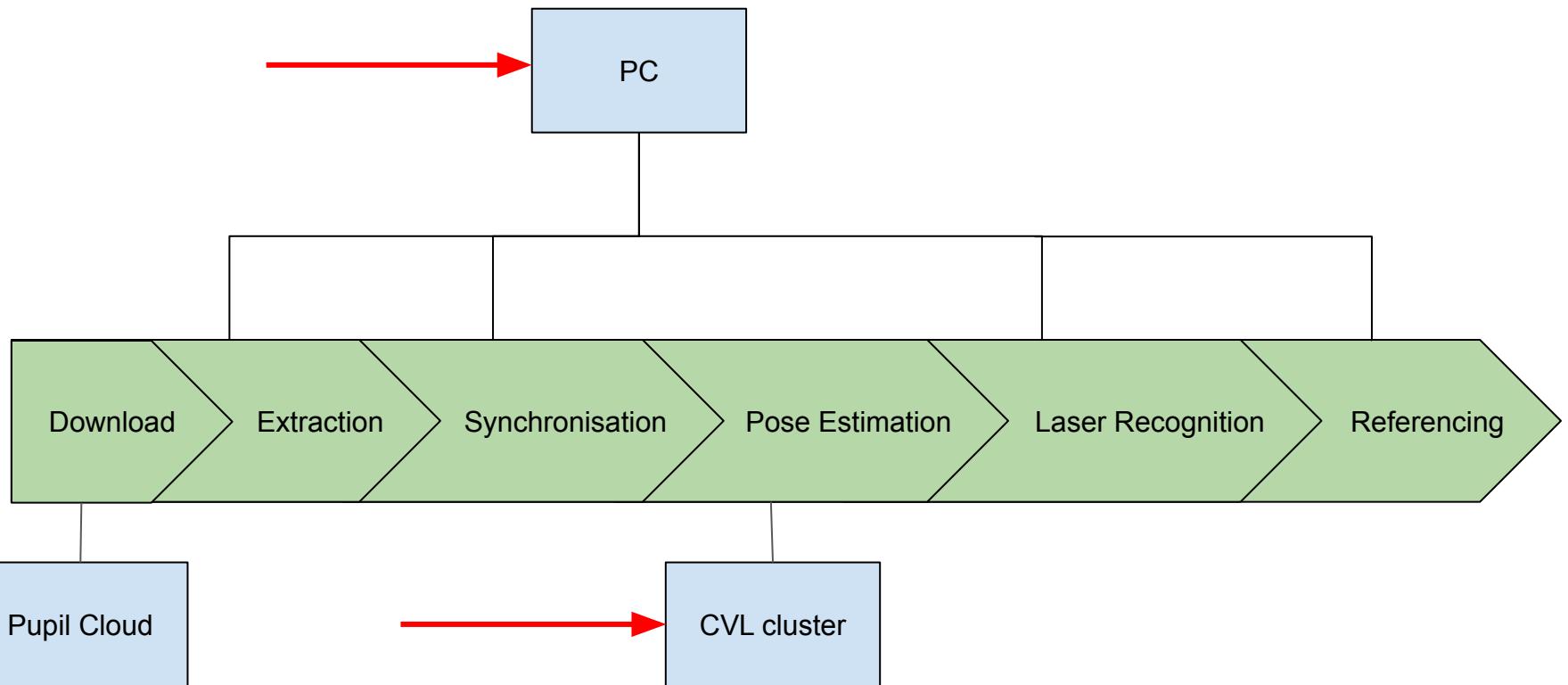
The Complete Setup



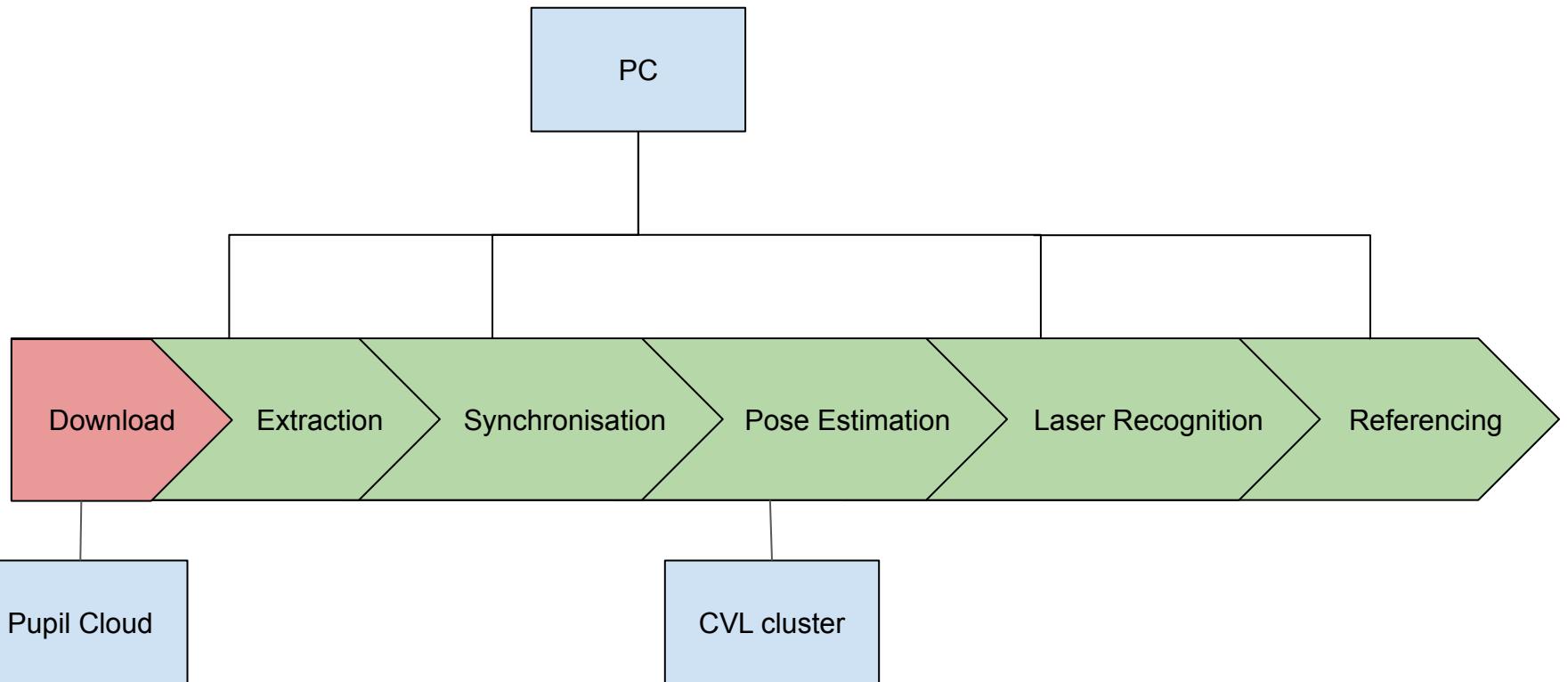
Recording setup



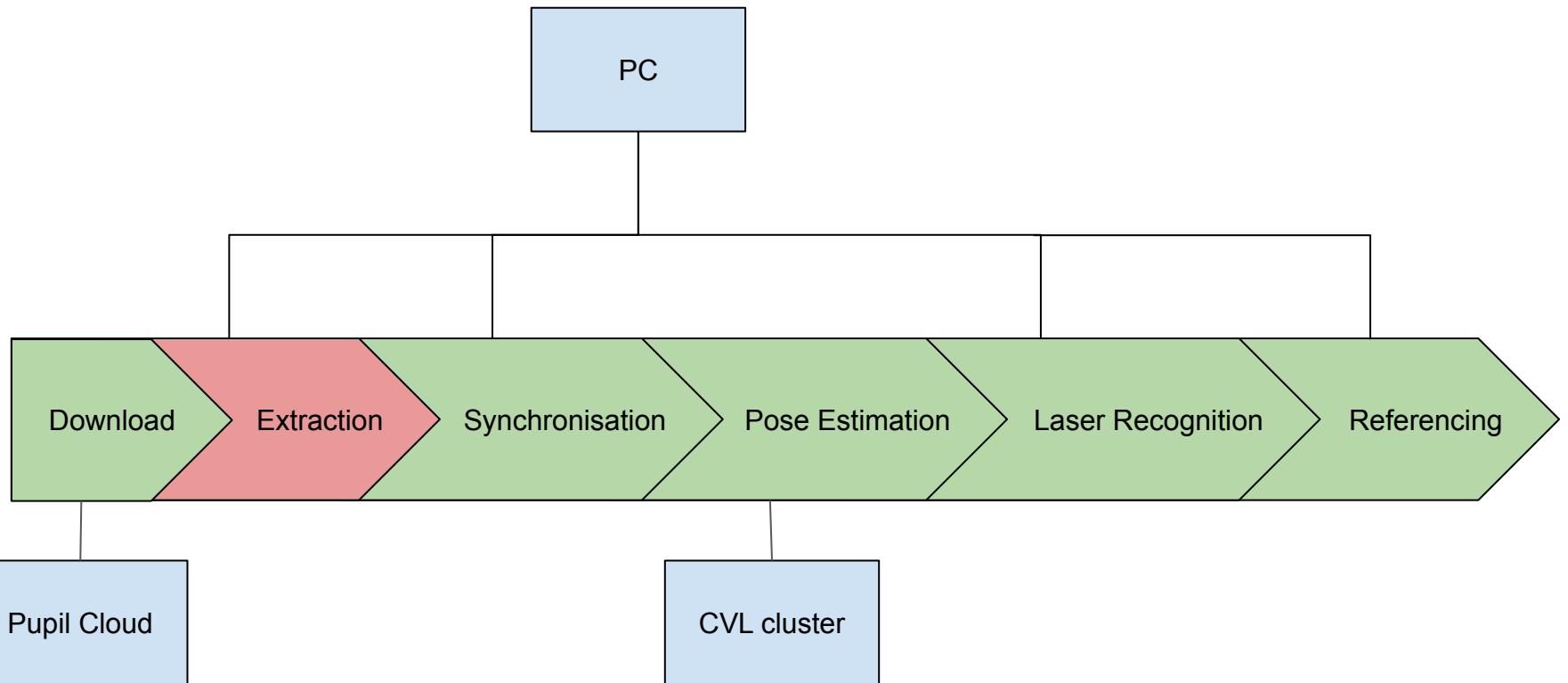
Post Processing Pipeline



