Underwater Human-Robot Interaction via Biological Motion Identification

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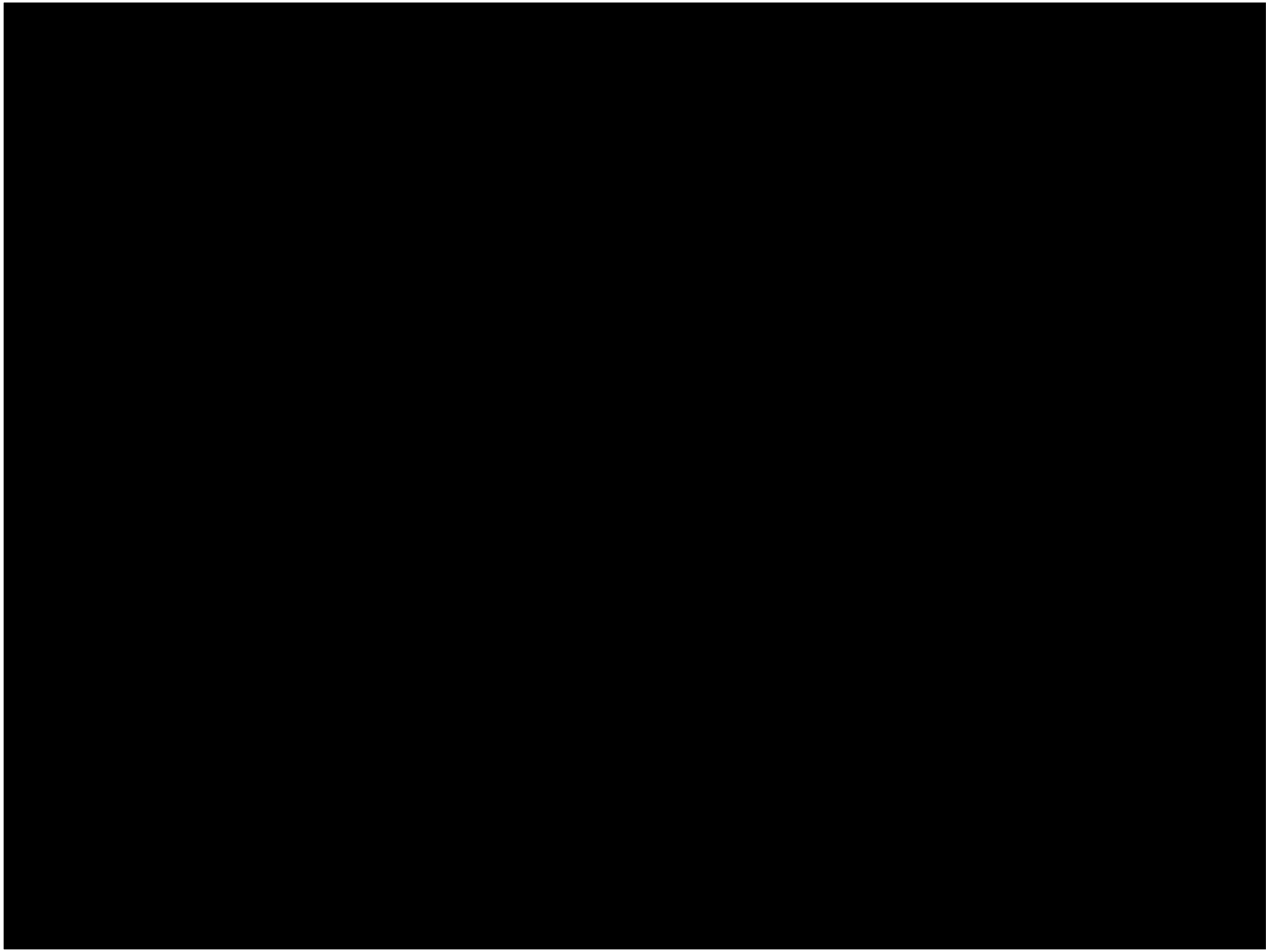
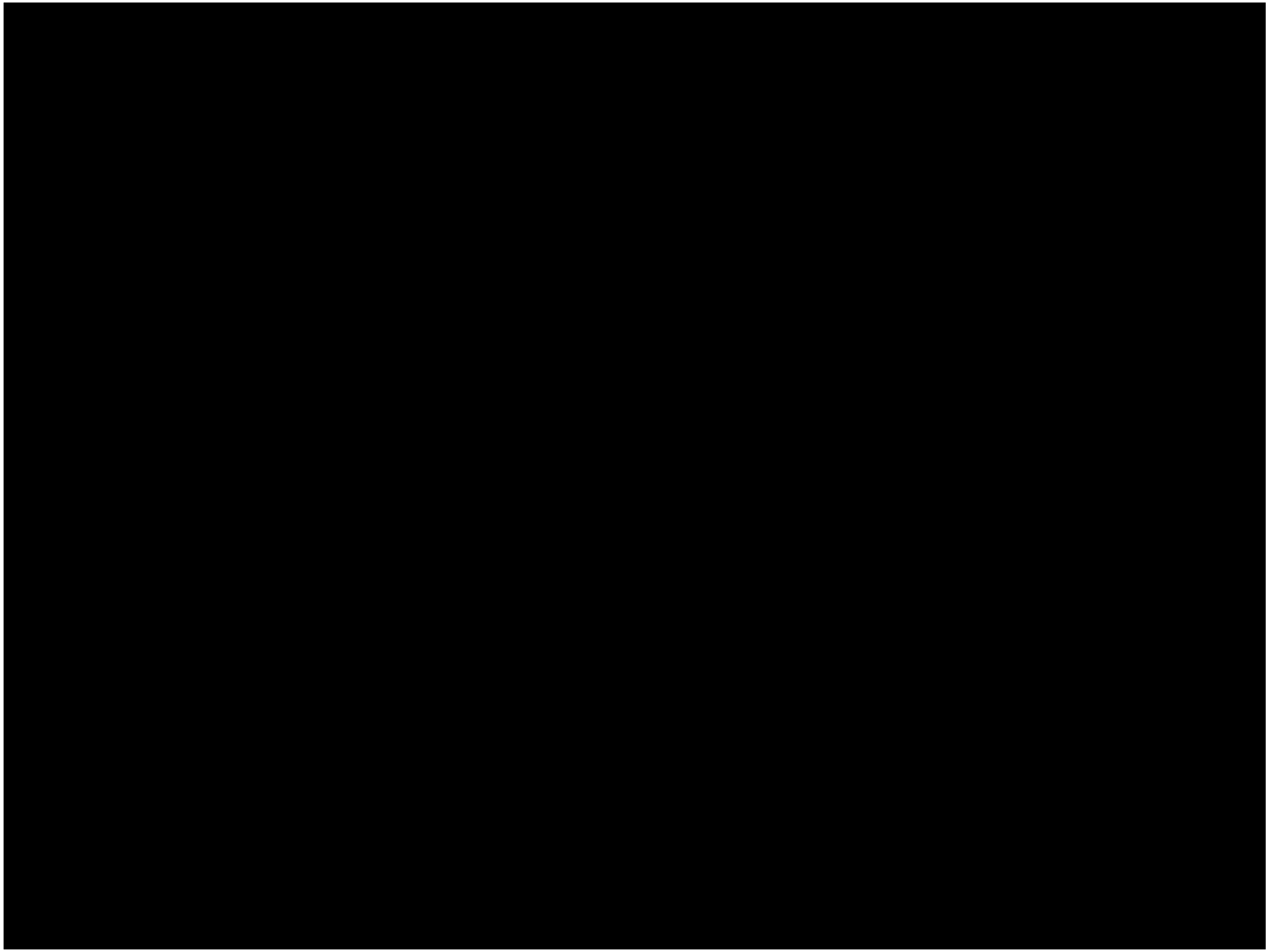
Introduction

