Biomass estimation in the cages

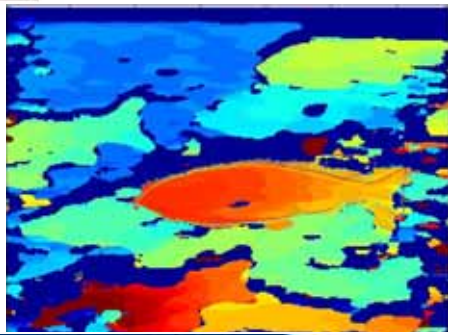
Some technologies and ideas based on optics

Some postulates

- To obtain estimates for the total biomass and the fish weight distribution with a desired accuracy we need:
  - A combination of local and global measurements
  - The local measurements need to sample many places
  - The local measurements need high resolution to obtain fish density and size
    - High frequency acoustic
    - Optical methods
  - The global measurement produces a coarse relative density map for the cage volume that, when calibrated with simultaneous local measurements, gives a good estimate for the total biomass

Stereo camera (VICASS)

- Measures the weight distribution
- Can potentially say something about the local fish density
- Is today semi-manual and offline, but can potentially be made automatic and real time online
- Advantages
  - Principle is proven (manual)
- Challenges
  - Fully automatic analysis is difficult



Distance map generated from stereo image

Laser plane / camera triangulation

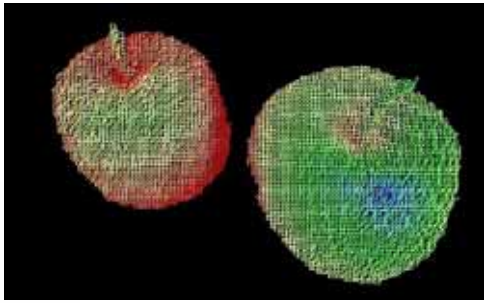
- Principle
  - Vertical laser stripes (IR) are projected onto the fish with a horizontal angle relative to the camera
  - The stripes on the fish are seen with the camera and the distance is computed with triangulation
  - The 3D geometry of the fish is built as the fish passes the instrument
- Advantages
  - Accurate distance and 3D geometry
  - Can be combined with stereo camera
- Challenges
  - High contrast in the laser stripe due to specular reflection into or away from camera
  - Damping of IR in water

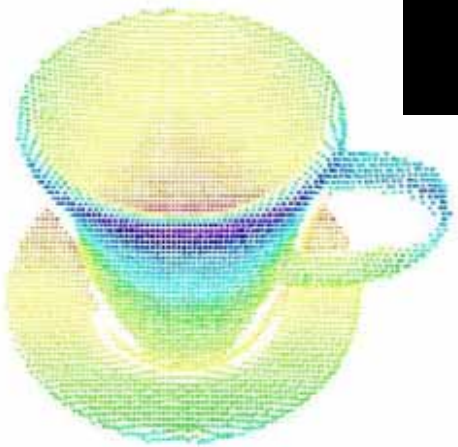
3D time of flight camera

- Measures in real time (50 fps) distance to objects in all pixels in the image
- Uses IR modulated light and phase measurement to estimate distance
- 0.3 – 5 meter (in air)
- Accuracy ~1 cm

- Advantages
  - Segmentation of individual fish is potentially trivial

- Challenges
  - IR in water (absorbance)
  - Visible light may disturb fish
  - High contrast (direct reflections) degrades accuracy severely

