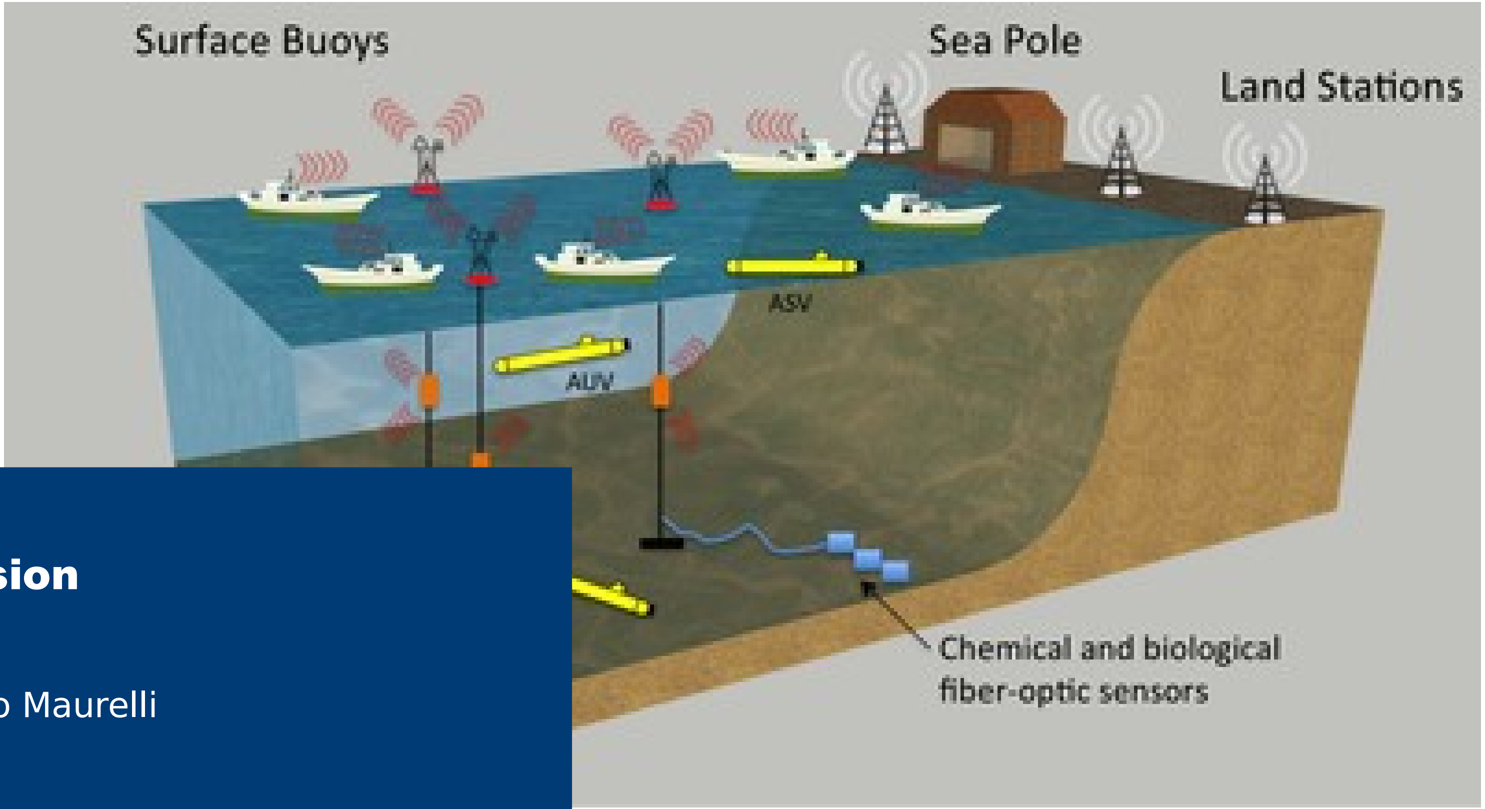

Computer Vision
Lecture 24

Prof. Dr. Francesco Maurelli
2019-11-20

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Underwater Vision

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    - Green/blue: the light problem
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2. Practical use
    - Underwater inspection (+control)
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    - Positioning and navigation
3. Specialised applications
    - CV in sonar images processing
    - Laserline sensor

Why underwater vision?

- We already have THE Underwater Sensor – sonar!
- There is plenty of problems with (computer) vision underwater
  - Visibility, light
  - Marine fouling
  - Distortion
  - Turbidity, turbulence, marine snow
  - Glare
  - …
- The answer? Yes, all this is true, but you can still do a lot of useful things with underwater vision!

