A composite background image featuring a blue sky with an airplane, a cityscape, and a body of water with a boat and offshore structures.

# MOTION AND MOUTH-OPENING-FREQUENCY OF SALMON IN A STRESS-EXPERIMENT

## OWITTOOLS AP2: VISUAL ANALYSIS

16.2.2022 OWITTOOLS-Webinar

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# Overview

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- Aim / Background
  - IMS CO2 Experiment
- Visual Analysis
  - Stereo Image Processing / 3D reconstruction
  - Trajectory extraction of the Salmon
  - Mouth-Opening-Frequency
- Results
  - Trajectory Motion-Measure
  - Mouth-Opening-Frequency

# Aim

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The main aim within this OWITTOOLS subtask is to investigate/verify that selected **non-invasive visual measurements** from salmon videos are suitable to extract information that can be linked to the welfare of the fish.

Focus is on the **mouth-opening-frequency** (breathing) and the fish **motion**.

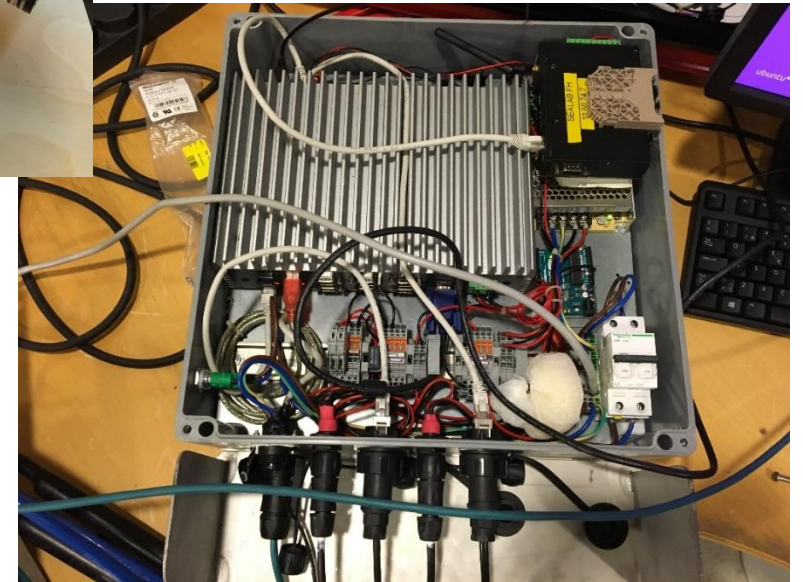
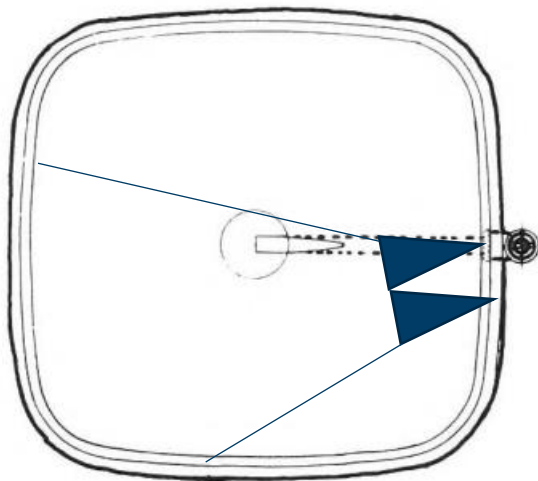
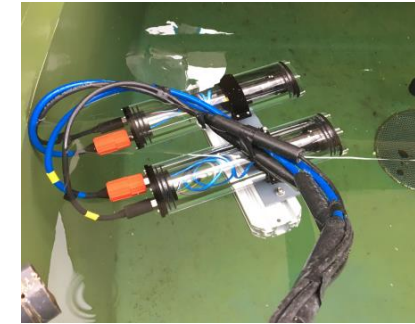
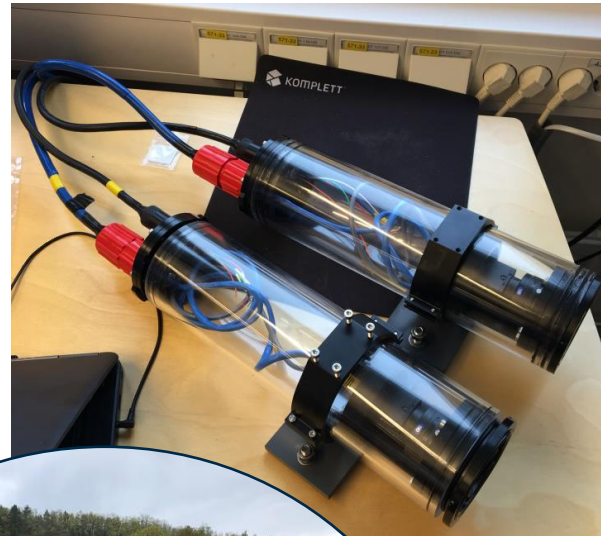
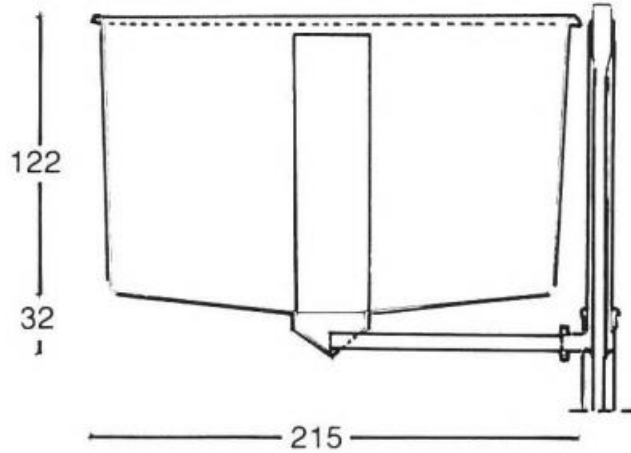
# Background: IMS Experiment (Stereo-camera)

- Stereo-Camera placed in a Tank at IMS (19.5.2021-13.7.2021)
  - Stress Experiment: Increased CO<sub>2</sub> concentration 10:20 (for ~6 hours)
  - Recordings scheduled every 15 minutes for 5 minutes
    - Night recordings are too dark/ Varying framerate of the recordings /Bandwidth required an image "cropping" ...



