The Sound of Intelligence

Synchronized hydrophone recorders to study the communication of Orcas

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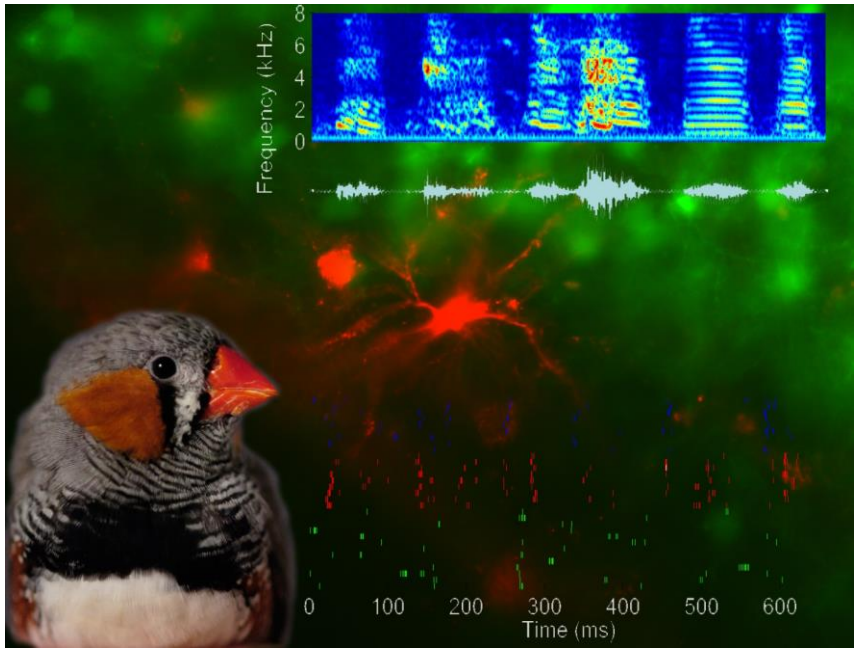
institute of neuroinformatics

Principles of Neural Information Processing

- Joint institute of ETH Zürich and University of Zürich
- Located on the campus Irchel
- In the group of prof. Hahnloser we study the neural circuits of singing in birds.

Model System: Zebra Finch

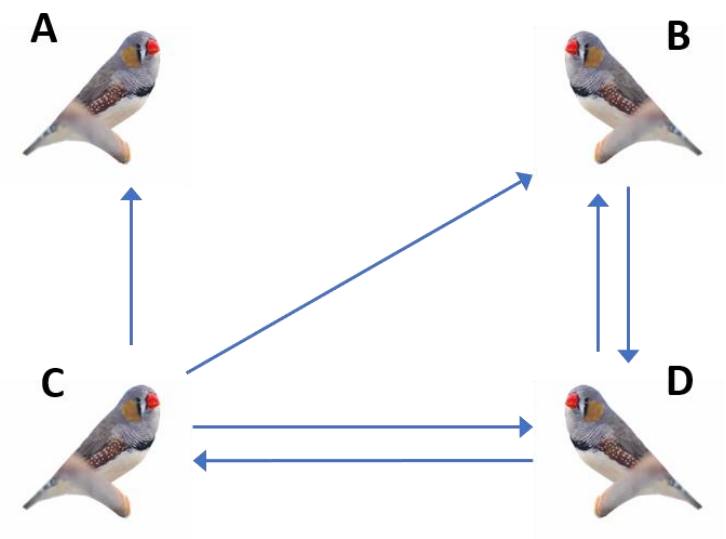


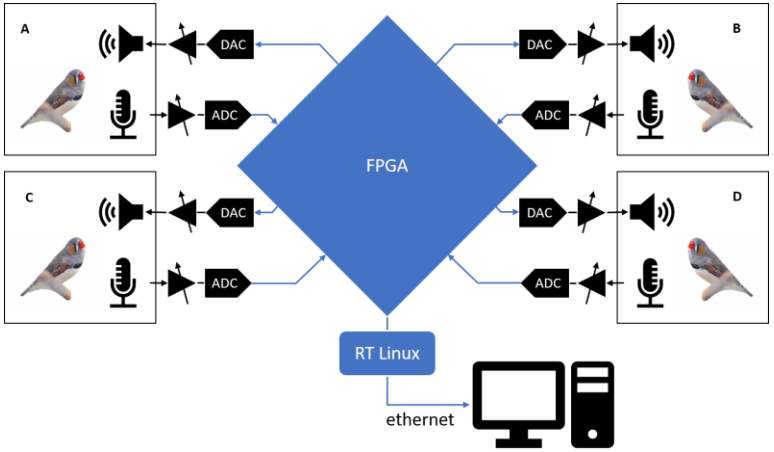
- Only male sing
- Only one stereotyped song
- Song is learned during the first 80 days from the father