Let’s talk about the problems first

- Visibility

Sometimes, one is lucky to see more than a meter!

- Glare

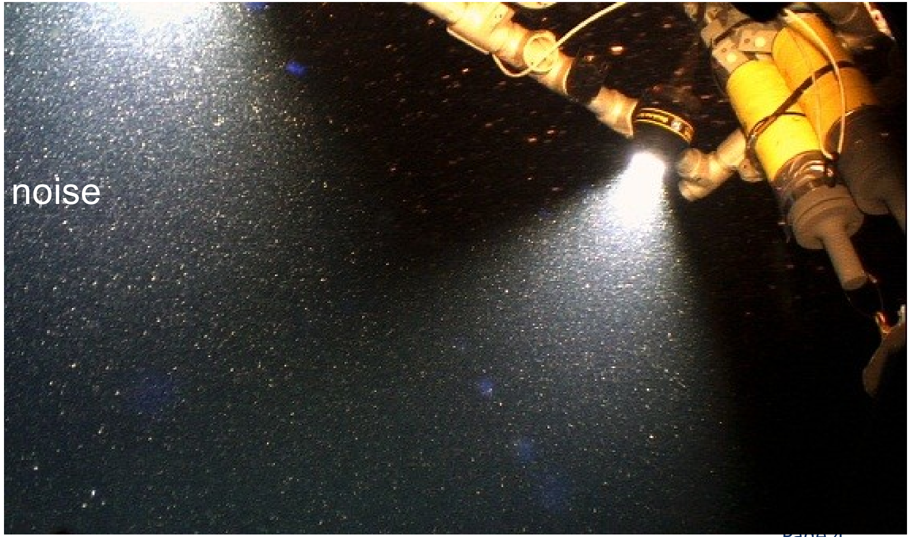
Strong light sources create secondary sources

- Turbidity, marine snow

Particles/organisms suspended in water create image noise

- Kicked up silt particles

Even in clear water, it’s easy to create a cloud of silt



Let’s talk about the problems first

- Light spectrum attenuation
- Distortion (= result of refraction)

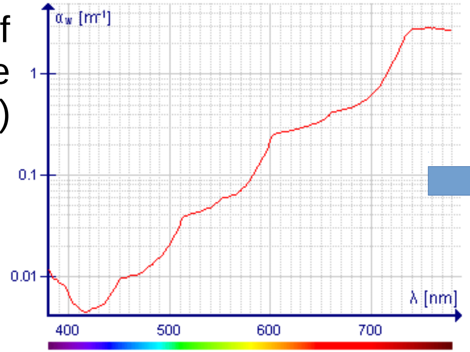
(further slides will cover this)

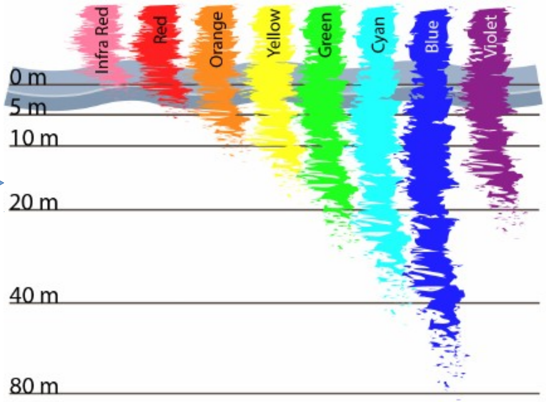
- Marine fouling

Seas are full of animals and plants looking for a place to attach themselves to

Green/blue: the light problem

Attenuation as a function of frequency of electromagnetic wave (= colour of light)





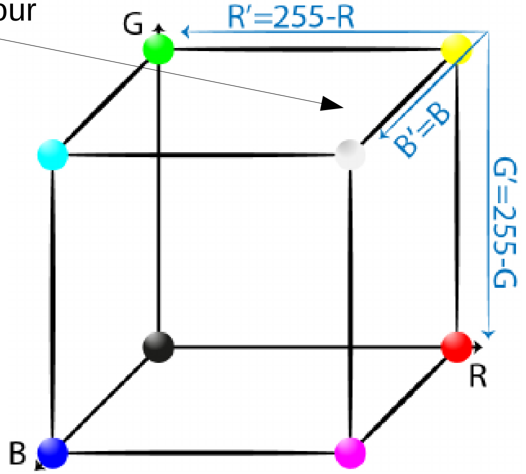
- Different light frequencies are attenuated differently
- With increasing depth, ambient light turns green/blue
- The same problem exists in the air but at a much smaller scale
- In the air, cameras correct it using white balance
  - It is more difficult in the water (missing wavelengths, high overall attenuation = less information in the image)