# Stereo-Camera within the Tank

- GSM-Modem, Computer, Microcontroller, Cameras



Stereo-Camera: Ingredients

5 We were "lucky" with the camera orientation!

NINA Research Station (Ims, close to Stavanger)

# Videorecordings

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- Hardware:

- 2 Industry-cameras: Blackfly BFLY-PGE-13E4C
- Lens: View angle 51 degrees (underwater)
- Internal harddrives (2x each with 1 Terrabyte) + External Backup-Hard-discs  
→ We recorded 690 Gb with video data (~12.5 Gb per day, incl. dark recordings)
- Video image size: **1280x1024** pixel 24bit (RGB-color)
- Remote access

- Recordings

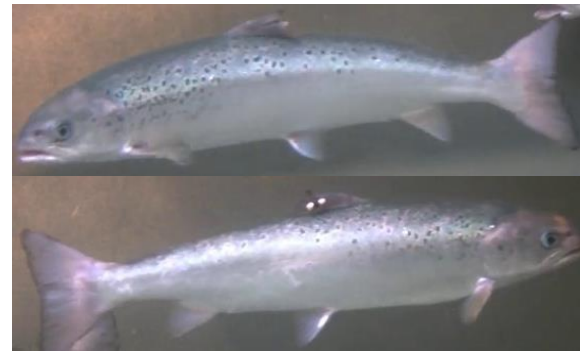
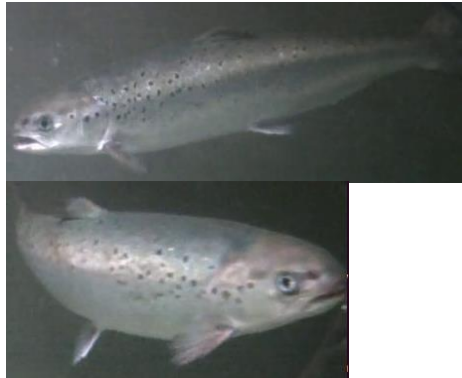
- In day light approx. ~**5min recordings** (7500 frames)
- Every quarter of an hour (dark/night videos were removed)

- Videos quality

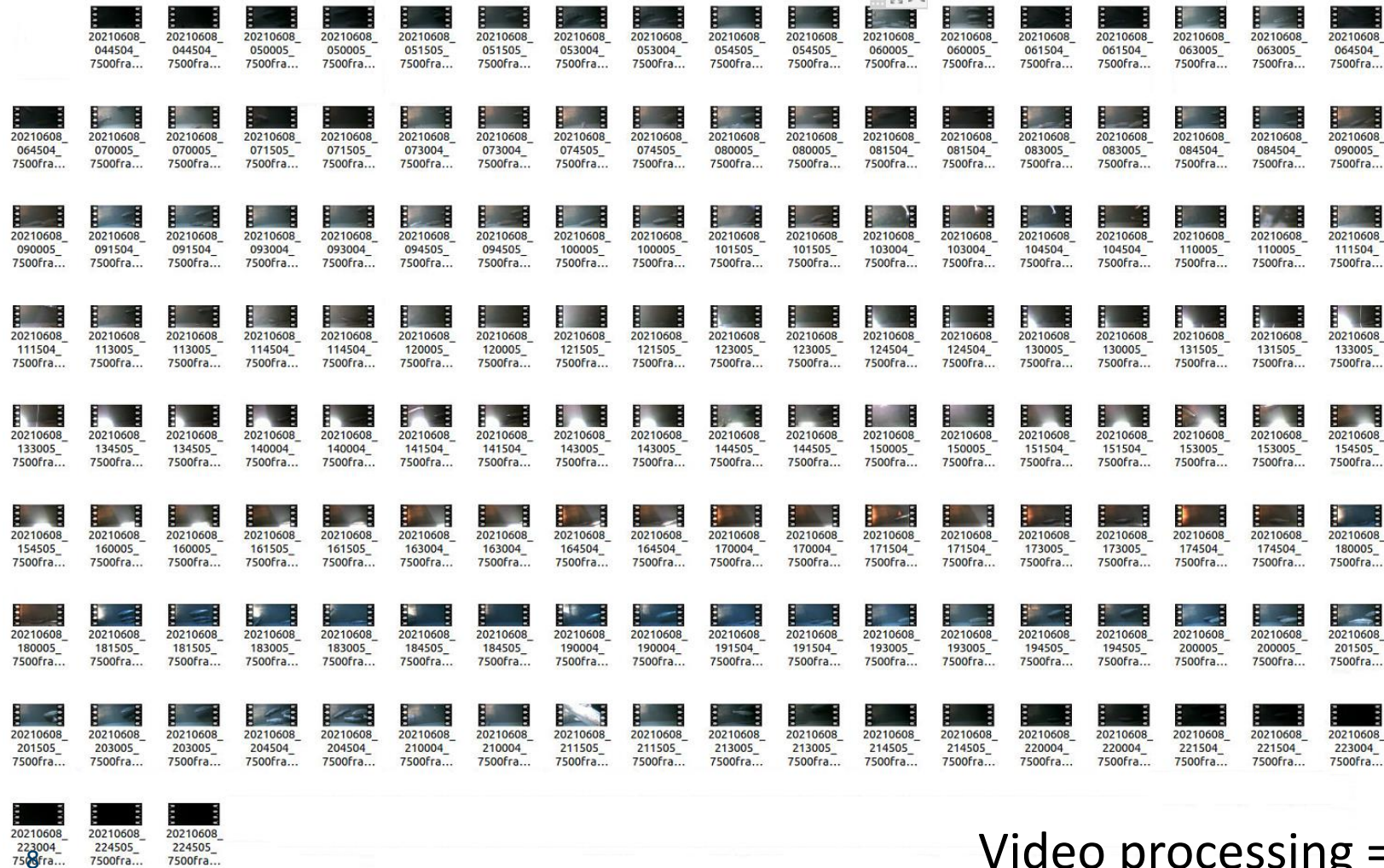
- Mostly of good quality (occasionally turbidity + low light)
- Frame-rates: 18-25 images/s (mostly ~24 images/s)

# Visual Analysis

- Data collected with a stereo camera at IMS in a Tank with 6 fish.
- Focus on CO2 stress experiment 8.6.2021
- Visual features:
  - ▶ **Mouth-Opening-Frequency**
  - ▶ **Motion-Trajectory**



# Recordings from CO2 Stress Experiment Day



- 8.6.2021
- Bright enough: 05:45-21:15
- => ~62x2 Stereo videos
- 6 GB

Video processing => “Big Data”



# Example Recordings

20.5.2021 18:18



20.6.2021 13:45



13.7.2021 07:00

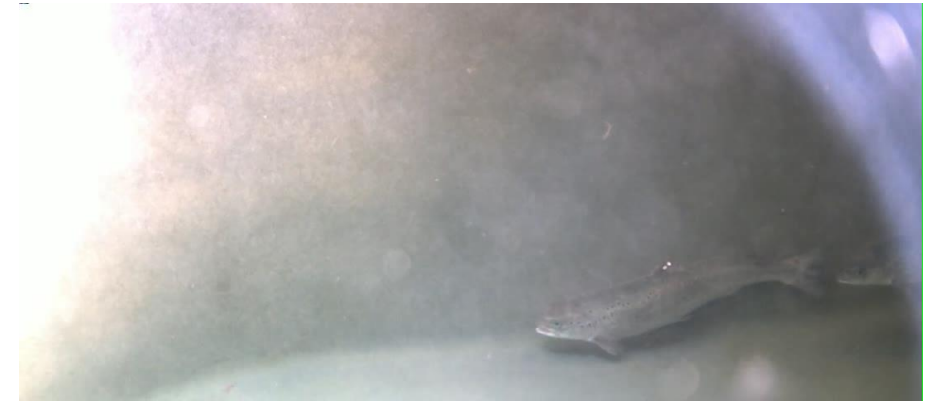
# Challenges

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8.6.2021 10:15 + 10:30 + 15:30