Vocal Learning

- Lots of animals vocalize, but not many are capable of what researchers call vocal learning. Vocal learning is the ability to imitate new sounds and use specific ones correctly in different situations. Bats, cetaceans (whales, dolphins and porpoises) and some birds are capable of vocal learning.
- Important for human language development
- Example: You hear a new word and you can say it on the first try. You have a reverse model from sensor data to motor control.

Experiments with a controlled communication network



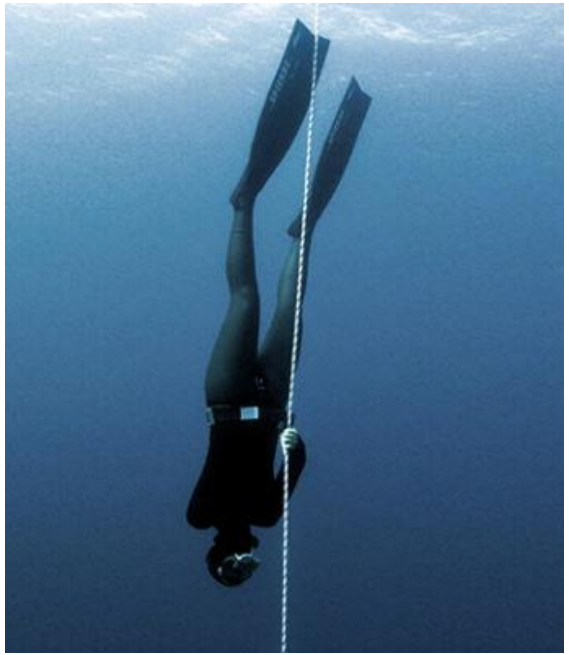


- CompactRIO for arbitrary connections
- Echo cancellation (LMS adaptive filter)
- Online song modifications
  (pitch shift, syllable blanking etc)