- visually detecting human motion
- follow a human diver
- multiple divers in the visual scene

Motivation

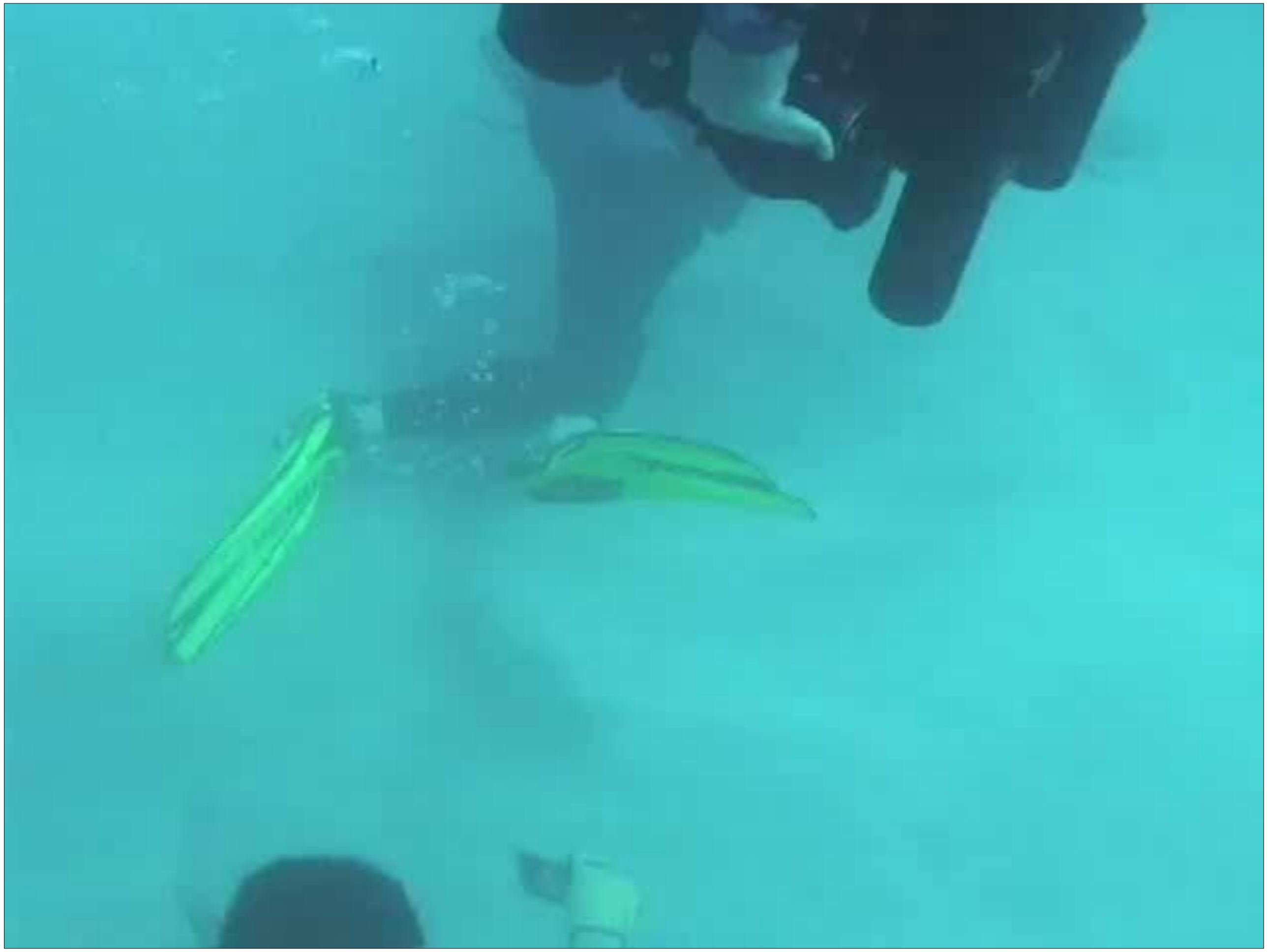


Motivation



MRL Mobile Robotics Lab at McGill University

That said...



Applications

- Diver's “buddy”
  – Monitoring marine habitats, migration pattern analysis
  – Learn from the diver for future autonomous experiments/exploration missions
- Inspection tasks
  – Cable/pipeline inspection, ship’s hull inspection