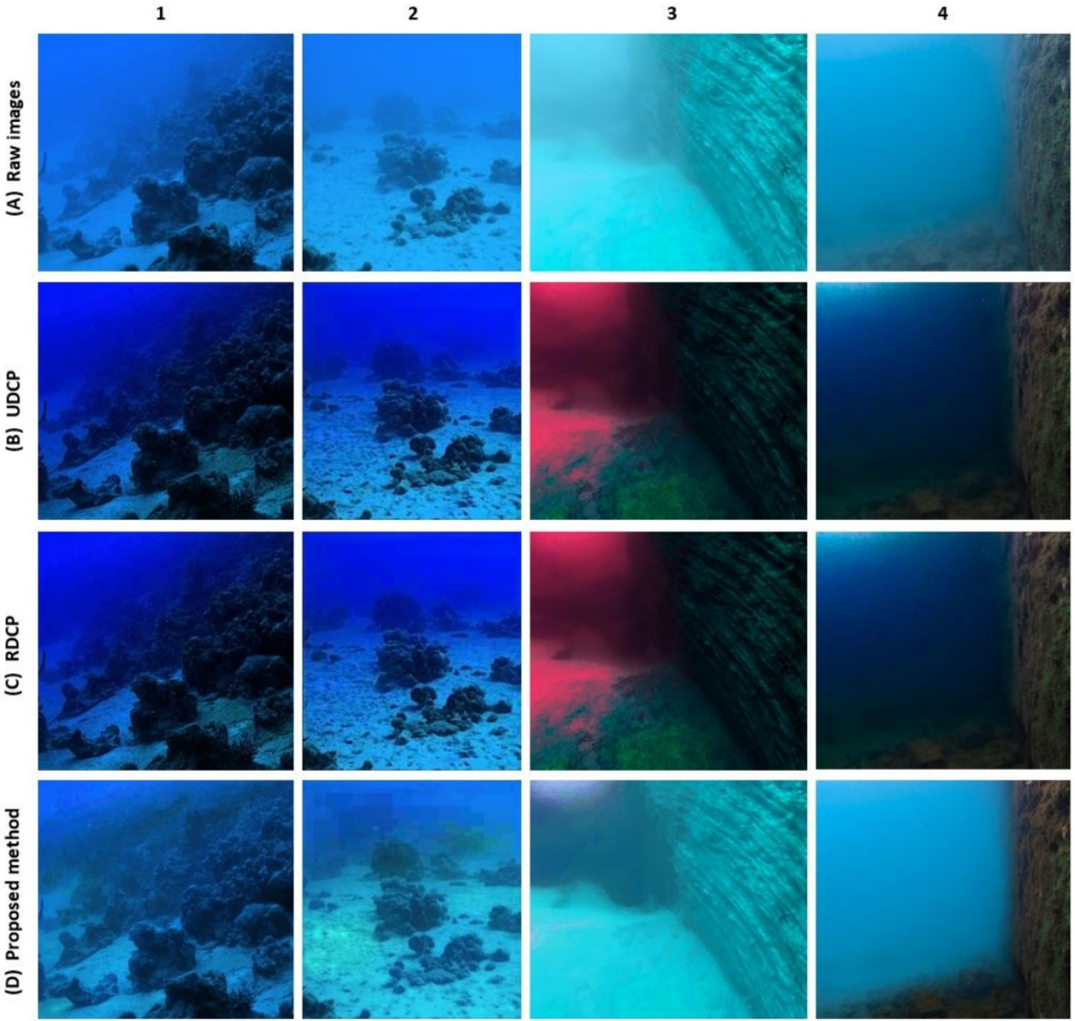
Solving the light problem

- Estimate the spectrum of the ambient light
  - We can easily guess it will usually blue-green!
- Correct for transmission losses
  - Colour modification
  - Intensity modification
- Physics-based solutions using polarising filters
- Algorithms like Dark Channel Prior have been adapted to work underwater
  - Look at the “non-sky” (not direct ambient light) patches
  - Search the separate colour channels for the lowest values
  - Assume that they come from back-scattering and correct the channel values

$$R' = 255 - R$$
$$G' = 255 - G$$
$$B' = B$$

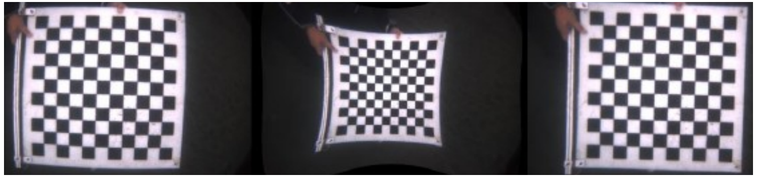
Blue does not need to be corrected since it’s the least attenuated colour