Let’s go somewhere else…

Bluehole Dahab

Freedive: no tanks, just one breath



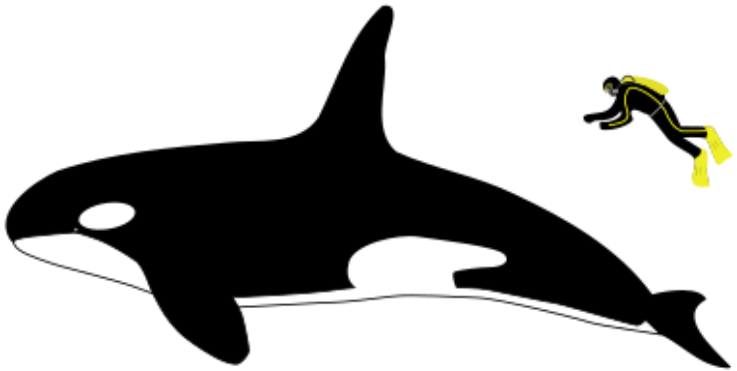
Jacques de Vos
underwater camera
man

Tromso, Norway

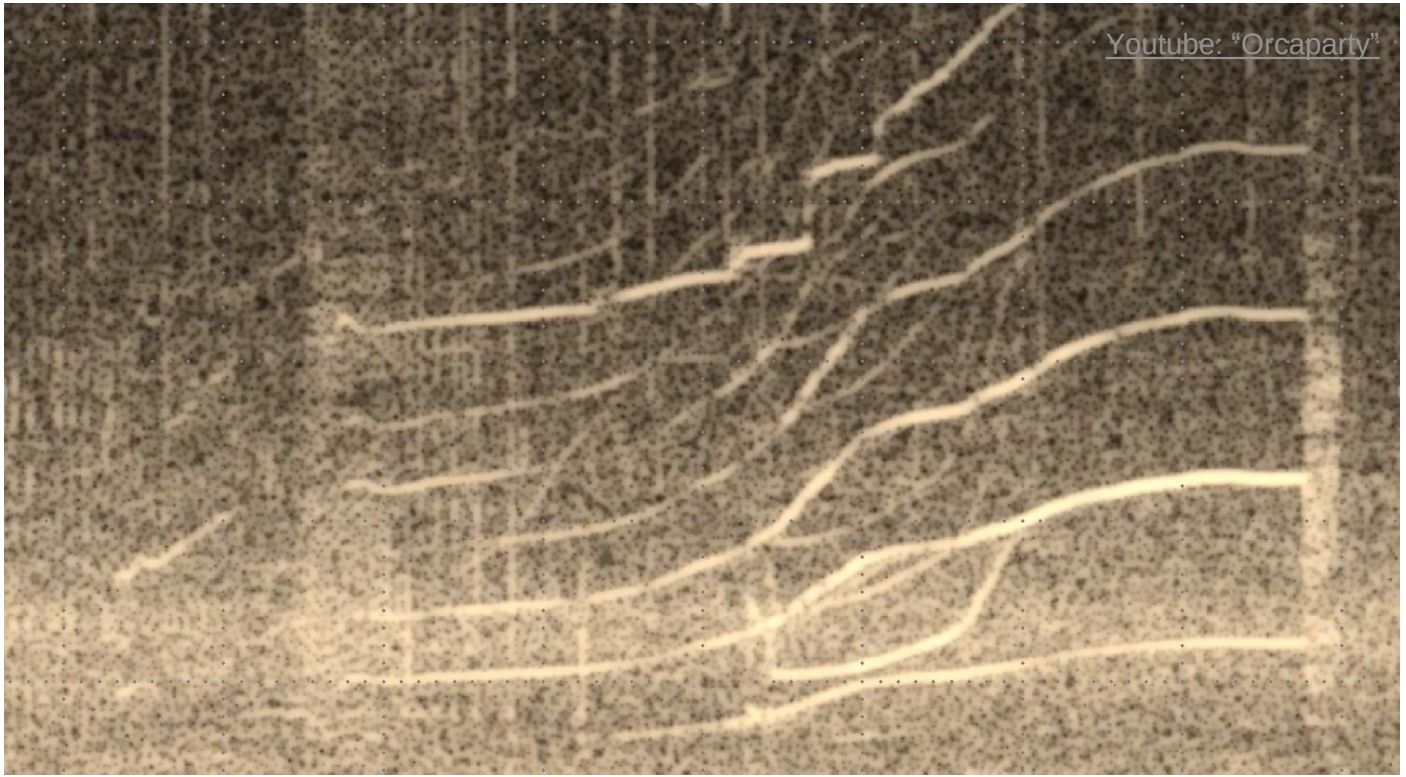
Orcas !

Orcinus Orca

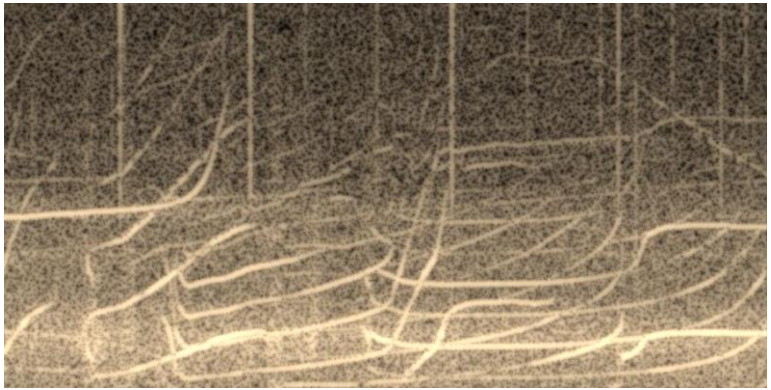
- Also called “Killer Whale”, “Schwertwal”, “Speckhogger”
- Top apex predator
- Very social with matrilineal groups
- Cosmopolitan
- Hilghly organized hunting strategies
- Animal culture
- 6 – 9 m, 5 - 10 t, dorsal fin: 2m
- 55 km/h