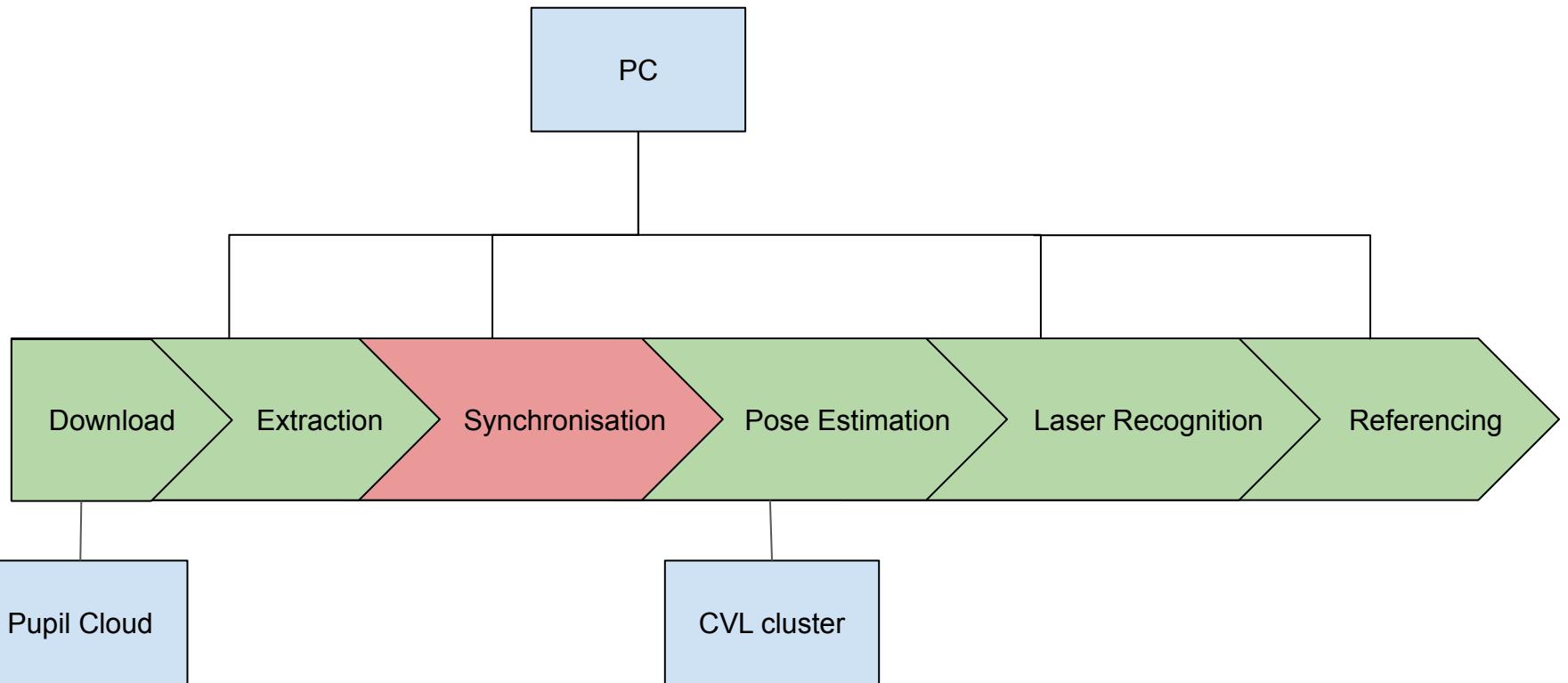
Post Processing Pipeline



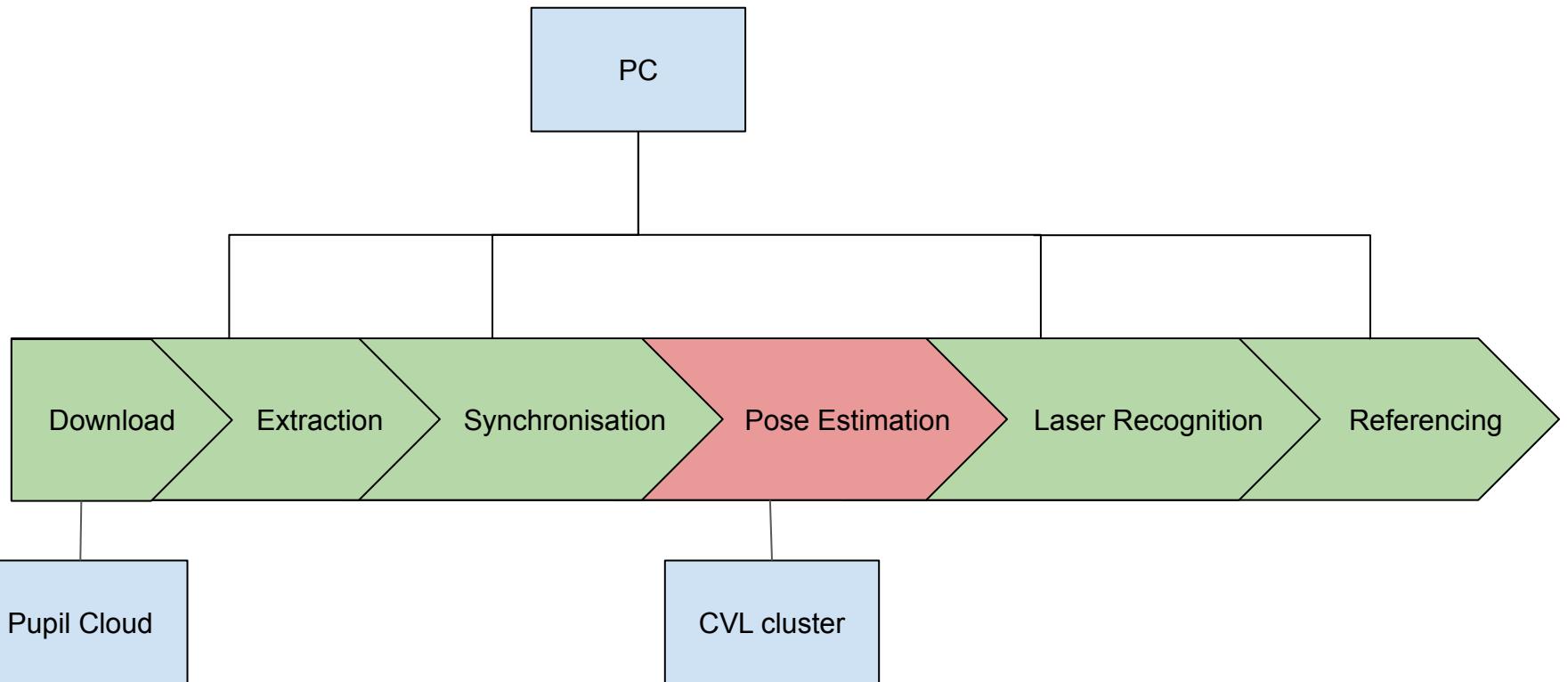
Post Processing Pipeline



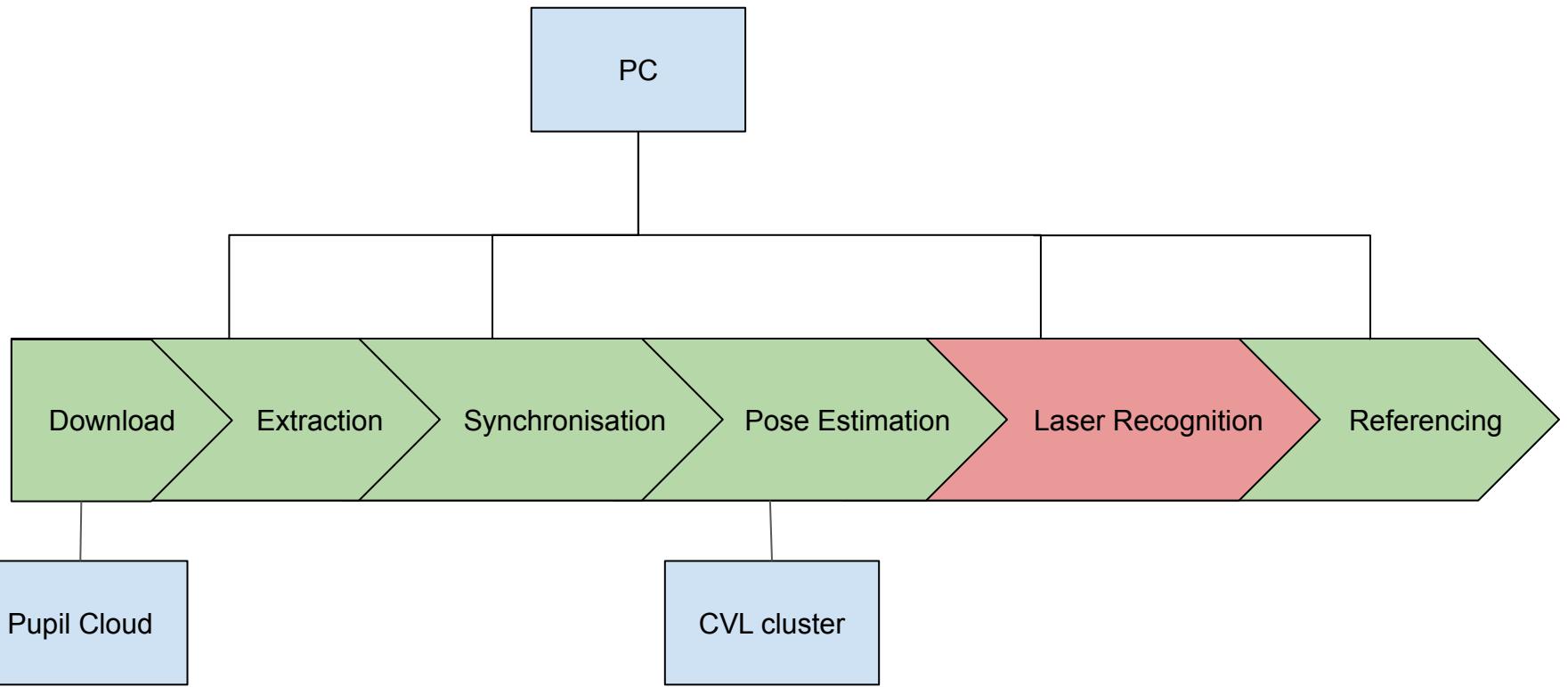