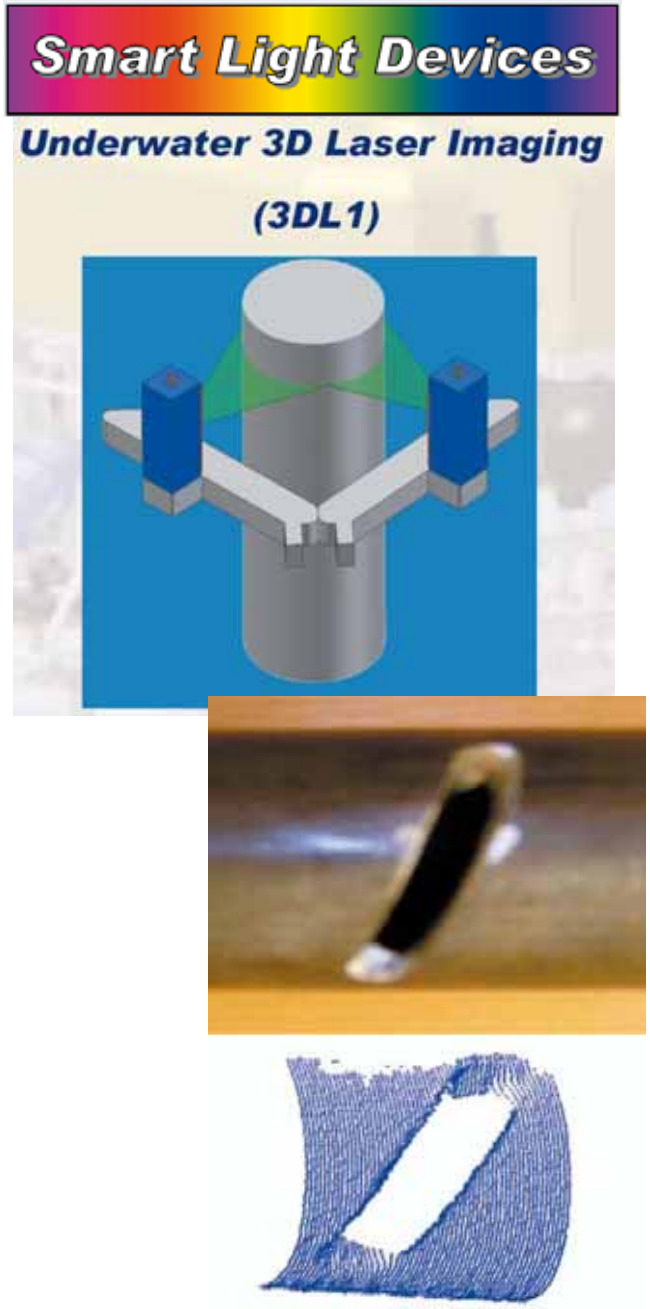




MESA IMAGING

3D laser scanner for small volume

- Specifications
  - Measuring volume: 60 x 60 x 60 cm (optional 1 x 1 x 1 m)
  - Resolution; 1 mm
  - 30 images per second
  - Green light
- Advantages
  - Very simple data analysis
  - High accuracy
- Challenges
  - Green light unwanted
  - High contrast
  - No experience with technology under water on fish



LIDAR - 3D laser scanners for large volumes

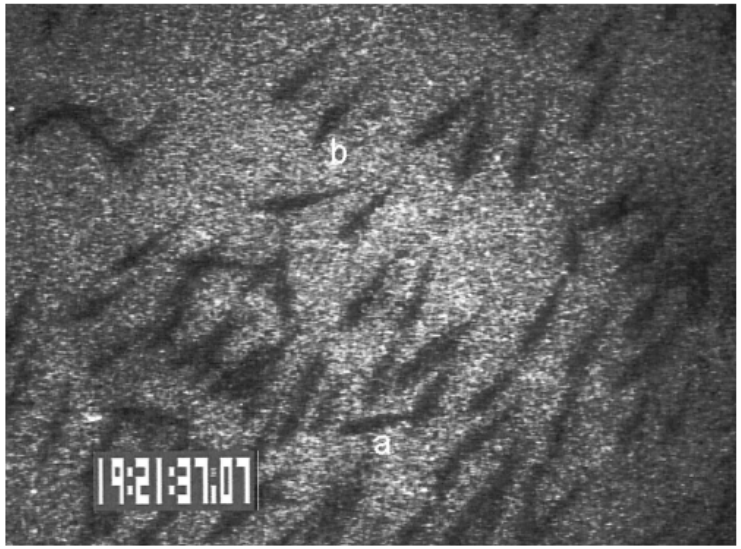
- Technology
  - Uses pulsed light in a similar way as radars use radio frequency
- Advantages
  - May have long range
  - Works better that other optical systems in turbid water
- Challenges
  - Green light unwanted
  - Cost
  - Dense schools of fish