1
2
3
4
(A) Raw images
(B) UDCP
(C) RDCP
(D) Proposed method

Distortion

- No camera is ideal – that's why we must calibrate them to rectify images

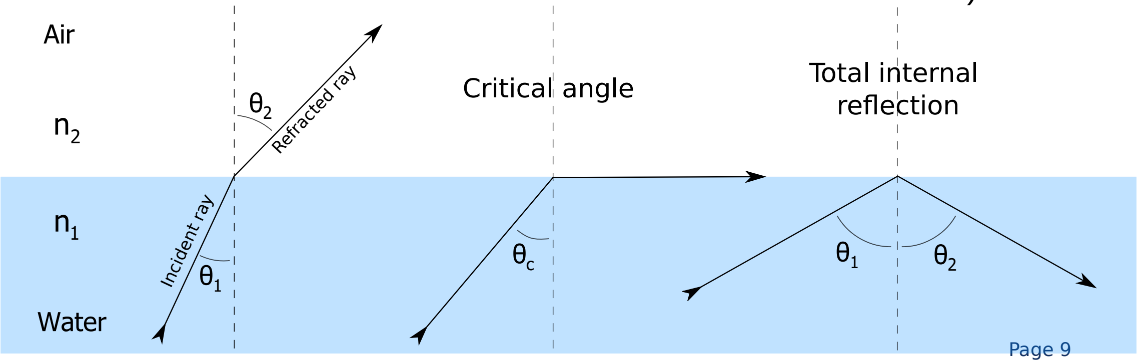


- A camera made for air will work differently underwater
  - Air refractive index: n_{air} = 1.00029
  - Water: n_{H2O}=1.33
    (salinity and temperature can modify it)
  - Glass: $1.5 < n_{glass} < 1.7$
  - Can be partially compensated by adjusting the focal length of the objective
  - Also: the housing...

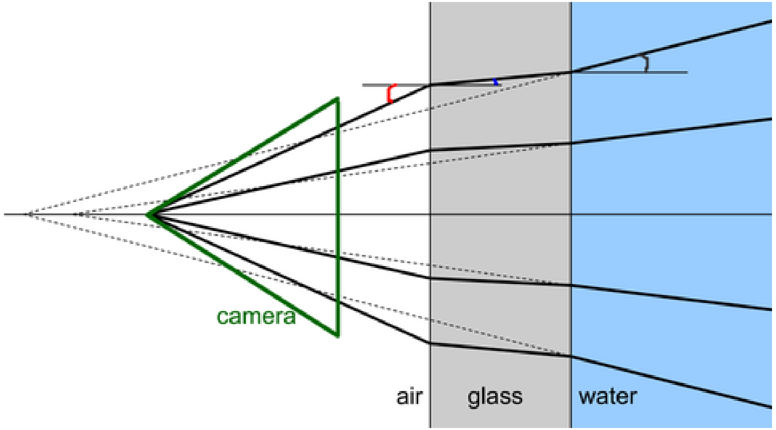
Snell's Law:

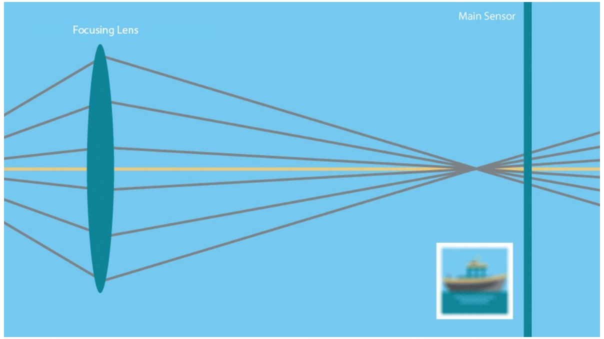
$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

(It describes how the angle of a beam of light changes due to refraction when it crosses boundaries between different refractive index media)



Distortion: influence of the pressure housing

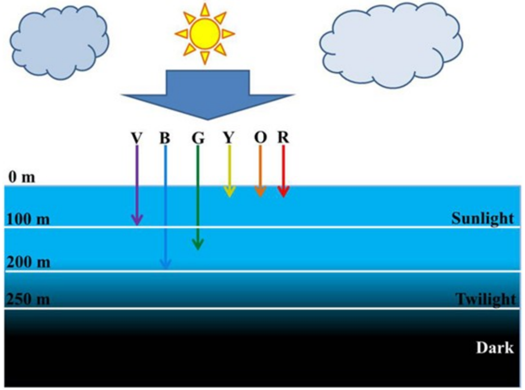




- Solution: special calibration with a displacement map
  - "Pinax" calibration developed at Jacobs is an example
- ...or just buy a dome-shaped camera housing!