Post Processing Pipeline



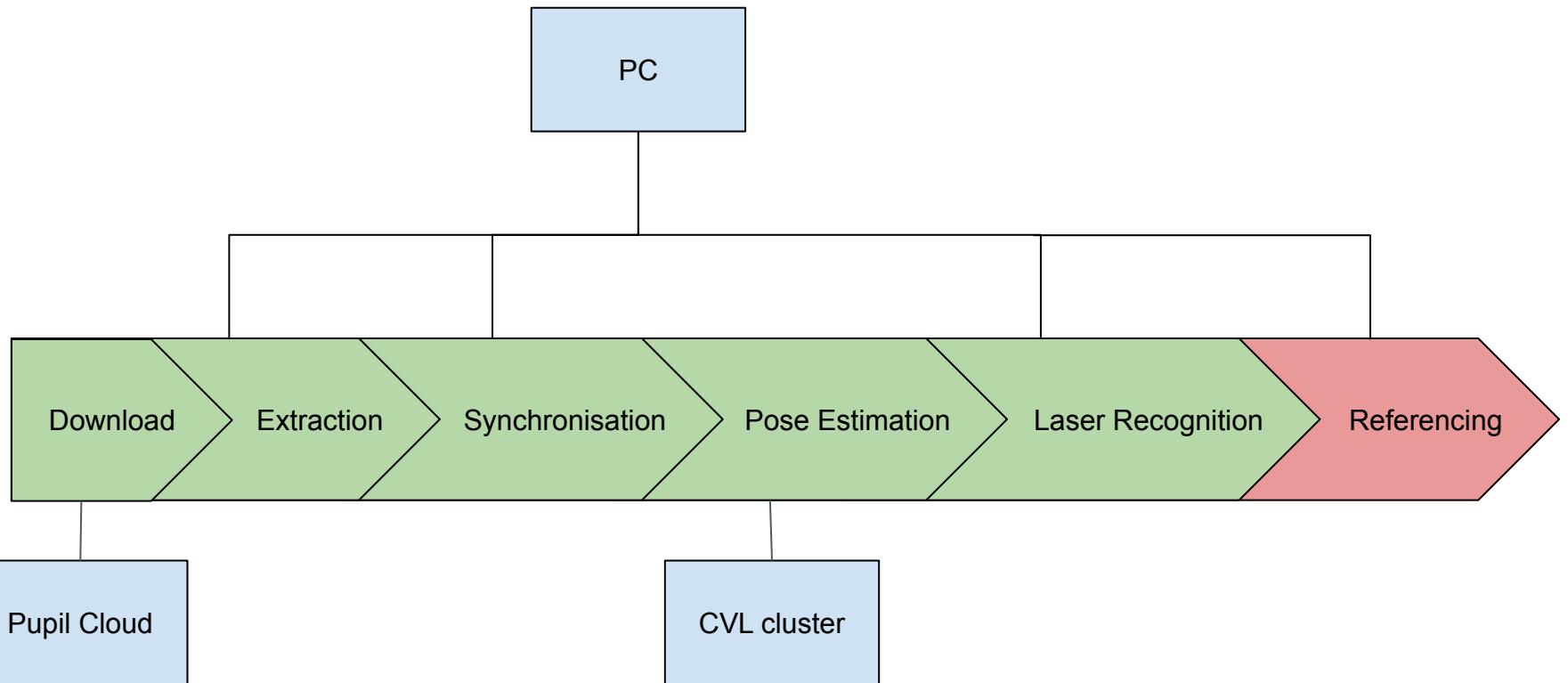
Post Processing Pipeline



Post Processing Pipeline

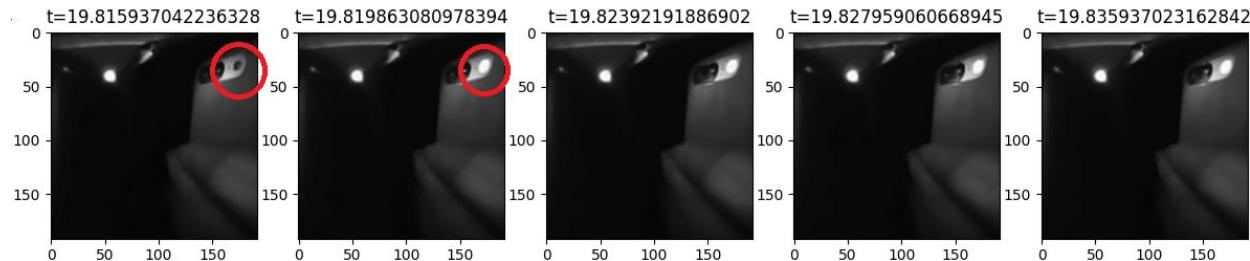