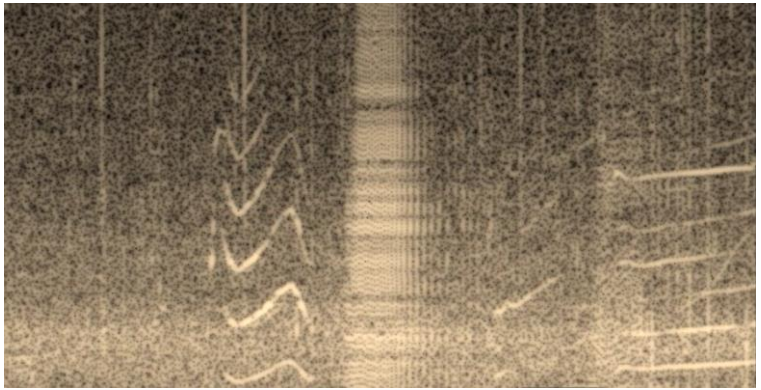


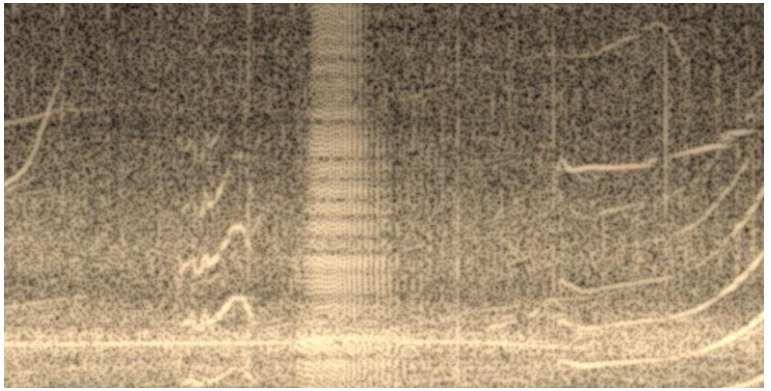
Spectrogram (Gabor transformation)



Recognize patterns?







Whistles, Clicks, Bursts

Let’s decode the communication of the Orcas!

- Signature whistles for calling
- Clicks for echolocation
- Bursts for communication?

Separation of bird's vocalisations

Reconstruction of vocal interactions in a group of small songbirds

Victor N Anisimov[1], Joshua A Herbst[2], Andrei N Abramchuk[3,5], Alexander V Latanov[1], Richard H R Hahnloser[2,4] & Alexei L Vyssotski[2]

The main obstacle for investigating vocal interactions in vertebrates is the difficulty of discriminating individual vocalizations of rapidly moving, sometimes simultaneously vocalizing individuals. We developed a method of recording and analyzing individual vocalizations in free-ranging animals using ultraminiature back-attached sound and acceleration recorders. Our method allows the separation of zebra finch vocalizations irrespective of background noise and the number of vocalizing animals nearby.

Vocal communication is an important aspect of vertebrate social behavior. However, investigations of vocal interactions have been hampered by difficulty in identifying and separating vocalizations of individual animals (**Supplementary Video 1**).

Many technologies for recording vocalizations from animal groups exist, most of which are inconvenient for one or several reasons. Microphone arrays used in studies of echolocating bats[1,2] cannot disentangle avian vocalizations because songbird calls are longer and of lower frequency than bat calls, and these song echoes interfere with the original wave from the source. Head-mounted