Distortion

- Another consequence: caustics
- It means: randomly focused, chaotically changing beams from the sunlight above
- How many computer vision techniques can you imagine that would work well in a discotheque..?



- Not a problem…
  - where the sunlight does not reach
  - where there is another source of light
- Turbulence also creates a similar effect
  - no easy solution so far

All these problems… Why bother?

Because many useful results can and have been obtained!

Underwater inspection

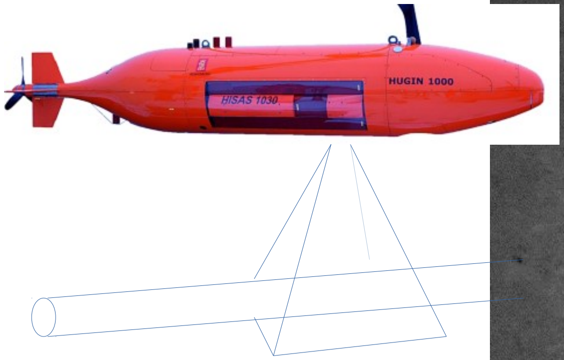
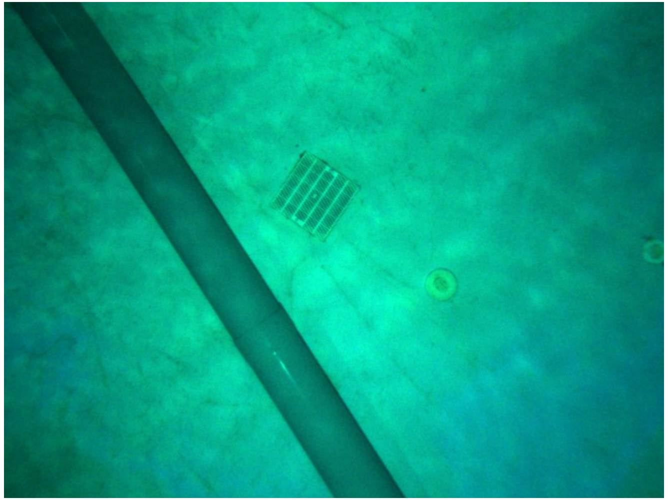


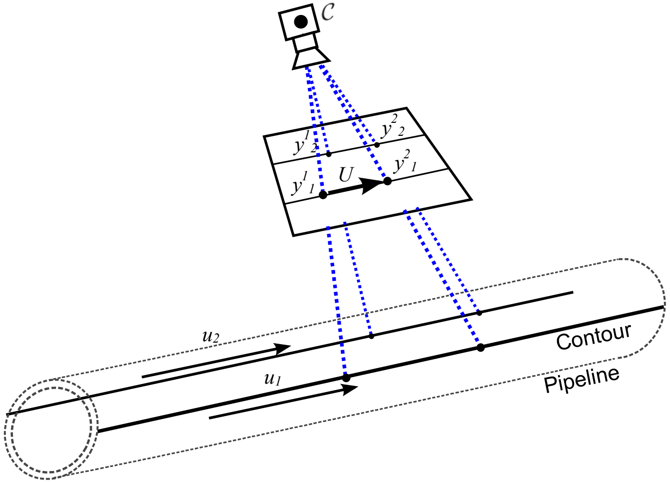
Image taken by an autonomous vehicle moving above the pipeline (in the centre of the image) with a down-looking still image camera

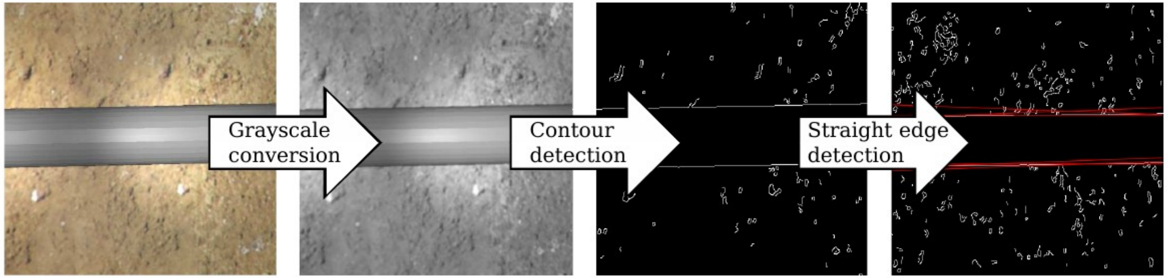
(You would probably never guess what the object next to the pipeline is using sonar...)