Post Processing Pipeline

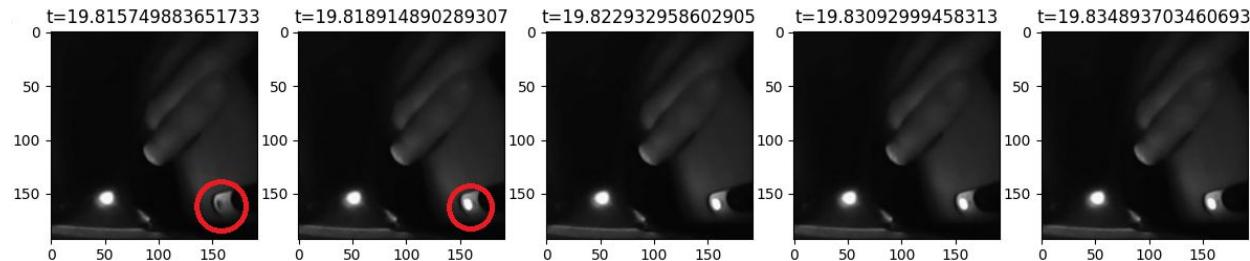


Synchronisation of cameras

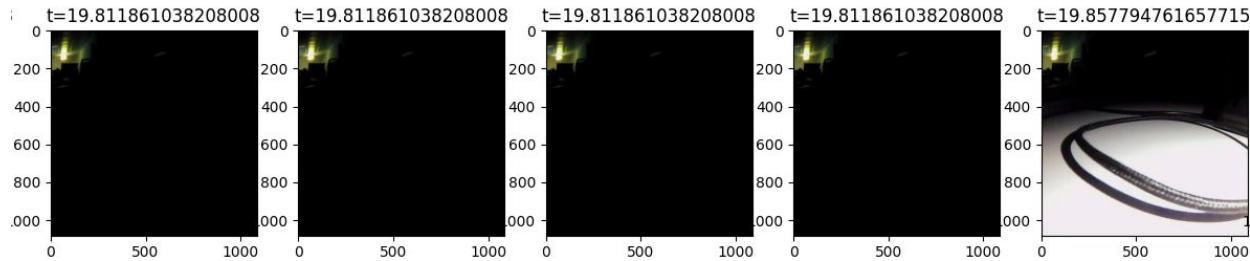
left eye
(200fps)



right eye
(200fps)



world
(30fps)