22.5.2021 13:45



27.5.2021 21:45

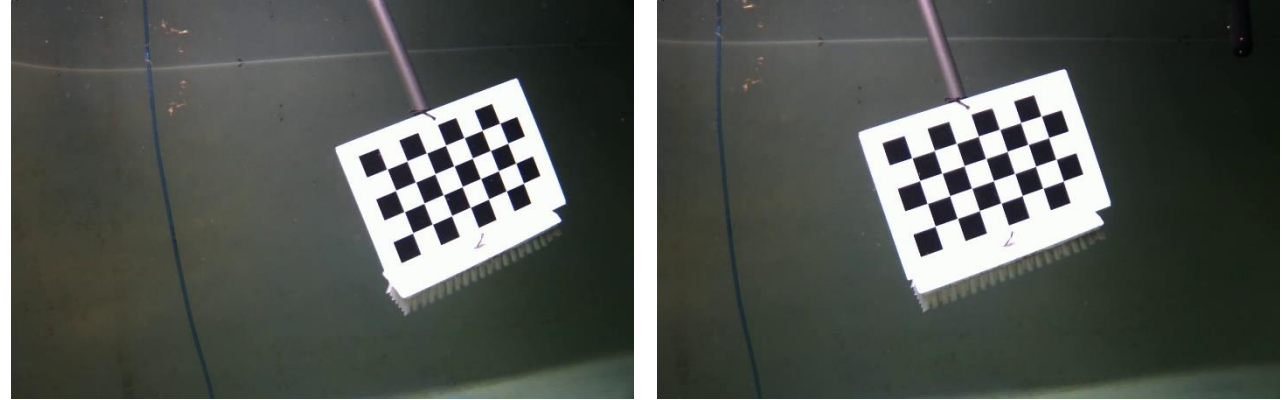
Noise,  
Varying lighting  
conditions,  
Occlusion,  
Reflections,  
Non-rigid objects,  
Varying framerates ...



# Stereo Image Processing

- Calibration of the camera-setup

- Checkerboard (underwater!)
- Internal camera parameters
  - focal length/view-angle
- External camera parameters
  - Baseline/camera distance, relative rotation



=> Information about the geometric camera setup:

Field of view: ~51.4 degrees  
Baseline: 15.03 cm

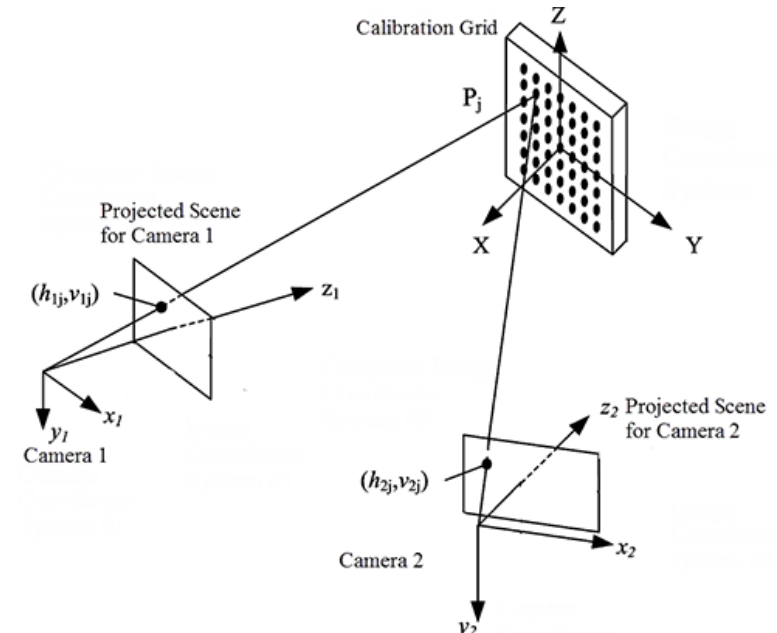
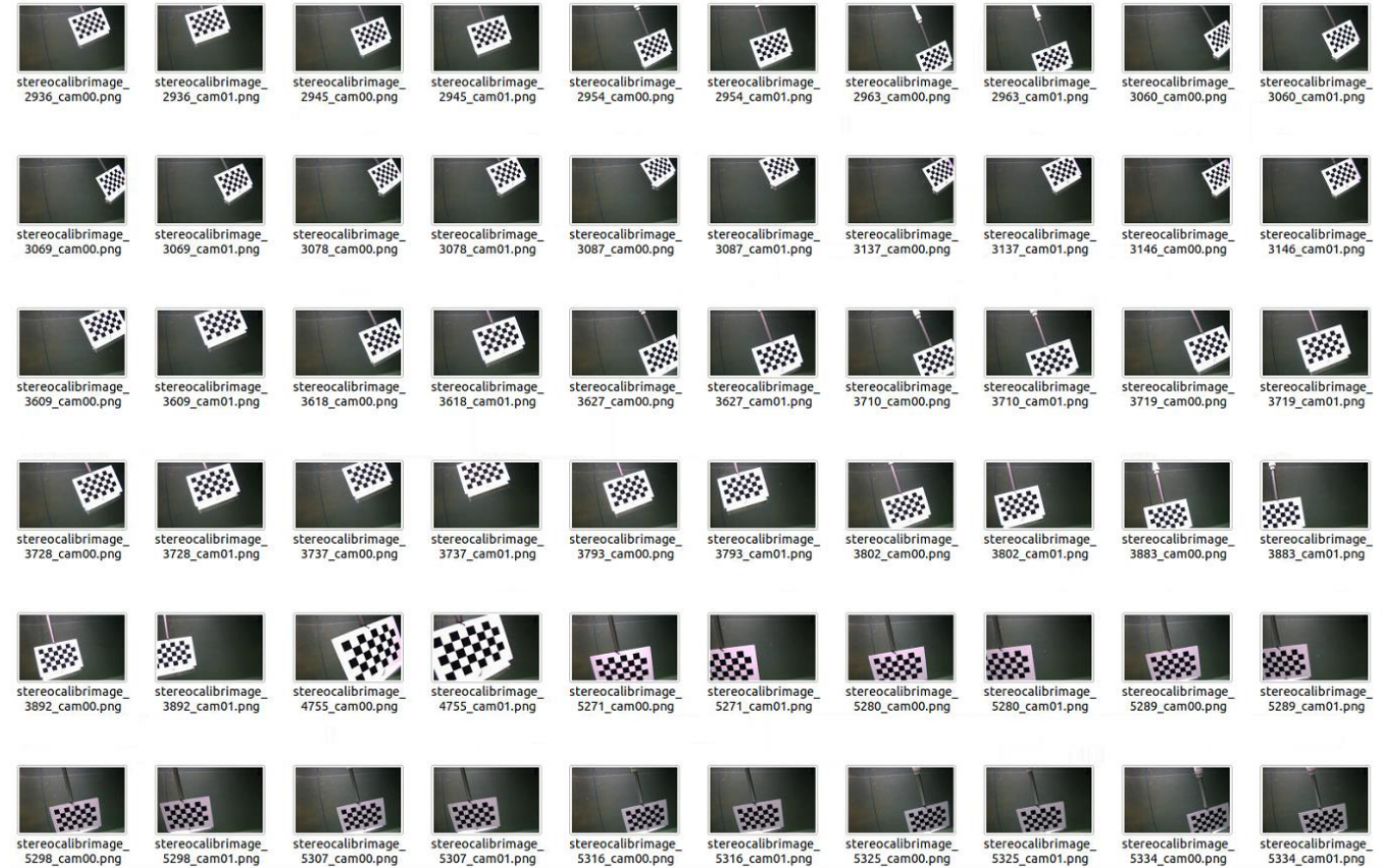