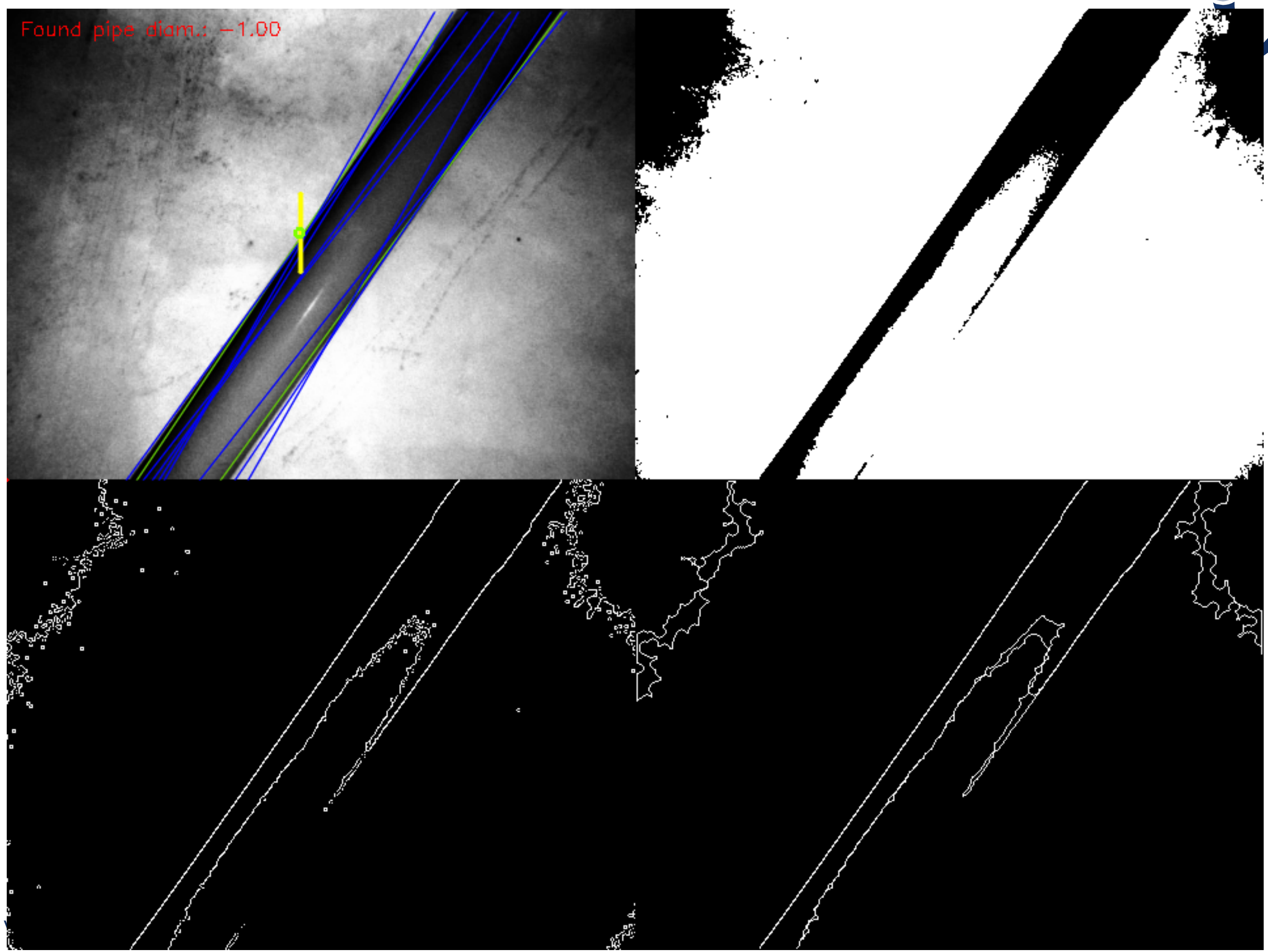
Underwater inspection + control

- Idea: use objects visible in the image as reference points for vehicle guidance
- Use line detection for pipeline following (control input computed directly from line coordinates + inertial sensor information)