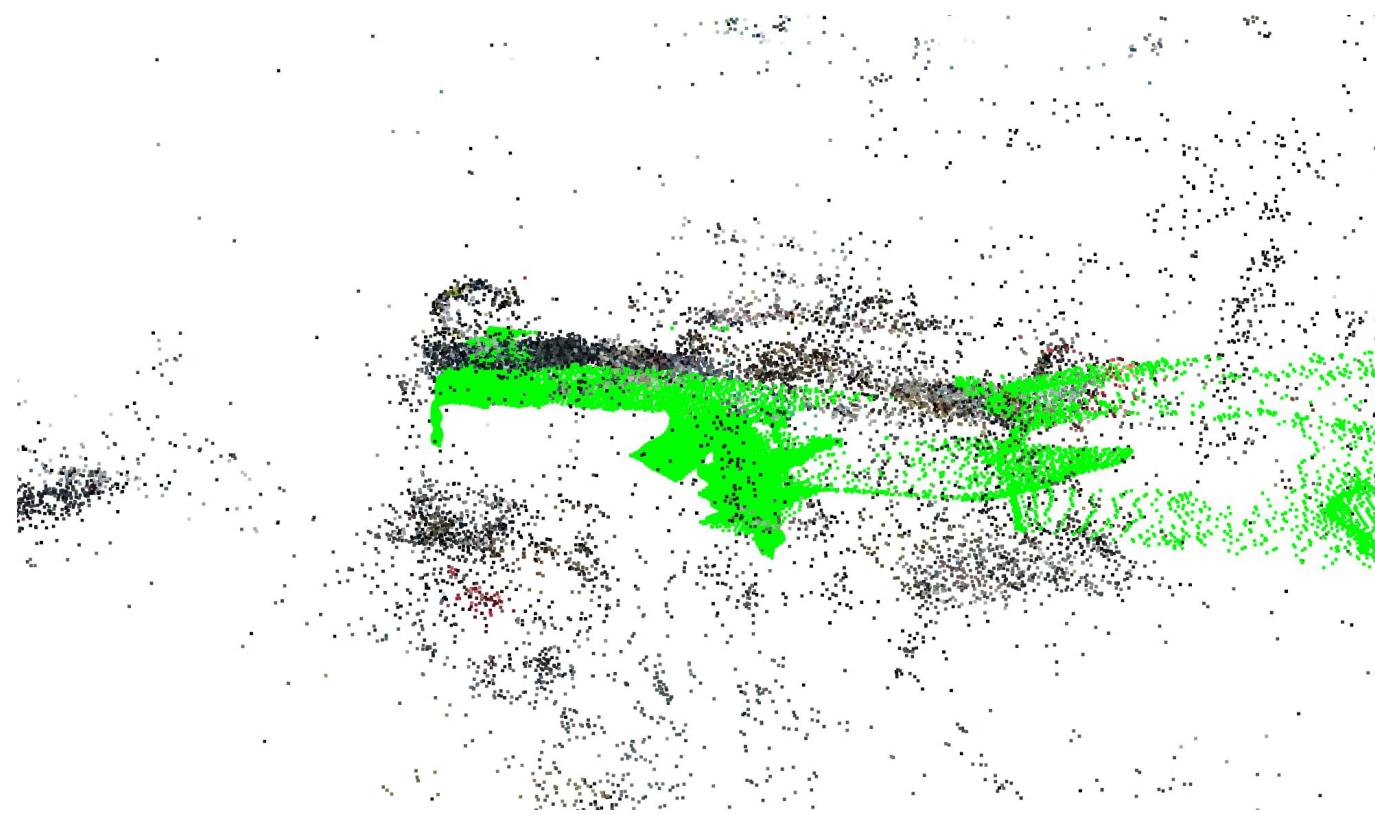


$$\lceil \frac{200}{30} \cdot \frac{1}{2} \rceil = 4$$

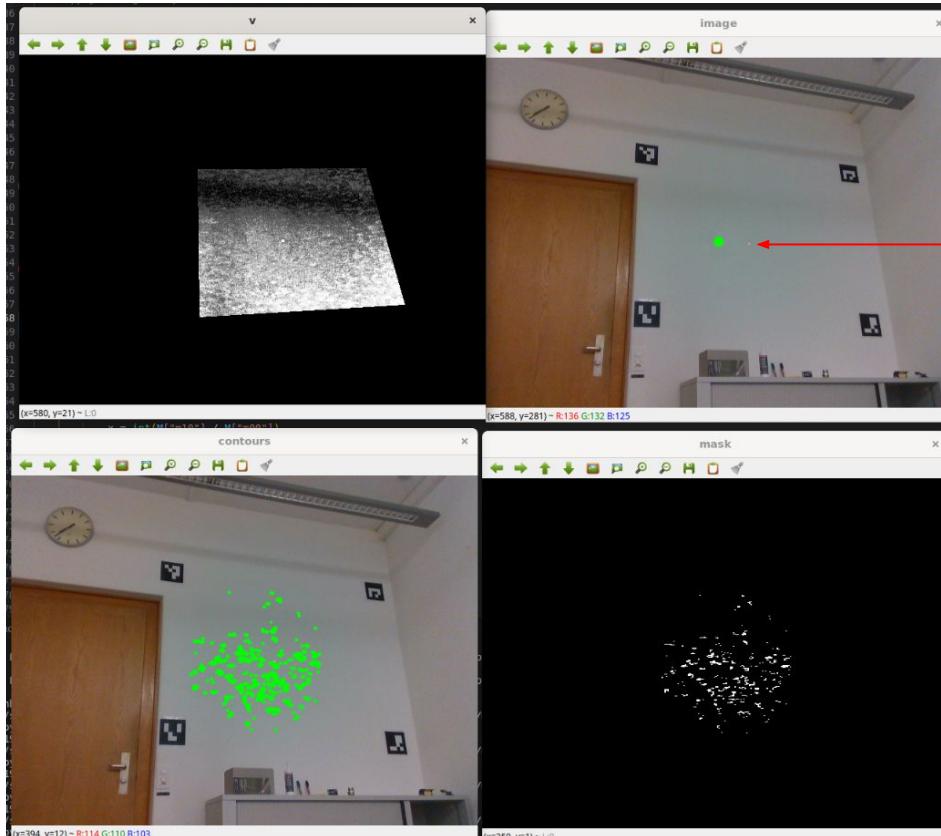
Camera Pose Estimation



Point Cloud Verification

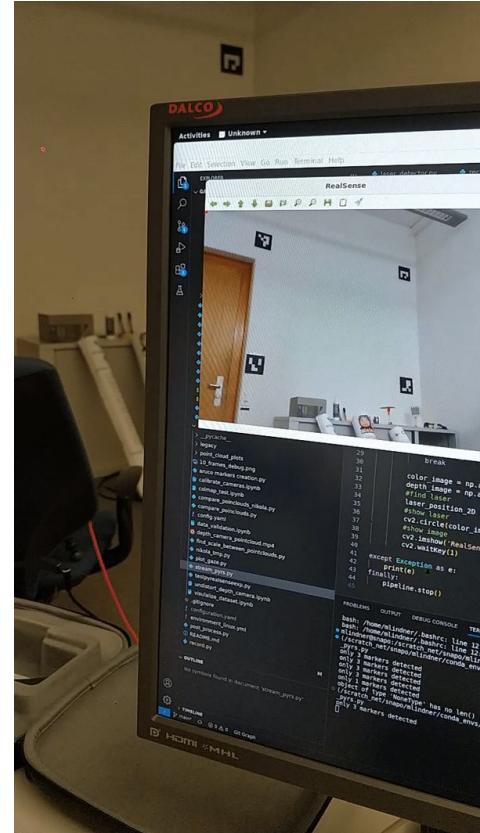


Laser Recognition



Failed attempts

actual
position



Successful recognition

Data-Set Creation

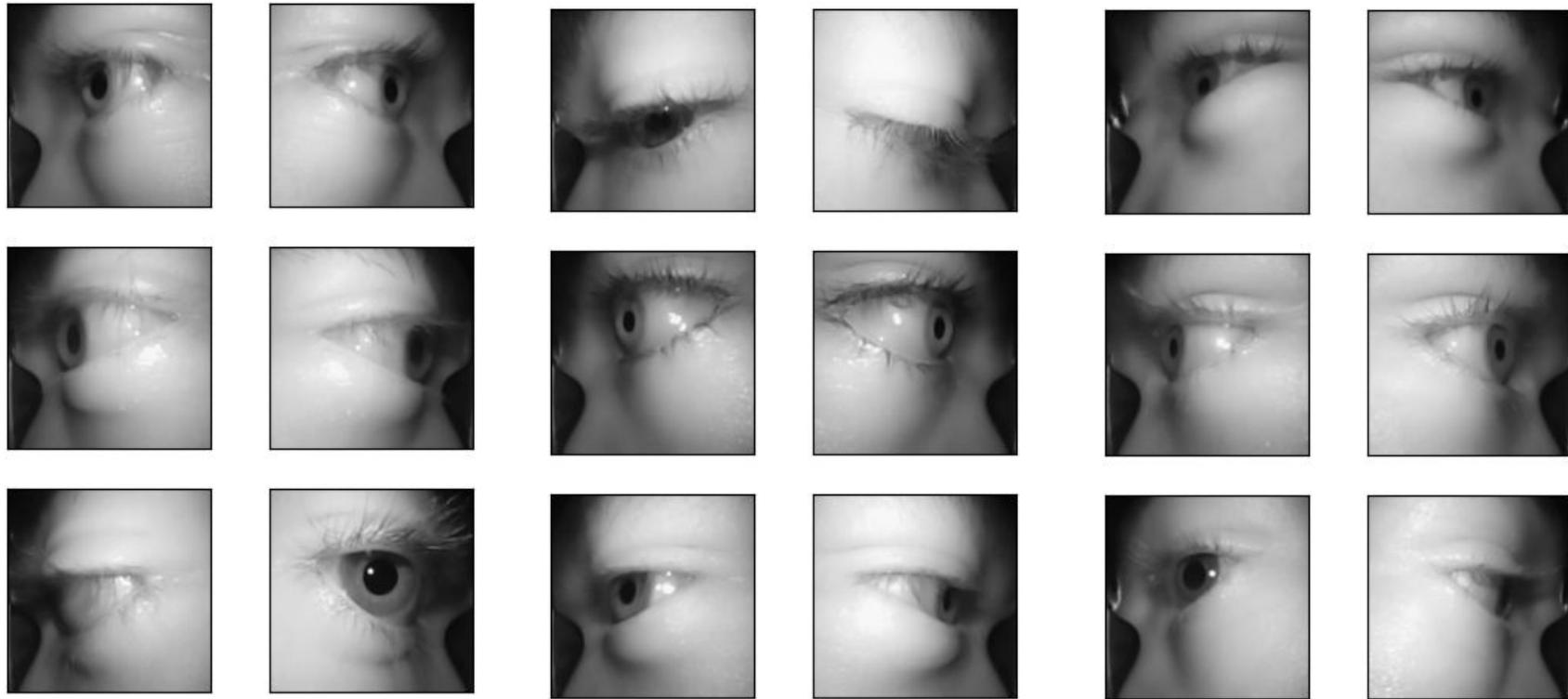


Operator