Image-source: [sourishghosh.com/2016/stereo-calibration-cpp-opencv/](http://sourishghosh.com/2016/stereo-calibration-cpp-opencv/)

# Stereo-Camera Calibration



- Calibration pattern of known size: (square 3.11 cm x 3.11 cm)
- Calibrate single cameras => internal camera parameters
- Calibrate stereo setup => external camera parameters

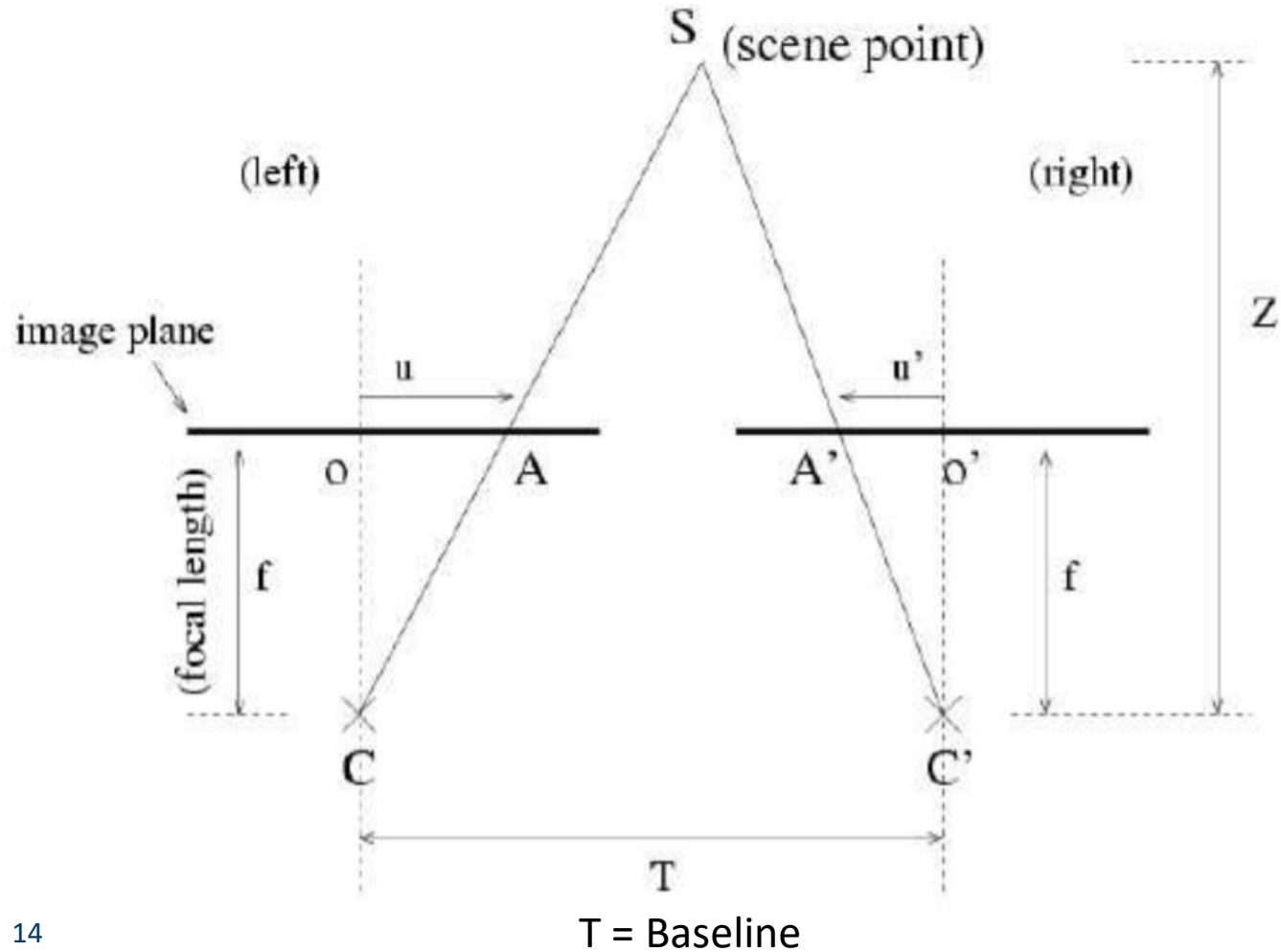
# Rectification

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- Knowing the geometric setup (external parameters) and the camera parameters (intrinsic parameters) one can “rectify” the images.
- => This transforms the images into “ideal” stereo-camera setup



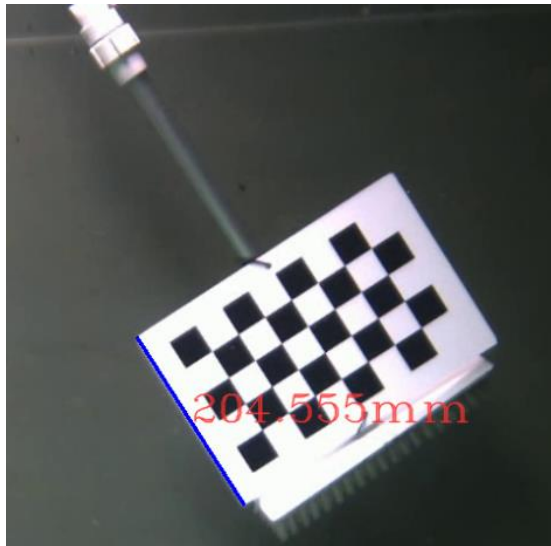
# Triangulation



- “ideal” stereo-camera setup  
=> parallel cameras

# Trajectory extraction of the Salmon

- Method development
  - Stereo-camera allows to extract metric measurements in 3D (i.e. length in meter, cm, mm)
  - Main steps: **Camera calibration, “Rectification”, Triangulation**