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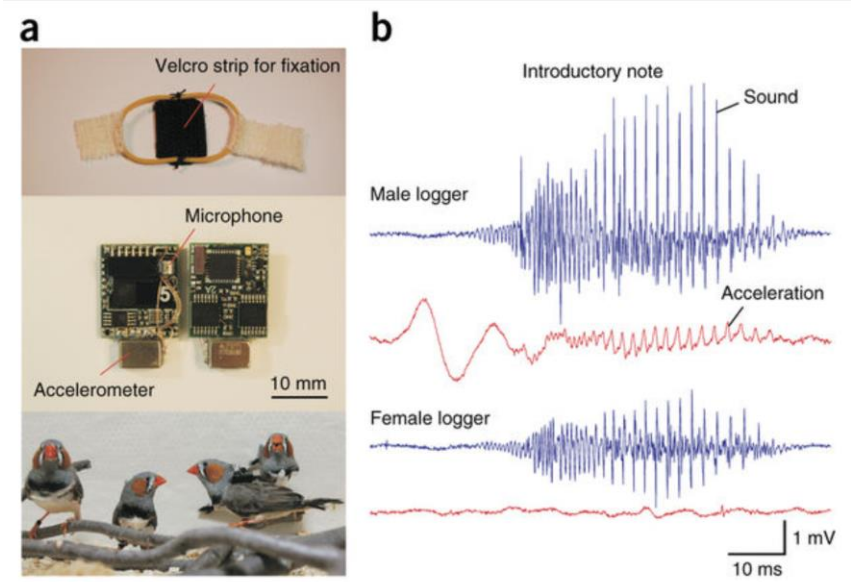
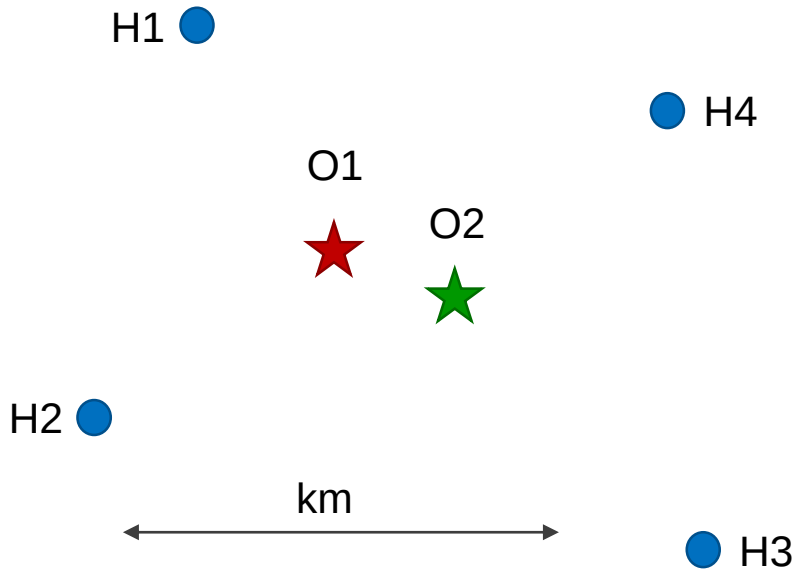


(**a**) Harness with Velcro strip for rapid fixation of the logger to the back of the bird (top), top and bottom views of Neurologger 2A used for sound and acceleration recording (center), and four zebra finches with the backpacks during the experiment (bottom). (**b**) Raw records of an introductory note recorded with backpacks placed on the singing male (top) and a listening female (bottom).

Separate the individual vocalizations

Long Baseline Localisation (LBL)

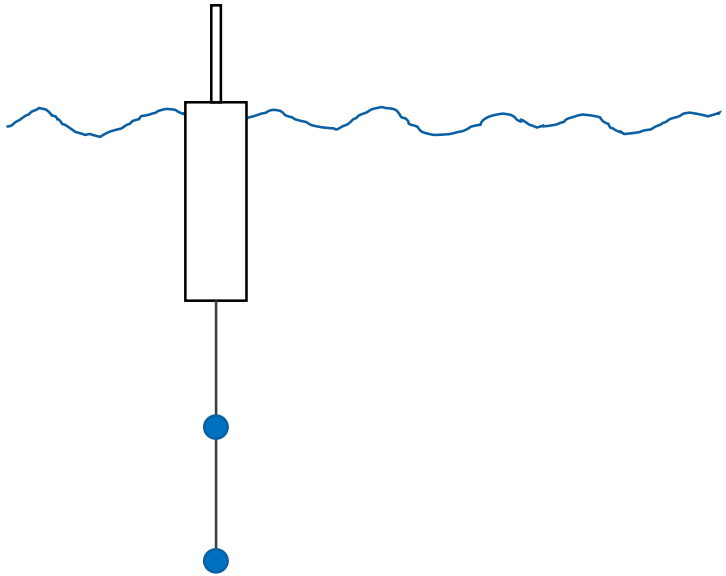


- 10 µs -> sound travels 1.5 cm

Sytem Overview

Free floating buoy with GPS synchronized hydrophone recording

- Two hydrophones hanging at 10 m and 20 m
- GPS receiver for timing and position
- Digitize with 24 bit at least 40kHz BW
- A lead acid battery for at least 6 hours operation 518 kJ (144 Wh)
- Watertight package, PE tube 200mm
- Flash light for retrieval
- Aluminum plate for heat distribution (ca. 10 W)