Outline

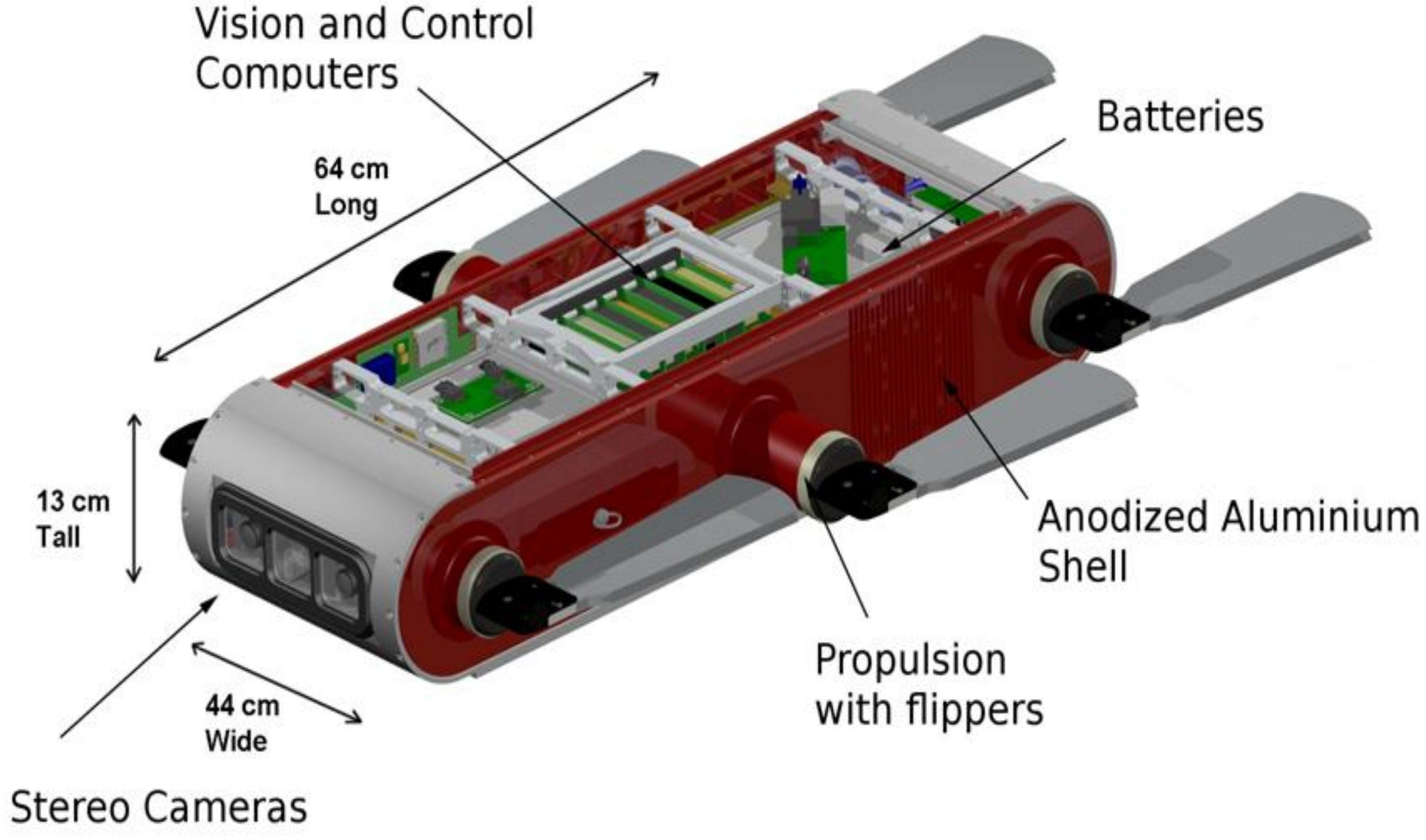
- Our platform, the Aqua family of robots
- Issues with underwater vision and visual servoing
- Our approach
  - Detection of biological motion
  - Fourier tracking
- Results
- Concluding remarks

Aqua robot

- 6DOF flipper motion
- Power-autonomous
- Stereo cameras
- Inertial and depth measurement

Junaed Sattar and Gregory Dudek. A Vision-based Control and Interaction Framework for a Legged Underwater Robot. Sixth Canadian Conference on Computer and Robot Vision, May 2009. Kelowna, BC.

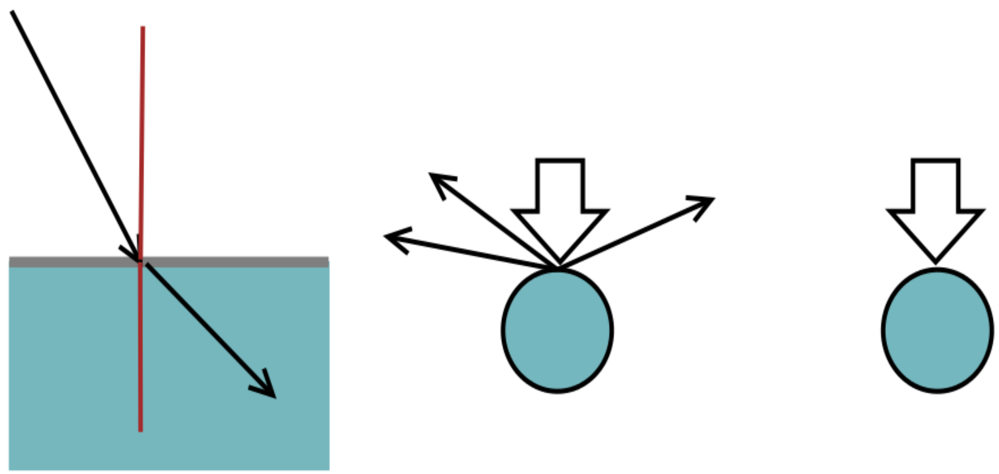
Technical overview

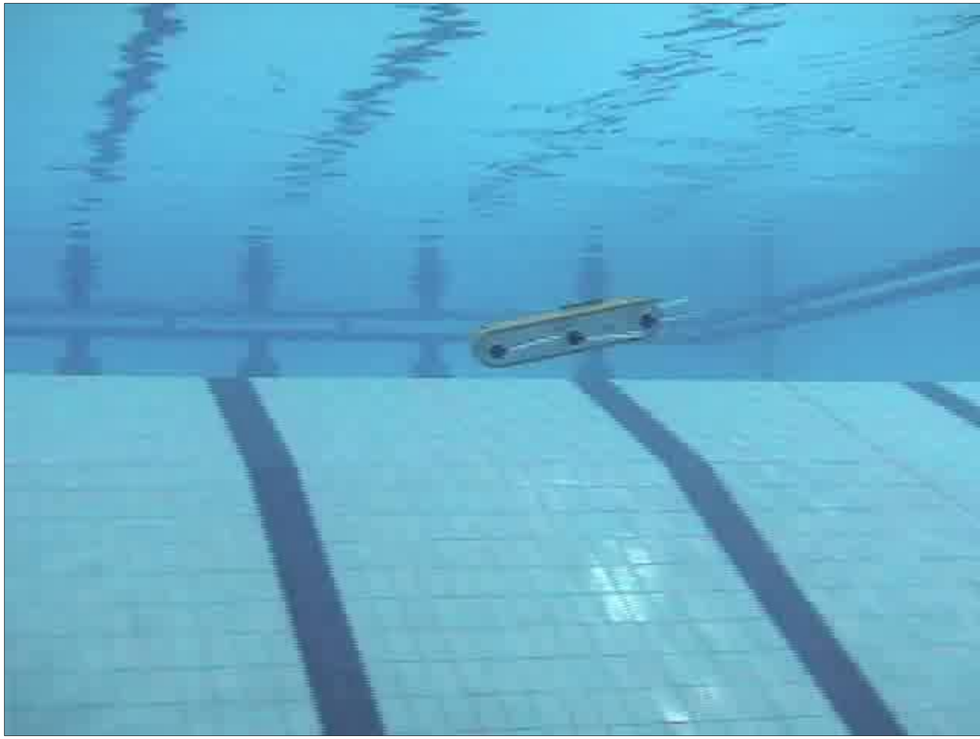


Mass = 16.5kg (ballasted for salt water)