Calibration “checkerboard”

Length of the calibration board: ~20x30 cm

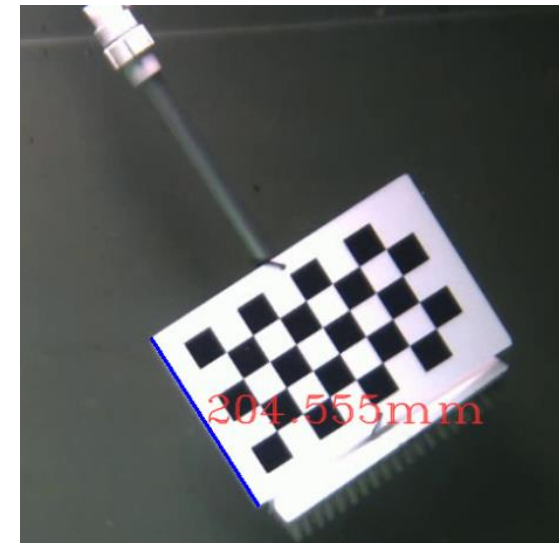


Rectification: Corresponding features like the eye at same y-coordinate

# Metric Data Extraction



~57 cm

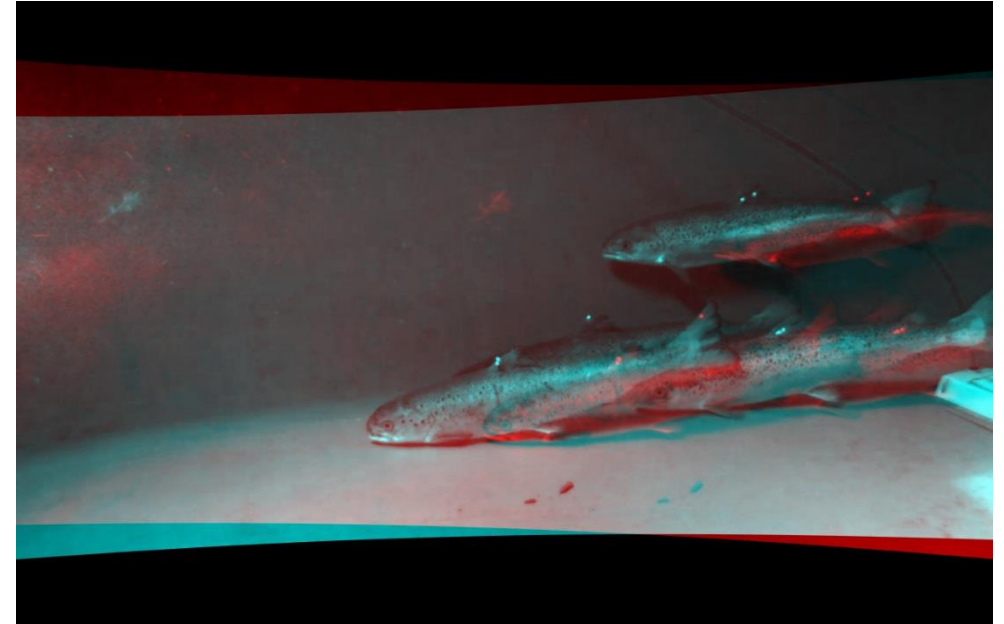


20 cm (20.4 cm measured)



# 3D representations, Pointcloud, 3D-Glasses ....

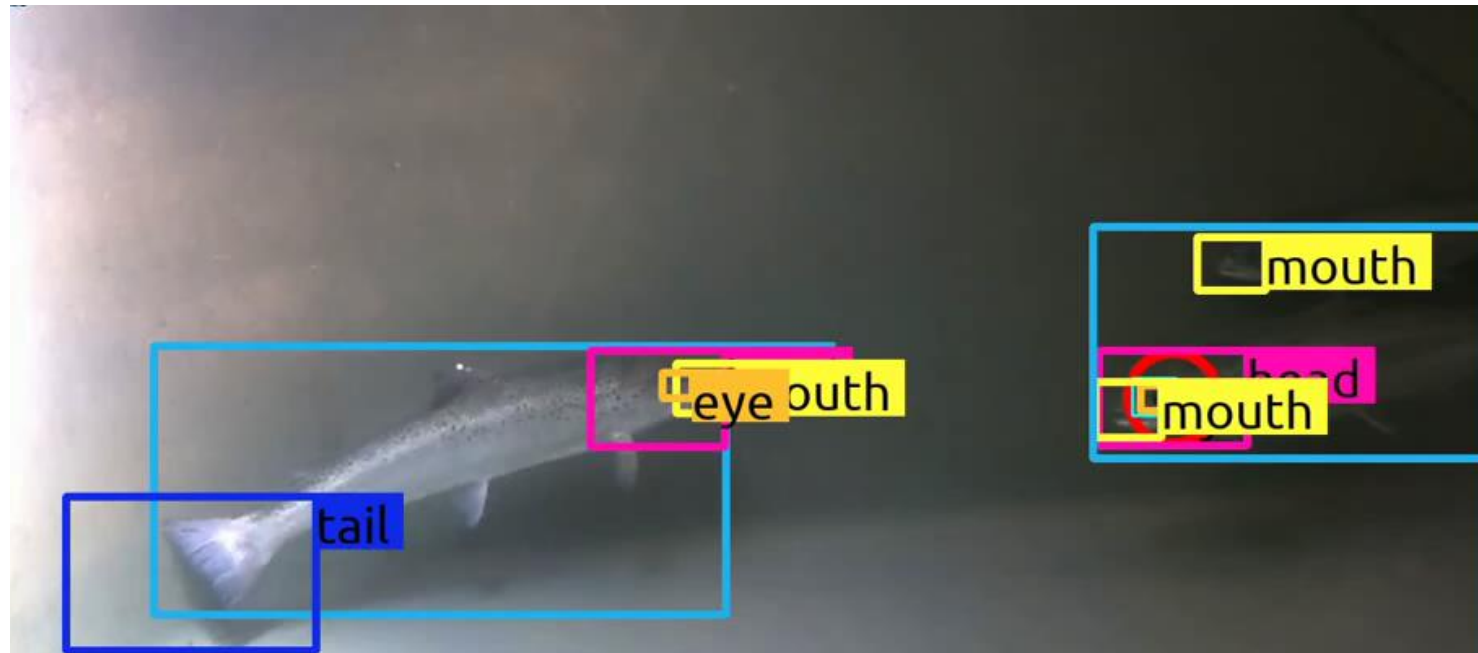
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Computing a correct dense pointcloud (reconstruction) is still challenging..