Compact RIO 9032

- WLAN
- RT Linux
- Good processor and FPGA

Analog Input: NI 9251

- 24 Bit, +- 3V
- 102.4 kS/s
- Analog filters, 40 kHz bandwidth (Orca: up to 120 kHz)
- 2 simultaneous channels
- Internal clock
- Synchronize multiple modules

GPS S.E.A. 9405

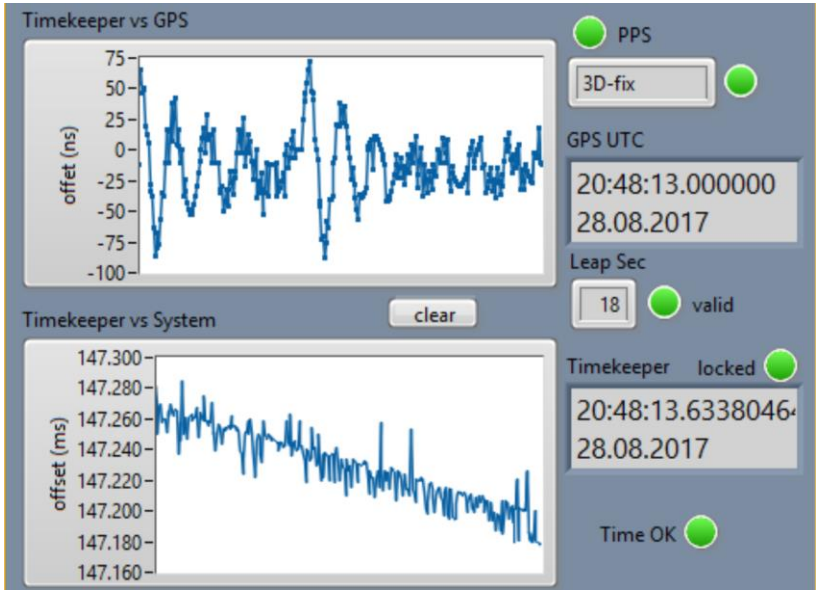
- Timing & Positioning
- PPS (Pulse per Second)
- Nanoseconds since 6.1.1980 (GPS Epoche)
- NI GPS 9467:
  for better precision: timing only
  position only at boot time

FPGA Timekeeper

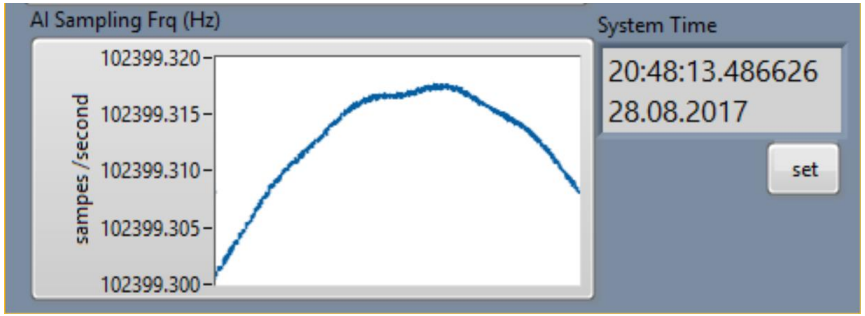
Syncronize the FPGA to the GPS Time

- Implements a digital PLL to synchronize to the GPS time
- Query a time stamp at any time: nanoseconds since 6.1. 1980
- +- 100 ns
- Closed source
- Only one timekeeper per FPGA