Airborne lidar imaging of salmon

James H. Churnside and James J. Wilson

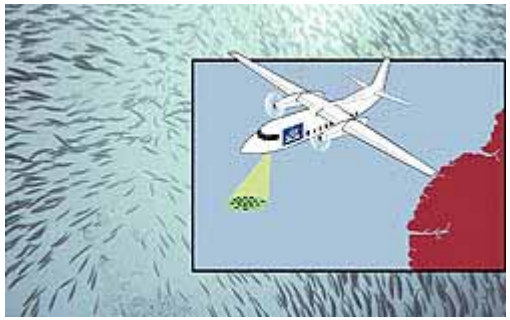
Lidar images of adult salmon are presented. The lidar system is built around a pulsed green laser and a gated intensified CCD camera. The camera gating is timed to collect light scattered from the turbid water below the fish to produce shadows in the images. Image processing increases the estimated contrast-to-noise ratio from 3.4 in the original image to 16.4 by means of a matched filter.

OCIS codes: 010.3640, 010.4450, 100.2980, 110.7050, 280.3640.



Salmon a few meters depth as seen with LIDAR from plane

Counting fish with a LIDAR from a plane



COUNTING FISH: The new laser is mounted in the belly of a plane that flies just 300 metres over the surface of the sea. Laser counting technology isn't yet fully developed for commercial use, but the prototype is already cheaper and quicker than current tallying techniques

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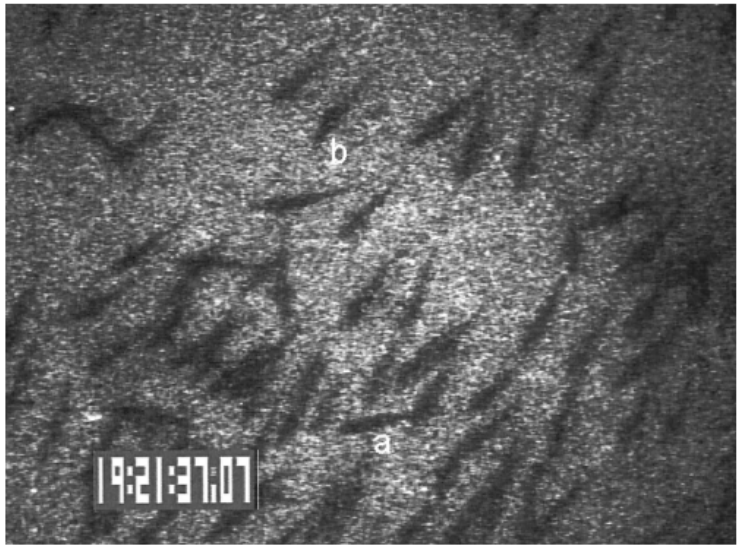

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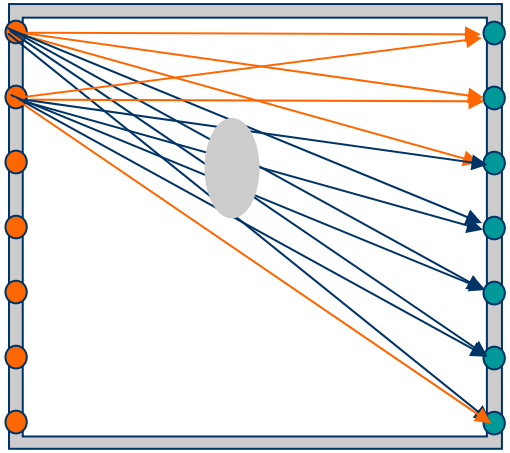
The detected salmon are at only a few meters depth

Light curtains and Computer Tomography (CT)

- Fish are detected by blocking of line of sight
- By combining information from a (possibly two-directional) grid of light sources and sensors, a CT approach can be used to image the cross section area.
- A for instance radial cross section of the cage could be covered with a net of sensors
- NIR light is used to reduce disturbance of fish
- Different modulation frequencies or pulse coding could be used to distinguish the different sources.
- High frequency ultrasound might be used instead of light



Sides: 1 – 5 meters