# Motion-Trajectory based on the eye

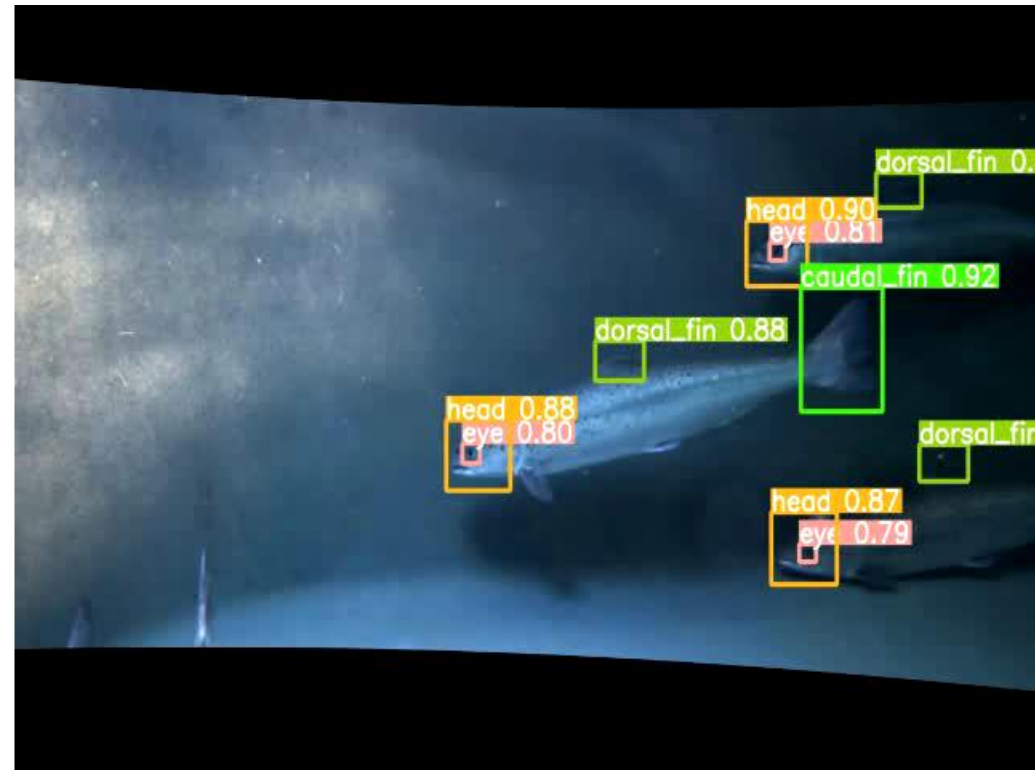
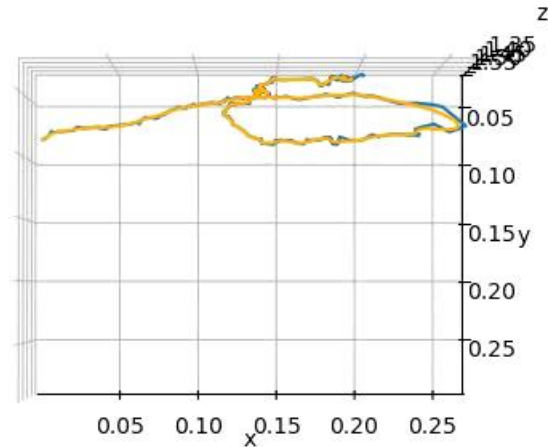
- Exploitation and development of Computer Vision Methods to detect and track the eye in the left and right video
  - ▶ **Motion-Trajectory** can then reconstructed



Detections of Salmon parts along with tracking them allows the analysis of motion details of the salmon.

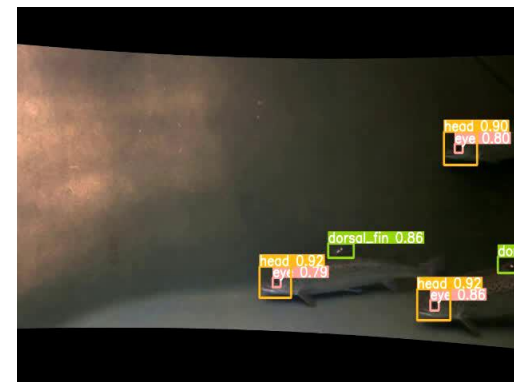
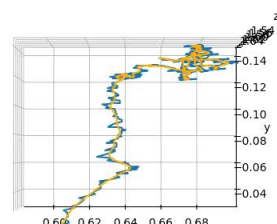
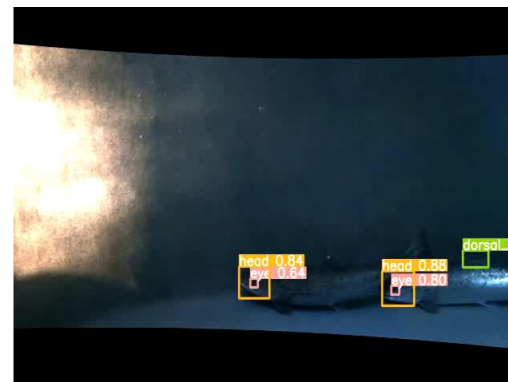
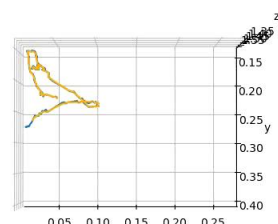
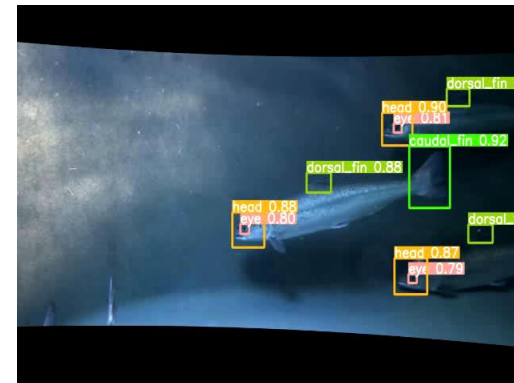
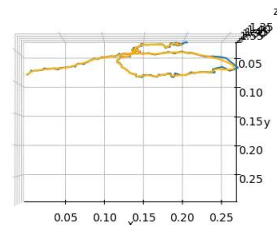
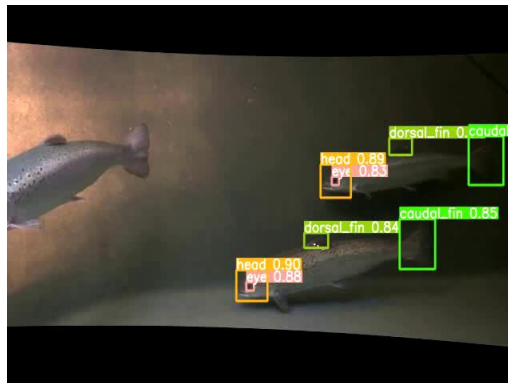
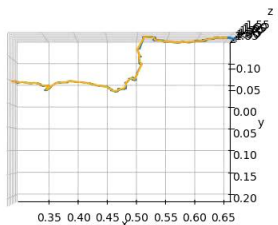
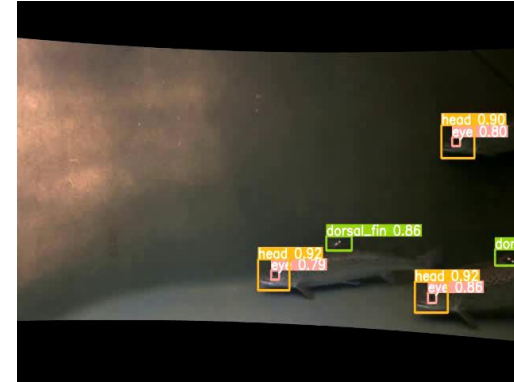
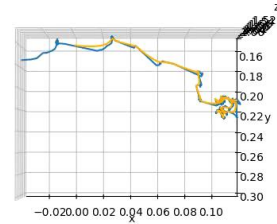
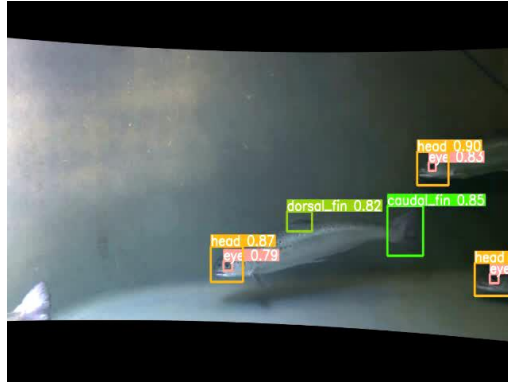
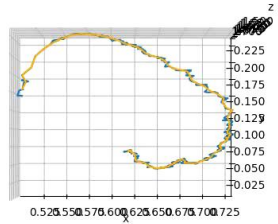
# Trajectory extraction of the Salmon