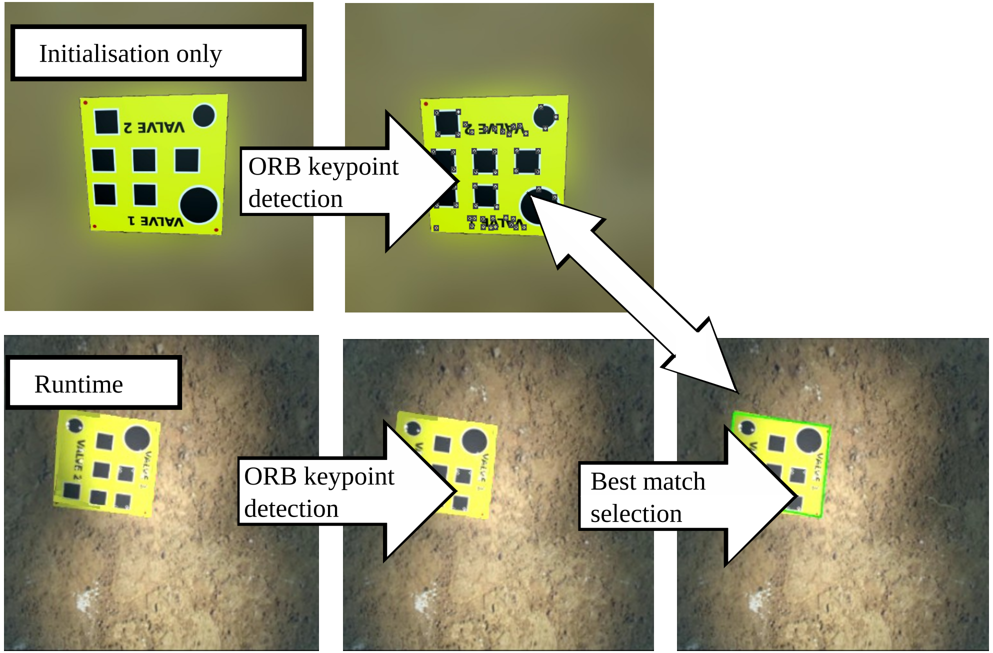


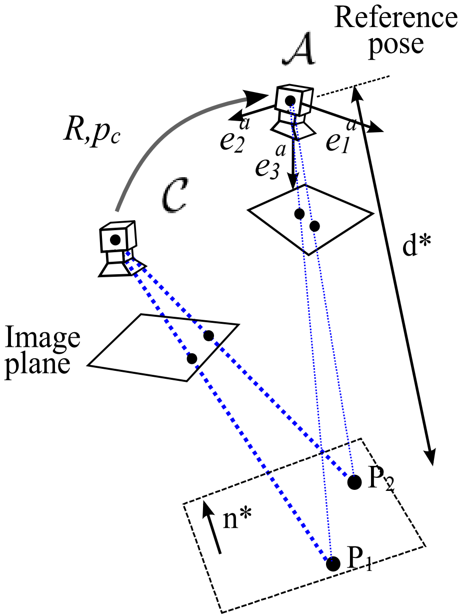



Found pipe diam.: -1.00

Underwater inspection + control

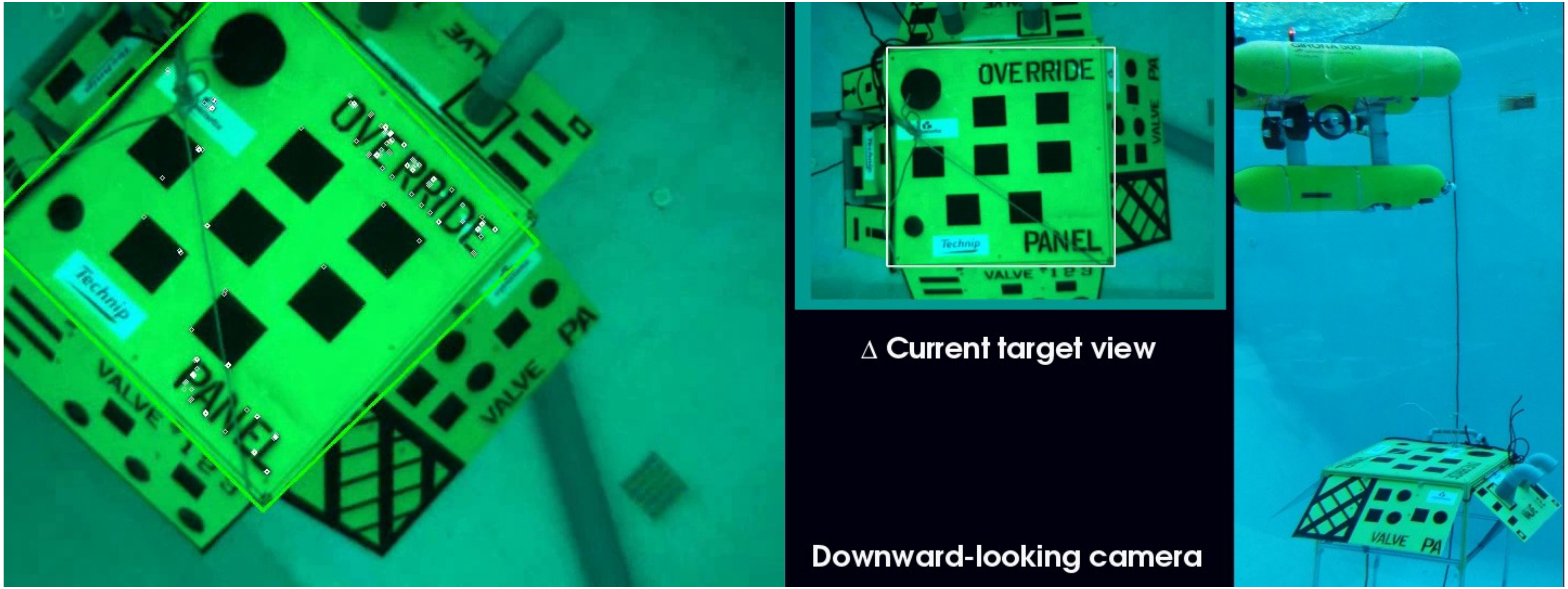
- Use planar homography for stabilisation and inspection trajectory following (control input computed directly from homography matrix + inertial data)