Clock comparison



- GPS Time
- Timekeeper Time
- Clock of RT System
- Clock of AI Module

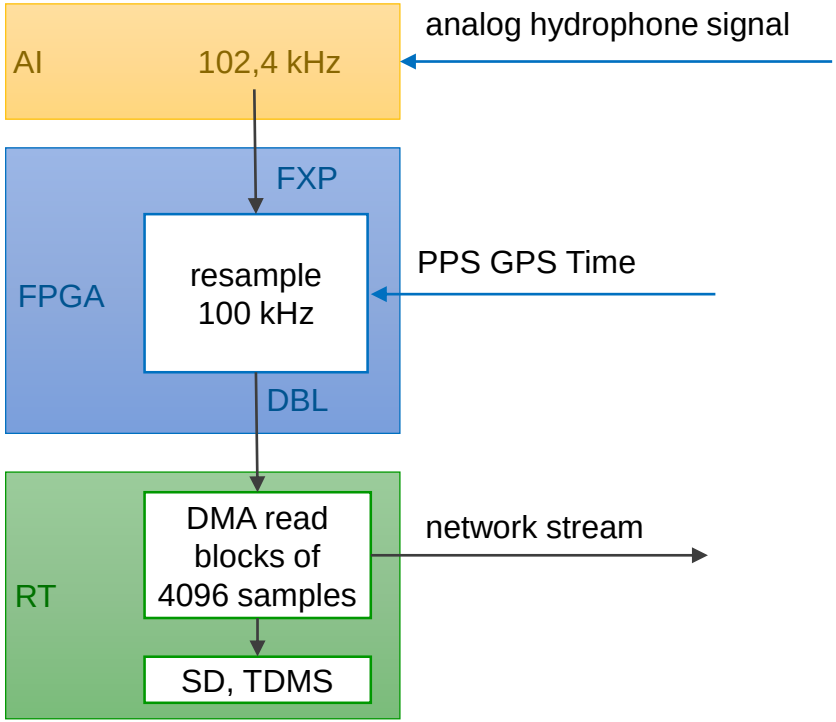


Resampling

Align all samples of all recorders

- Resample and align the samples to global 10 us period (100kS/s)
- Done on the FPGA on live data stream
- Linear interpolation (future: cubic interpolation)

Datastream


AI
102,4 kHz
analog hydrophone signal
FXP
FPGA
resample
100 kHz
PPS GPS Time
DBL
RT
DMA read
blocks of
4096 samples
network stream
SD, TDMS

Stream to Disk

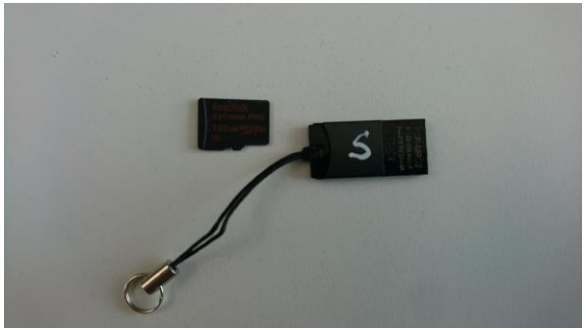
Fileformat

- TDMS
  - direct stream to disc
  - supports waveform data (timestamp only for first sample)
  - Hydrophone signals 100 kS/s, GPS & system monitoring 1 S/s
  - Metadata like serial numbers, calibration, operator, preamp gain etc.
- HDF5
  - would be preferred to conform with institute's guide lines for data storage
  - is not supported by LV RT