Participant

Data-Set example images



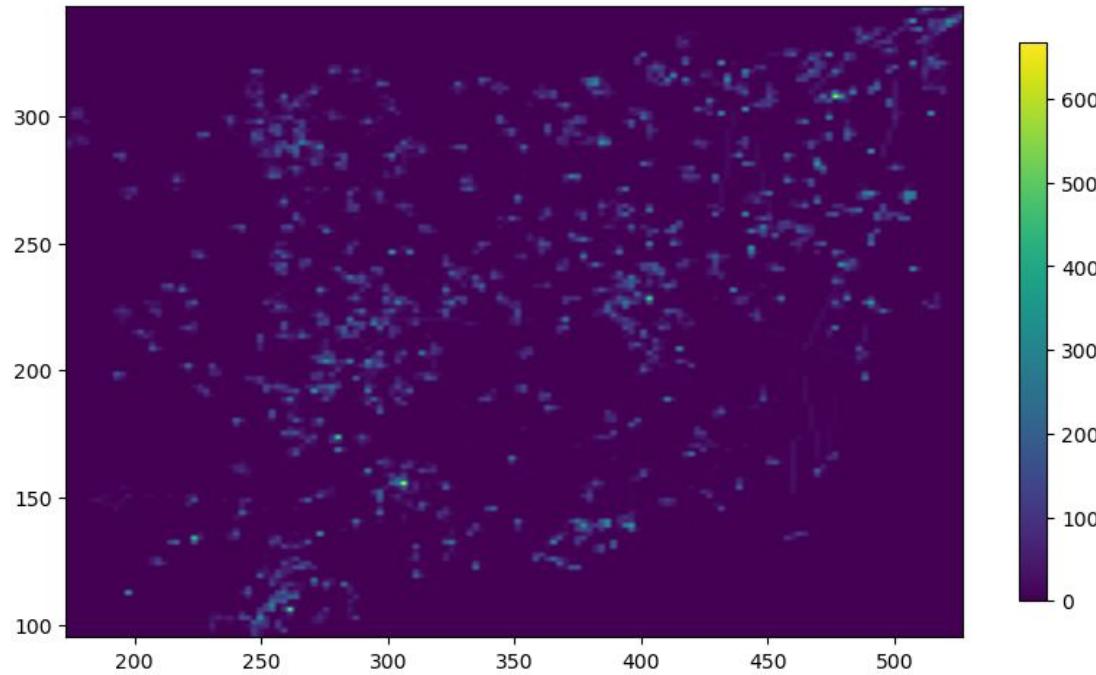
200,000

Number of how many data-points we recorded

Statistics

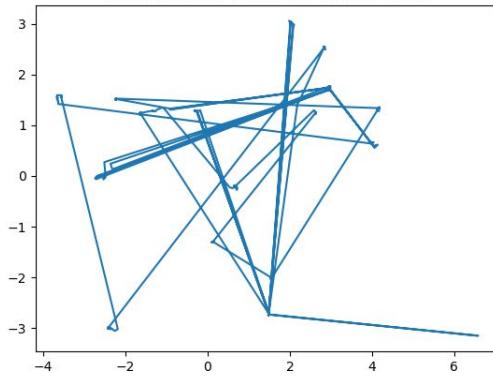
- 20 Participants
- Almost 500.000 images
- reduced the data-set size to
50GB

Laser Heatmap

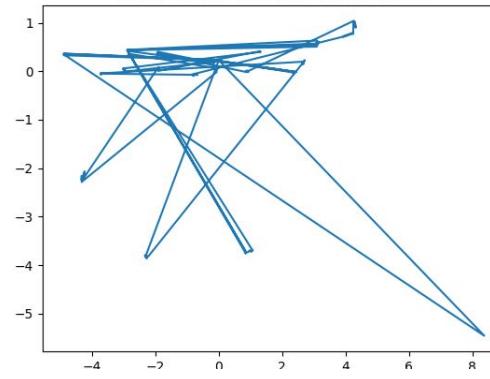


Paths from above between each event

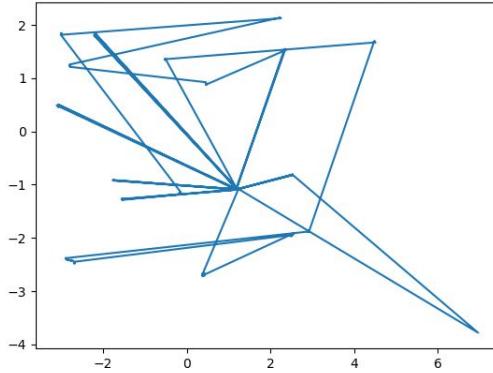