Underwater Vision

- Lighting variations
- Object apperance changes

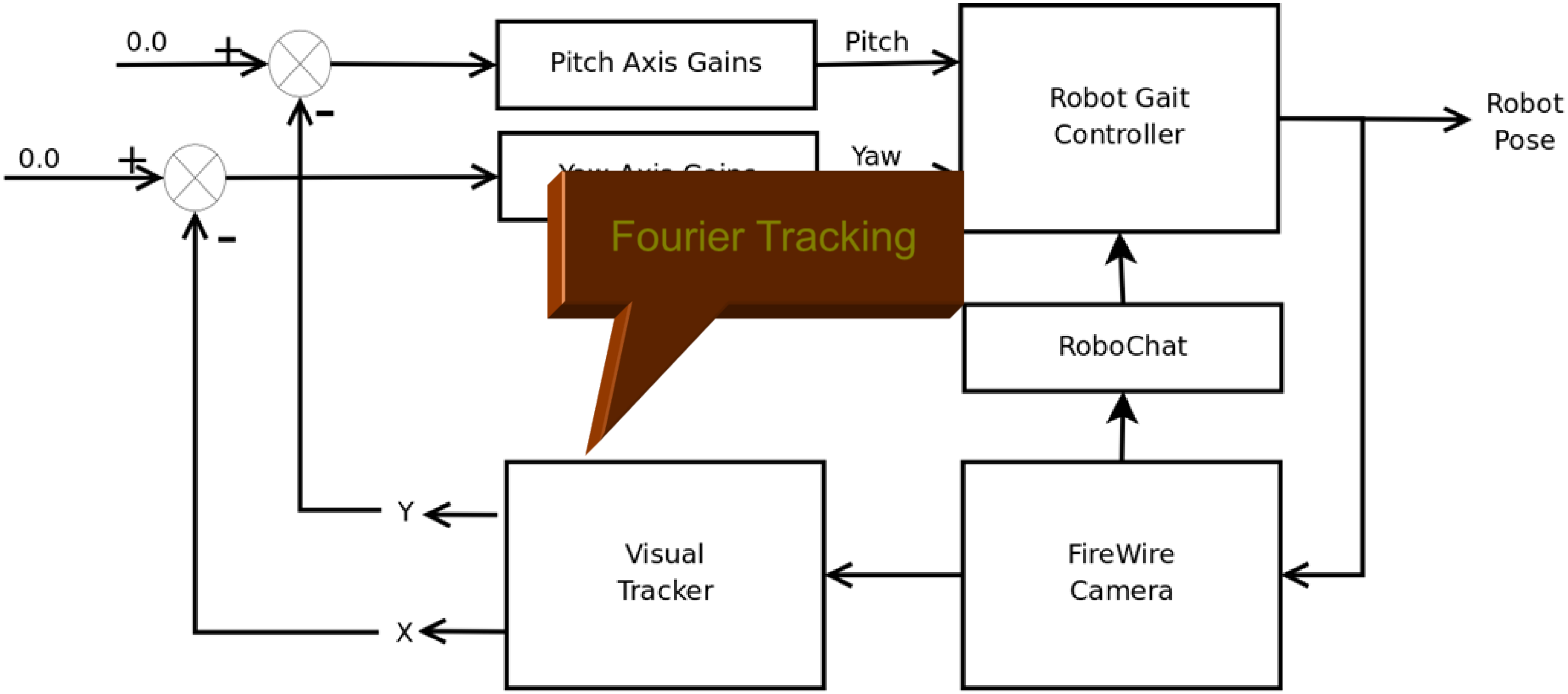




Refraction Scatter Absorption

Visual Servoing

- Vision-guided pose modification
- Target following, assembly, robot surgery



Cues for Tracking

- [Sattar & Dudek, ICRA 2006]
- lighting variations, attenuation, ambiguity
- Shape
- too slow and complicated for real-time deployment
- **Motion**
- Intuitive, but is it easily detectable?