Stream to Disk

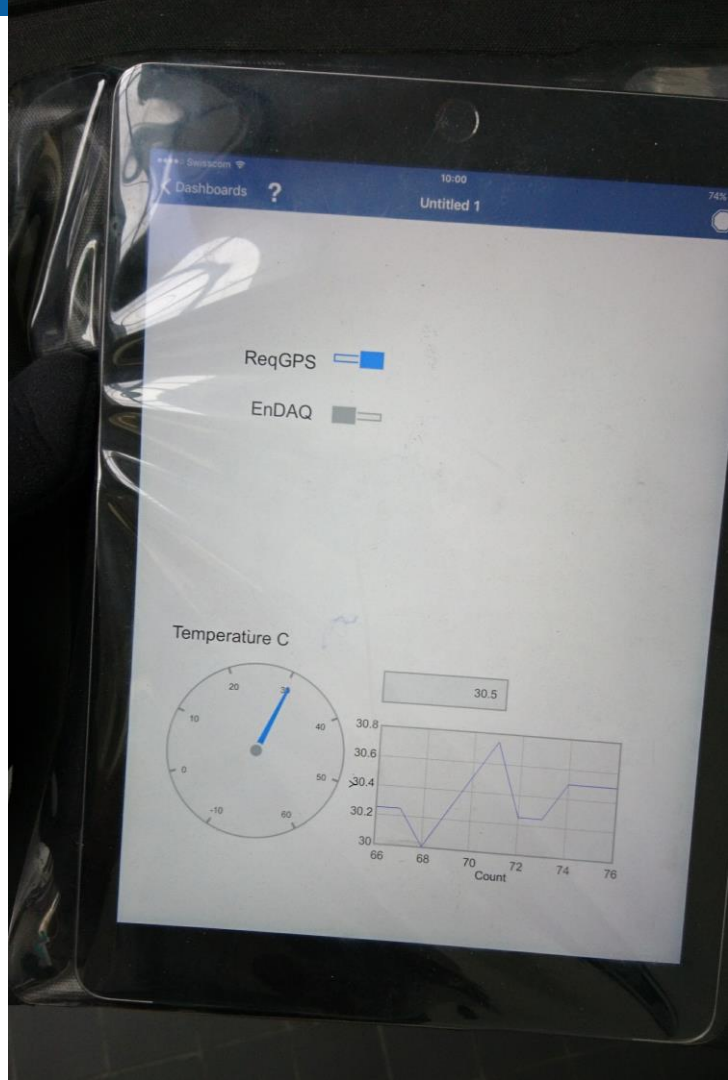
Physical storage

- SD Card
  - USB SD Card adapter
  - 128 GB
  - min 6 hours of recording
- Filesystem
  - format in EXT3 on RT Linux
  - Filesystem accepts sudden power down
  - Not readable on windows
  - Read via FTP



Data Dashboard

- iPad in watertight envelope
- Operate the buoy when close to it
- WiFi range 20-50 m
- Monitor temperature, GPS status and memory
- Control data acquisition (on/off)



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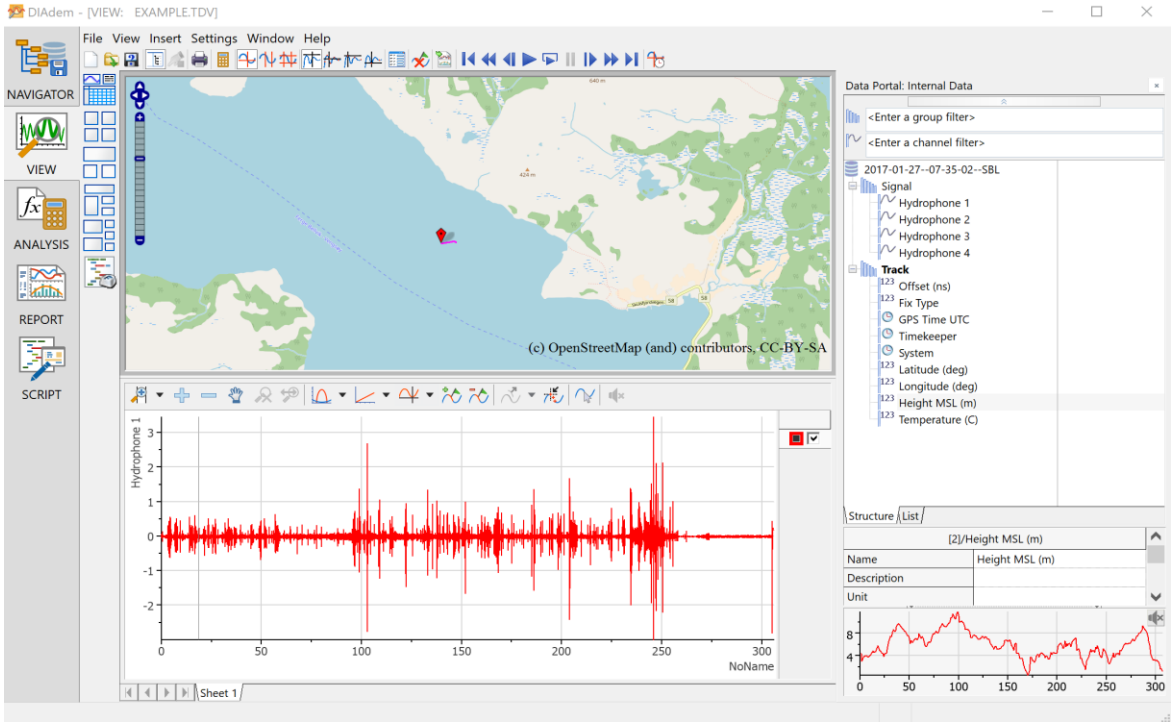
Diadem

Manage the file repository



Algorithms

A difficult problem!

- Known as “Cocktail Party Problem”
- Or “Blind Sound Source Separation”
- E.g. MUSIC “multiple signal classification”
- We will try “particle filters”

Towards Deciphering the Communication of Orcas

- Synchronization of independent recorders down to the sample rate
- Four free floating buoys
- Stream all data to disc for offline processing
- Next Mission: Dez. 2017 in Norway

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