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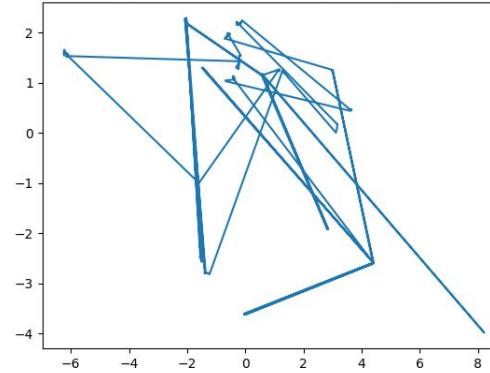
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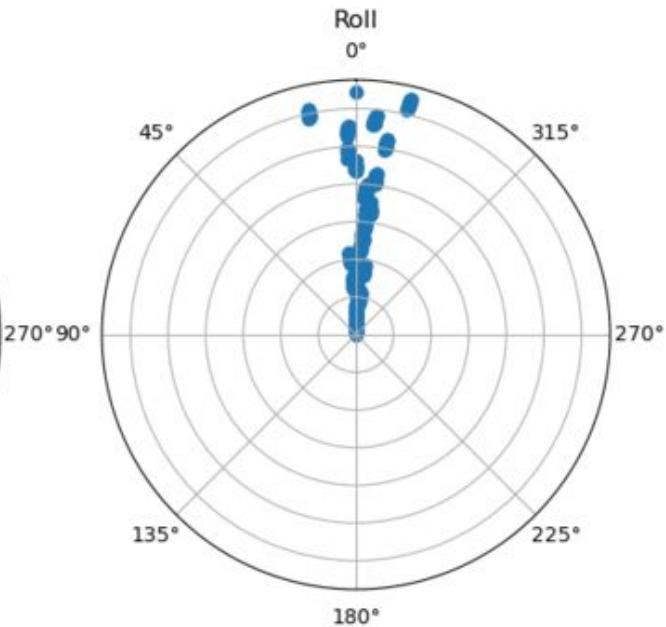
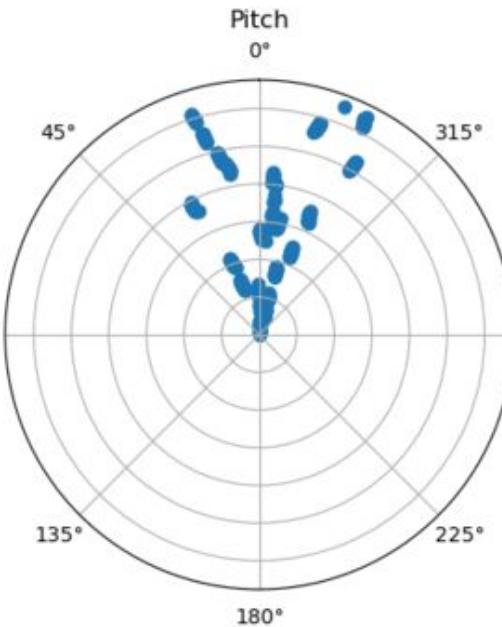
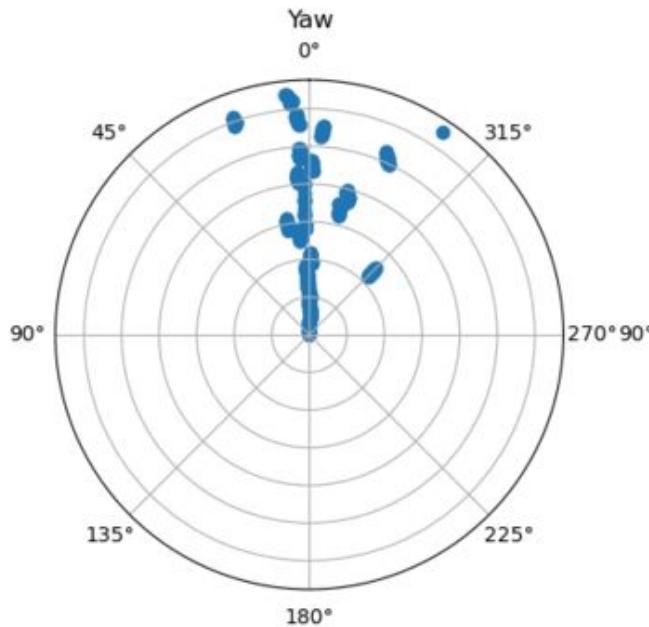
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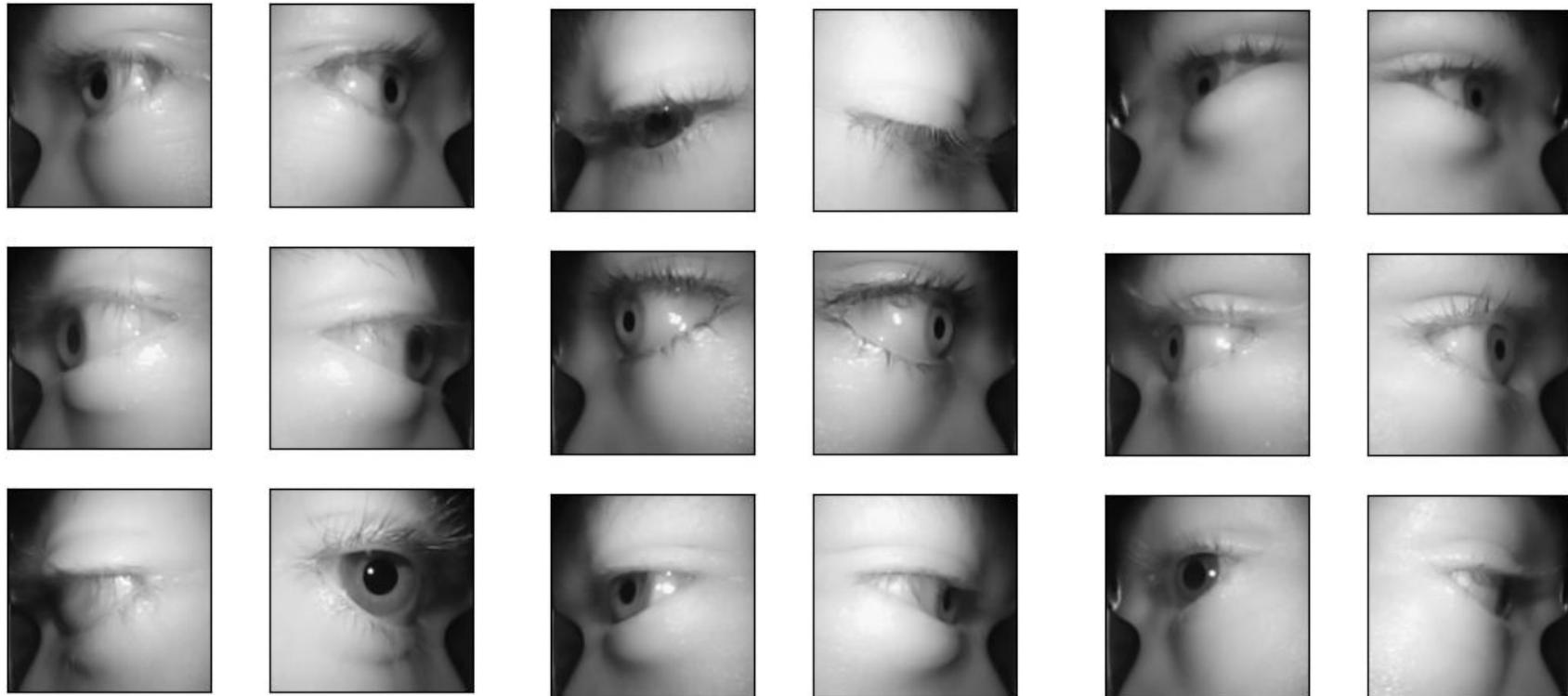
Yaws, Pitches, Rolls