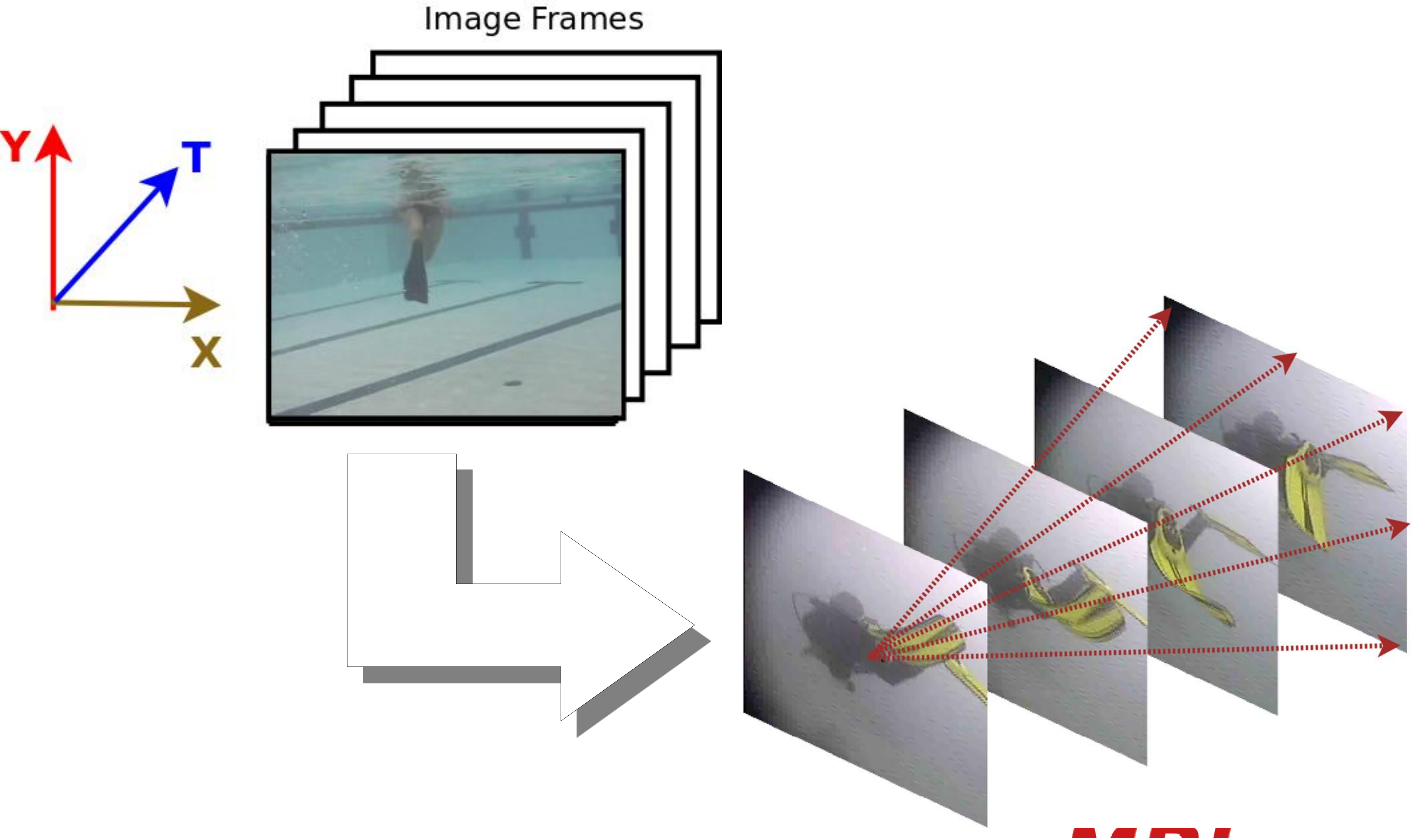
Past work

- Freeman & Adelson, 1991: Steerable filters.
- Niyogi & Adelson, 1994: Walking figures in XYT
- Nixon, Tan & Chelappa, 2005: Person ID from walking gaits
- Zivkovic, Krose; IROS2007. People detection.
- Sattar, Dudek, IROS2007: detect motion of divers directly away or towards the camera

Approach

- Detect periodic motion
- Compute local amplitude spectra
- Find regions with high amplitudes of low-frequency signals
- Track locations using an Unscented Kalman Filter