- Following the eye of the salmon in the stereo-image-pair we can compute the trajectory of the eye/fish.
- Requires a robust detection of the eye (Machine Learning exploiting for example Deep Learning)



Example of an extracted 3D trajectory of a single salmon (Salmon in the centre)

# Many Trajectories ...



# Mouth Motion Analysis

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- Exploiting Machine Learning Algorithms and Computer Vision we can track the heads of the salmon for further analysis !



# Mouth Motion Analysis

- ▶ Good visual conditions allow an automated extraction of the Mouth-Opening-Frequency

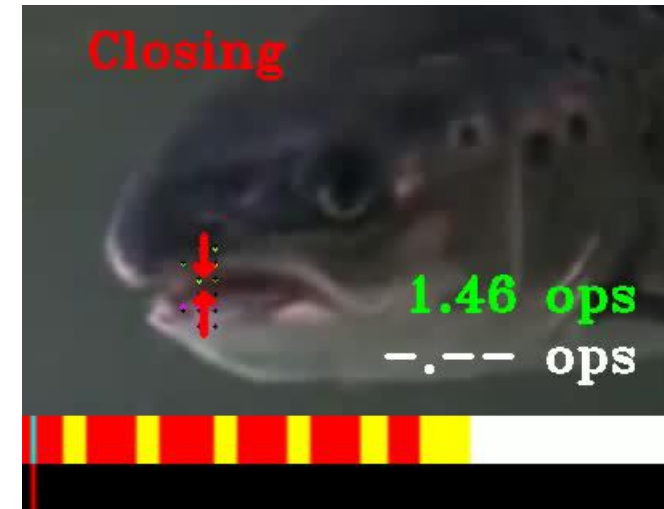


Ground Truth  
Measurement

## “Difficult scenes”:

Small motion

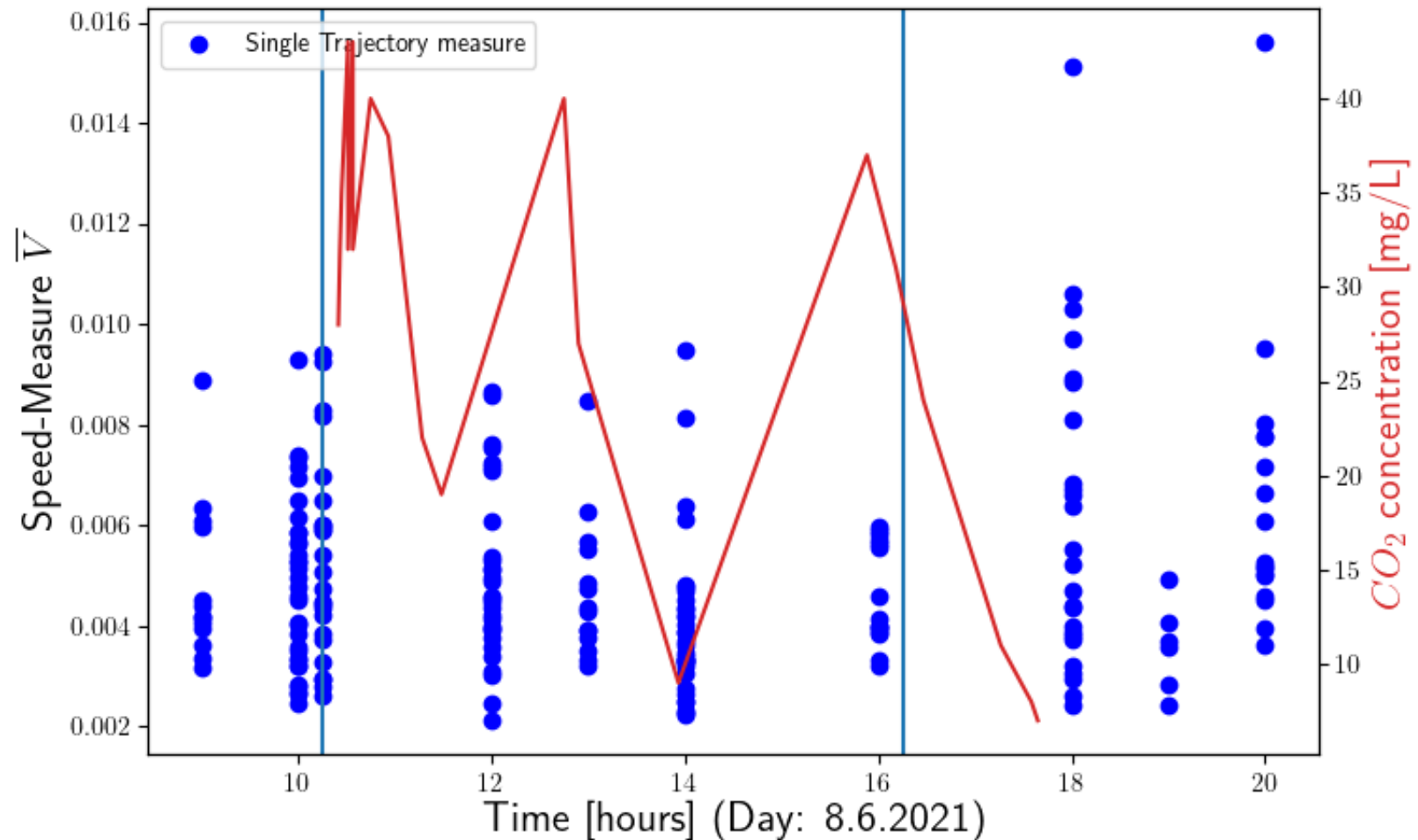
Large orientation changes



# Results: Trajectory Motion-Measure CO2

- Observations:
- Current “motion measures” show no strong correlation to the CO2 levels.
- Potential Explanations
  - Bayes towards “stationary” fish-trajectories. (we miss relevant fish trajectories)
  - Accuracy in Z-direction is highly noisy.

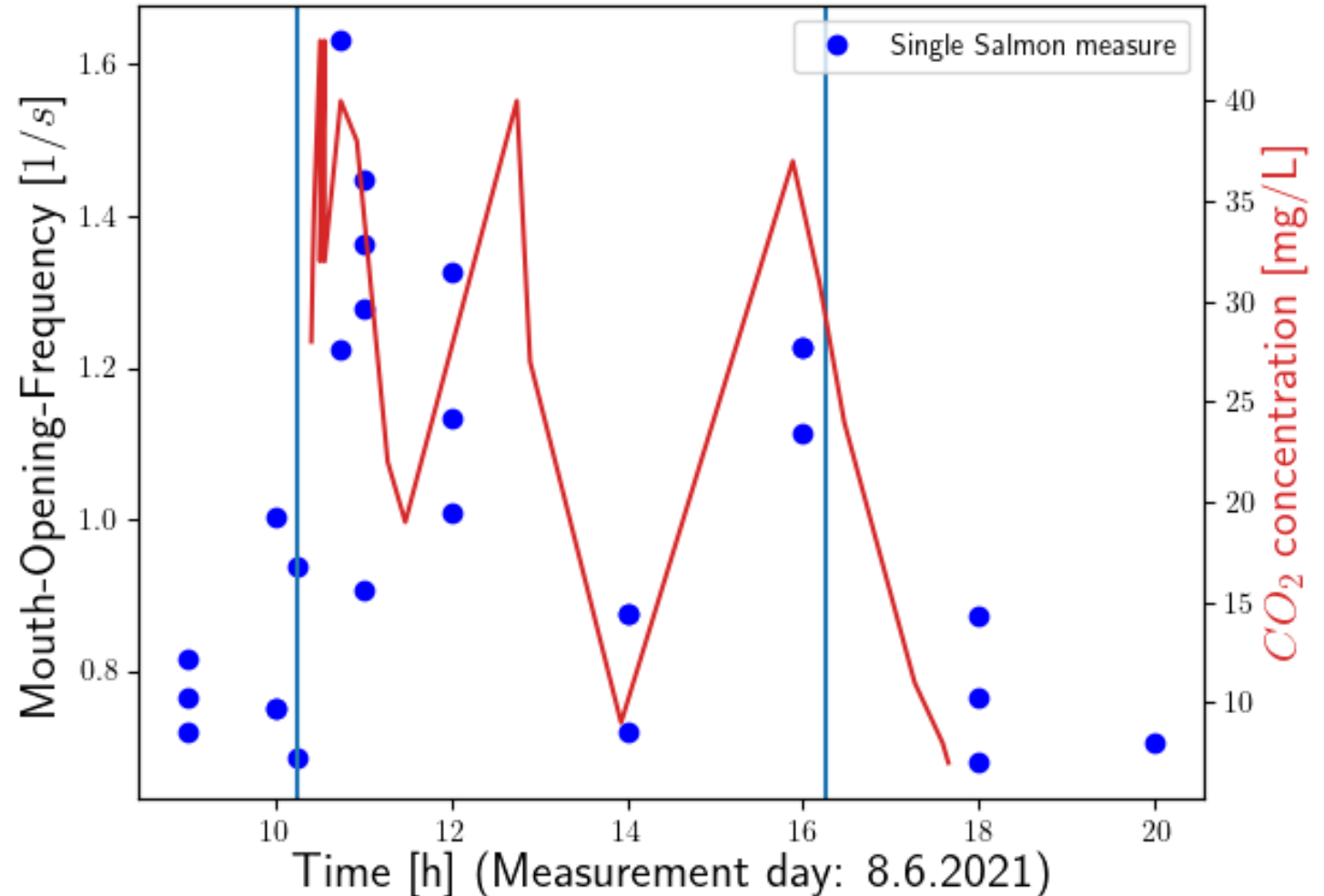
Motion Measurements  $\bar{V}$  based on extracted Trajectories



# Results: Mouth-Opening-Frequency CO<sub>2</sub>

Mouth Opening Frequency (CO<sub>2</sub> Experiment)

- Observations:
  - Increased/Decreased Mouth-Opening-Frequency agrees with increased/decreased carbon dioxide levels.
- Highly likely that we can observe the induced stress



We will learn more through a new FHF project BIORELEVANS (901736)



# Discussion

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- **Motion Extraction Approach:**

- Used Approach: Trace the fish eye in stereo videos to get a 3D trajectory and relative speed measurements
- Trajectory relative to the camera is extracted (speed measurements need water speed too.)
- Currently inconclusive results regarding CO<sub>2</sub> stressor, but the technique allows to determine fish motion (speed and direction).

- **Mouth Opening Frequency measurements:**

- Works automated in “ideal” conditions (lighting, opening-motion, distance to camera).
- The mouth-opening frequency shows a correlation with the CO<sub>2</sub> concentration stressor.
- Measures a biological status variable with meaning for welfare (Needs still a better understanding of all factors that influence the breathing [i.e. Temperature, O<sub>2</sub> concentration, Fish-size, etc.] )

- **More “Visual” Information may be extracted !!!**

- Example: Size measurements and tail motion frequency are promising candidates.



Teknologi for et bedre samfunn