Discussion & Future Work

Flaws	Solution
Diversity	More participants
Range of positions	Larger room
Dilated Pupils	Different lighting conditions
Projection only on a wall	Different Laser, Project on other surfaces
Laser is visible in world images	Make the Laser Blink

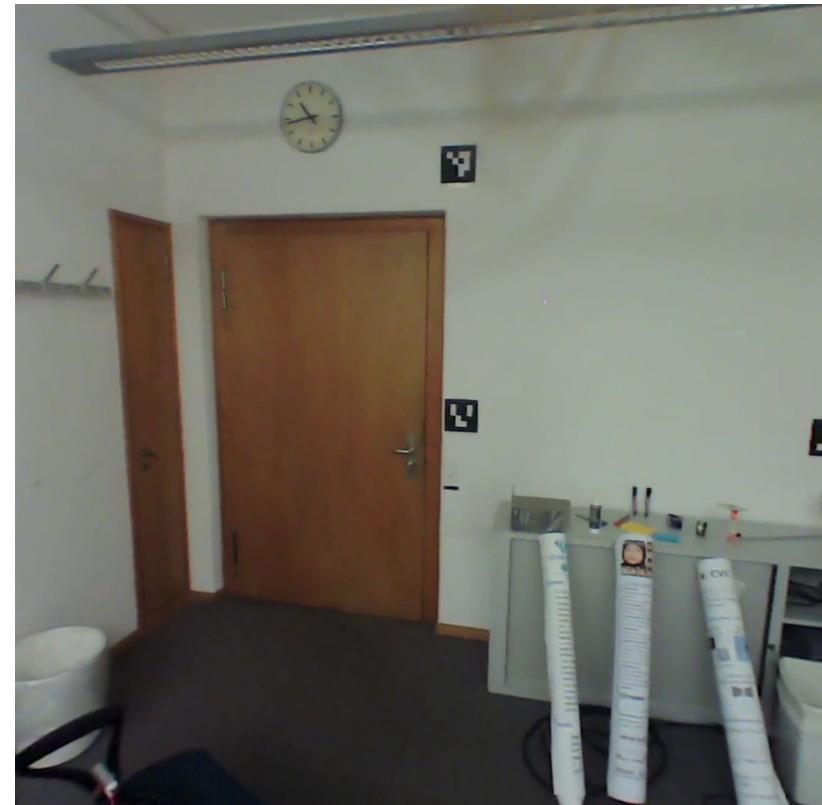
Conclusion



Thank you for your attention

More slides

Distortion removal



Recording Protocol

1. The participant is standing in front of the wall where the depth camera is facing.
2. The laser pointer is turned on
3. The recording is started
4. The laser pointer will be pointed at a random position, the participant is asked to look at the laser pointer for 3 seconds with a random position and random viewing angle. The operator will ask for a confirmation from the participant before pressing space to trigger an event.
5. Step 5 is repeated 20 times.
6. The recording is stopped.

Scale Estimation

- Calculated distances between sparse points and estimated camera pose of the depth camera by COLMAP
- Projected sparse points in the Depth camera
- Extracted the depths from the depth camera in those points
- Mean ratio of all the distances and depths