Step 1



Step 2

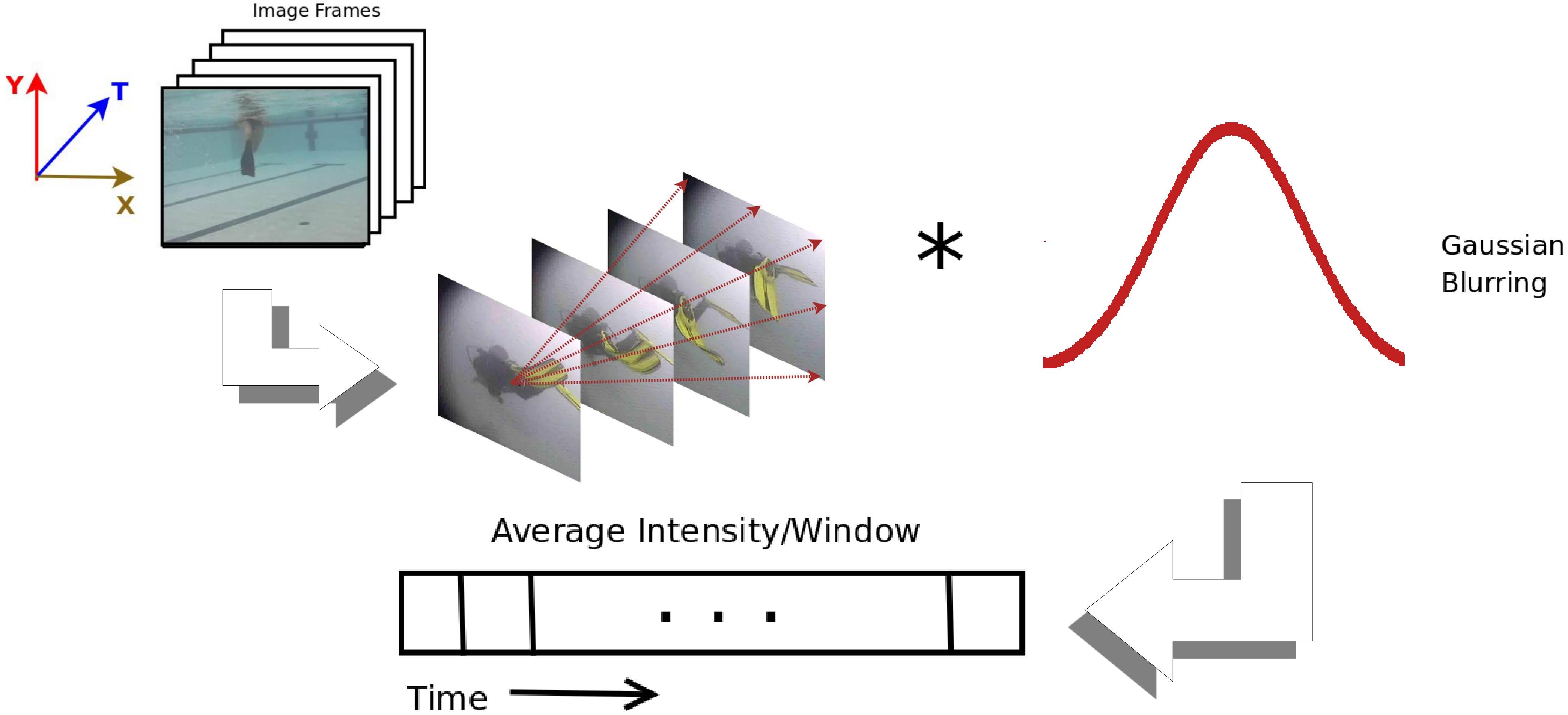


Image Frames
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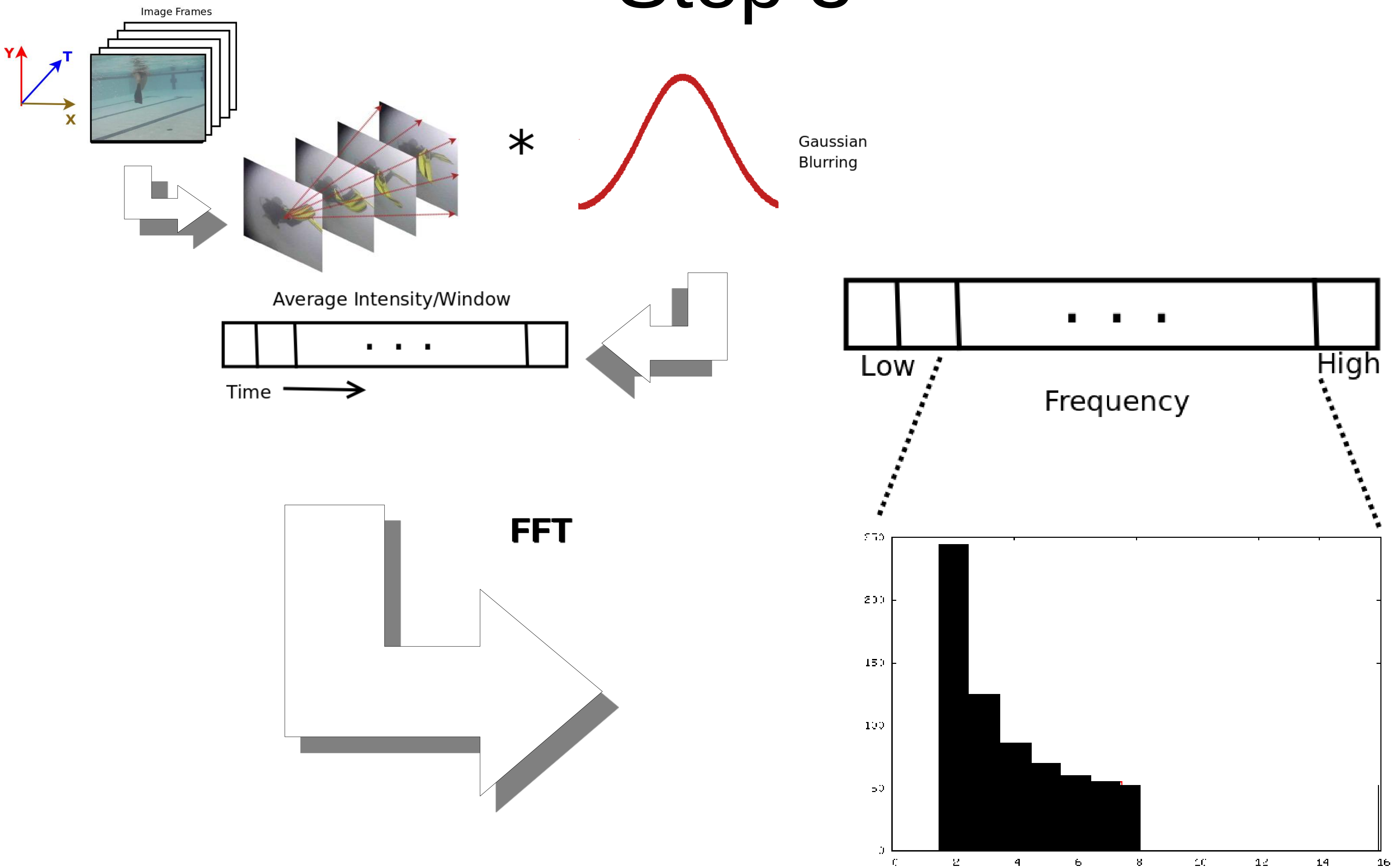
Blurring
Average Intensity/Window
. . .
Time

Step 3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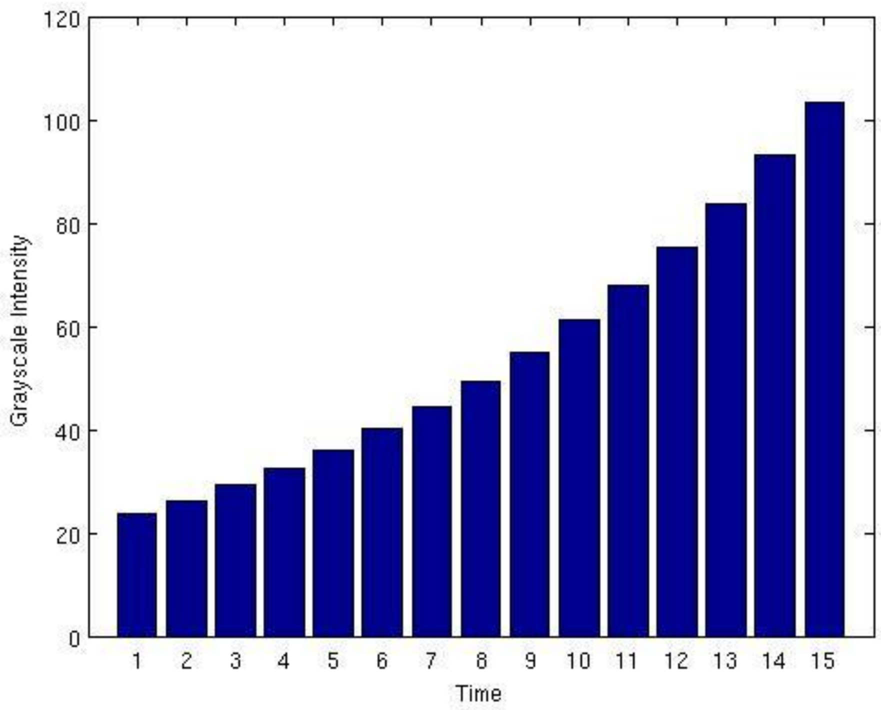
Low
High
Frequency
FFT
200
150
100
2
4
6
8
12
14
16

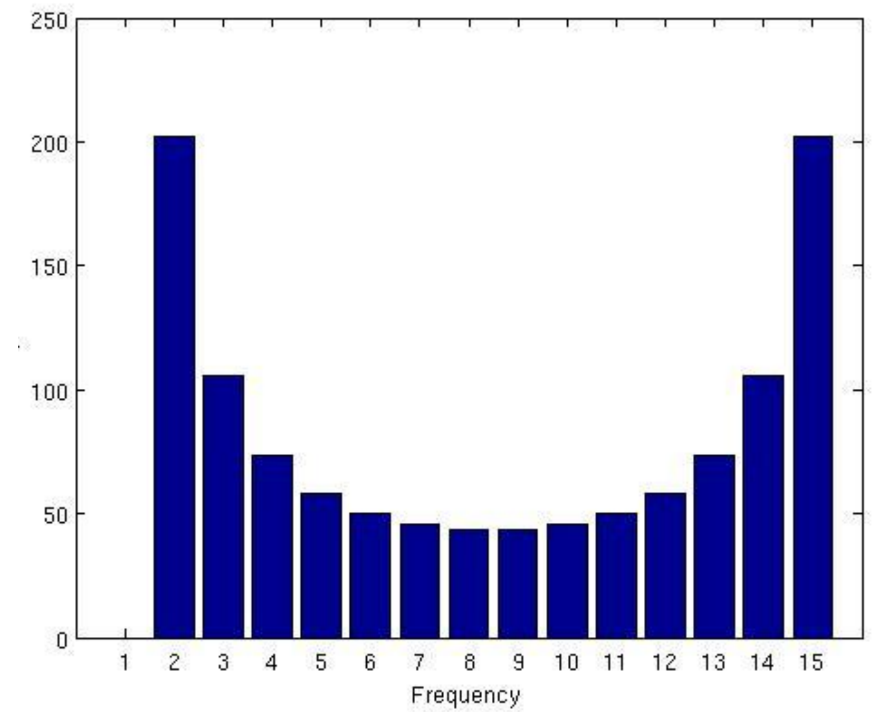
Application of the DTFT

- We use amplitude spectrum
- DTFT applied on temporal and spatial gait signatures
  - diver swimming directly away from or towards the camera
  - diver swimming in different directions in the video sequence

Filtering

- Employ an exponential weighting kernel, in time
- Compute amplitude spectrum for each such signal
- Match with a profile of typical diver's swimming gait



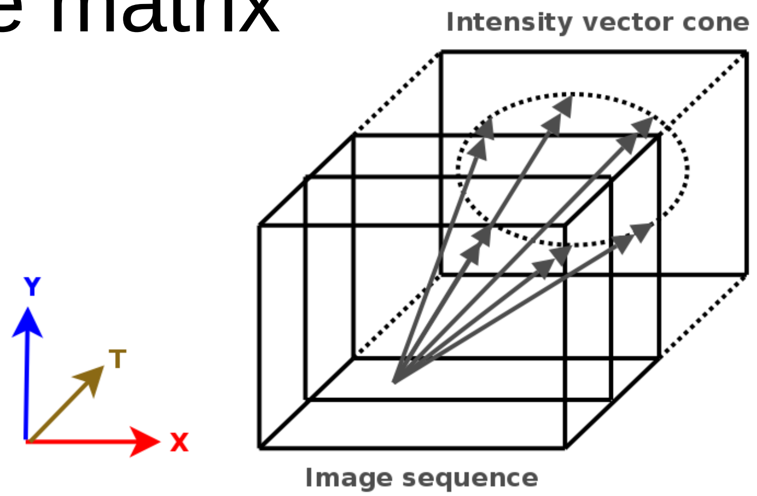


Tracking Enhancements

- Track positions along directions of motion using an Unscented Kalman Filter
- Captures non-linearity more accurately than an EKF
- Computationally less expensive than a particle filter

UKF

- N-dimensional random variable *x* with mean and covariance P_{xx} is approximated by 2N+1 points known as the <u>sigma points</u>
- This is the *“Unscented Transform”*
- Sigma points estimate the propagation of the mean using the state covariance matrix



Sigma points

$$
\begin{aligned}
\chi^0_{k-1|k-1} &= \mathbf{x}^a_{k-1|k-1} \\
\chi^i_{k-1|k-1} &= \mathbf{x}^a_{k-1|k-1} + \left(\sqrt{(N+\lambda)(P)^a_{k-1|k-1}}\right)_i \\
& \quad i = 1 \ldots N \\
\chi^i_{k-1|k-1} &= \mathbf{x}^a_{k-1|k-1} + \left(\sqrt{(N+\lambda)(P)^a_{k-1|k-1}}\right)_{i-N} \\
& \quad i = N+1 \ldots 2N
\end{aligned}
$$

Applying the UKF

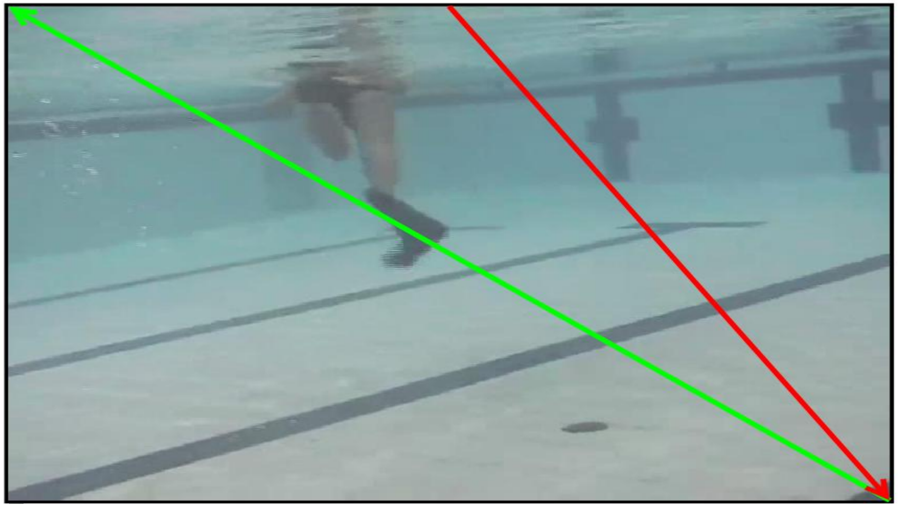
- Initial estimate: center point of the line depicting direction of motion
- Generate sigma points from initial estimate
- Propagate them through non-linear motion model:

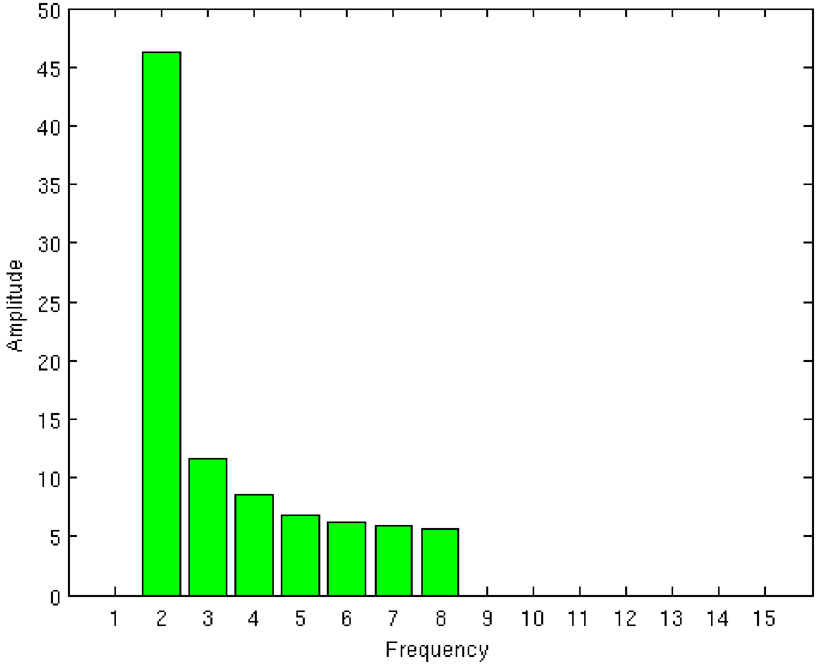
- New estimate as weighted mean:

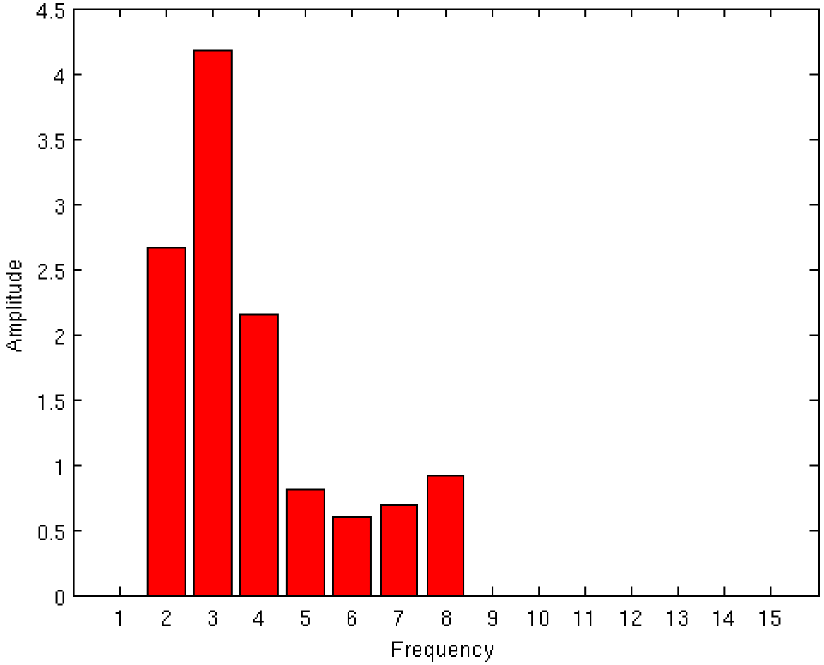
Experimental setup

- Experimentally validated on video footage
- One or multiple divers in the frame
- Over 6000 frames, 10 minutes of data
- 768x576 pixels, approximately 10fps detection rate
- Fourier window of 15 frames

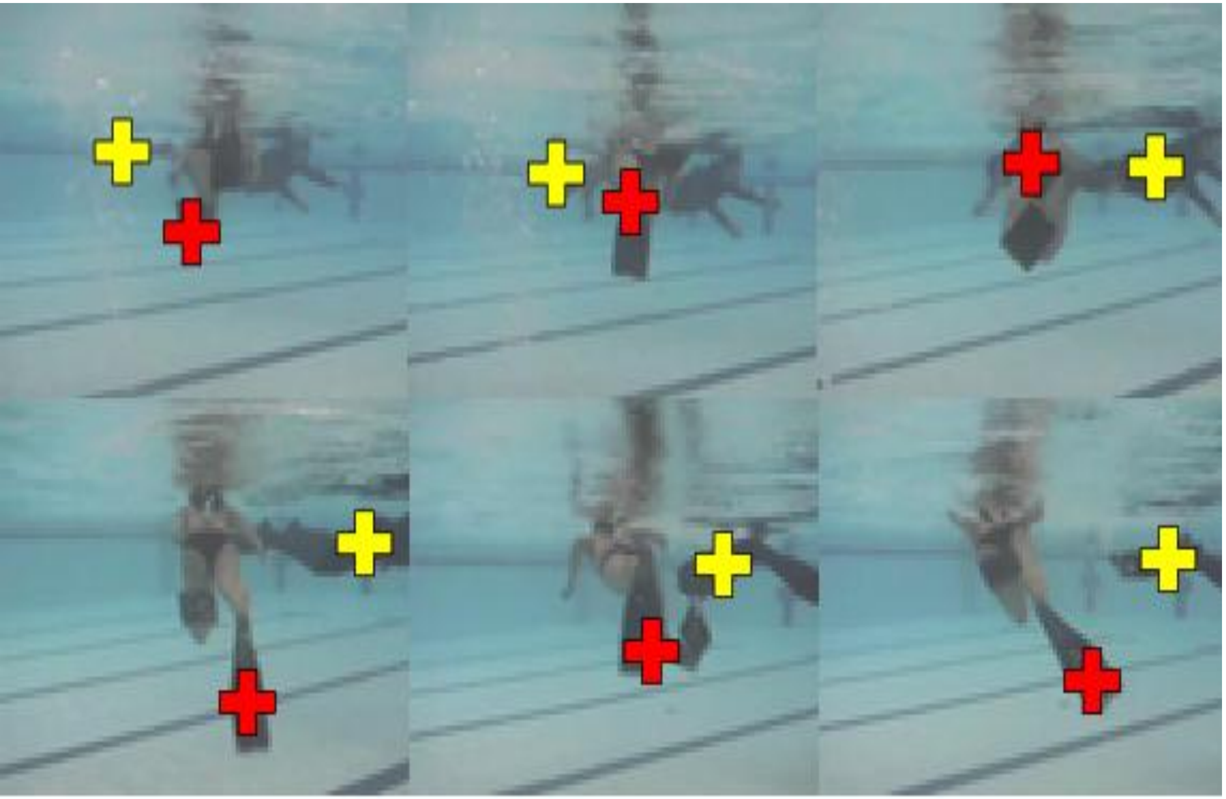
Results

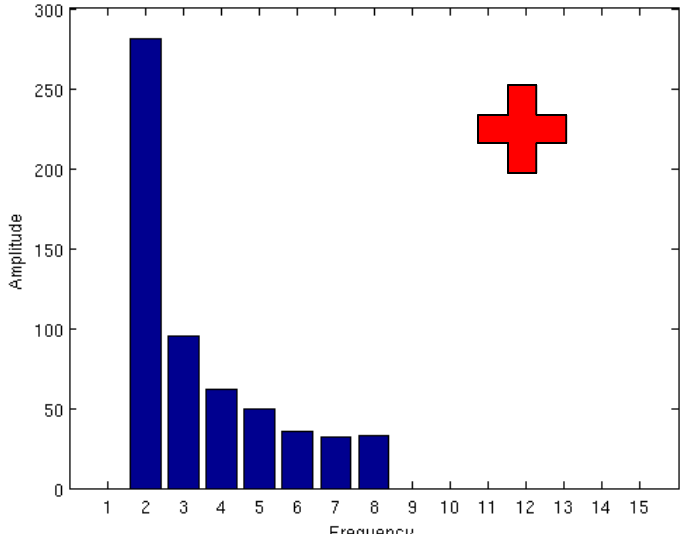


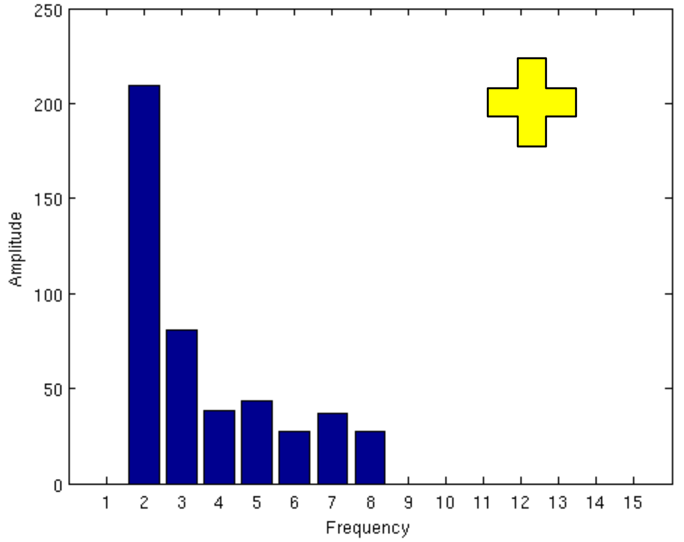




Multiple divers







Sattar, Dudek. RSS 2009.

Open water video

Conclusions

- Detecting and tracking divers in underwater videos for enhanced human-robot interaction
- Future work
- Detection of individual divers
- Learning motion models
- Investigate an equivalent approach for terrestrial environments