Here is an example how it can work on a square panel with some easy to detect features

Underwater inspection + control



Mosaicking and 3-D reconstruction

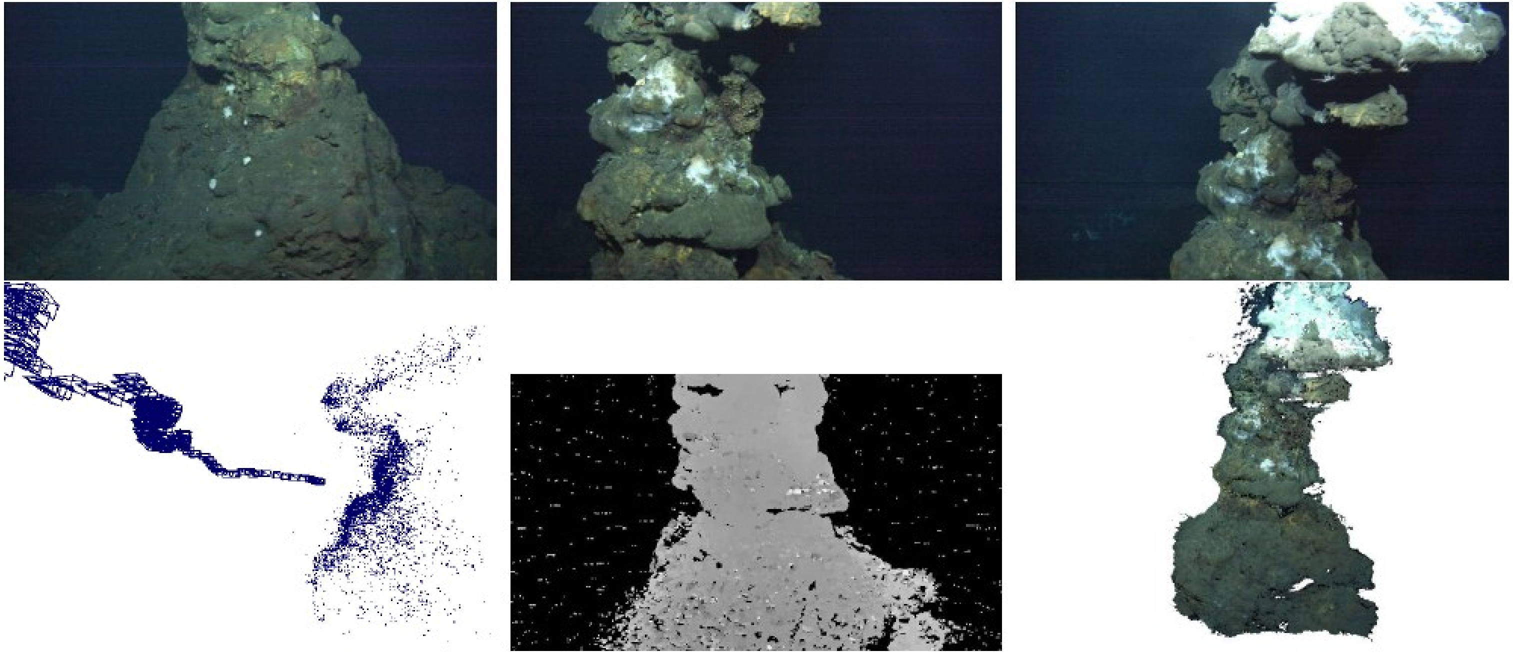
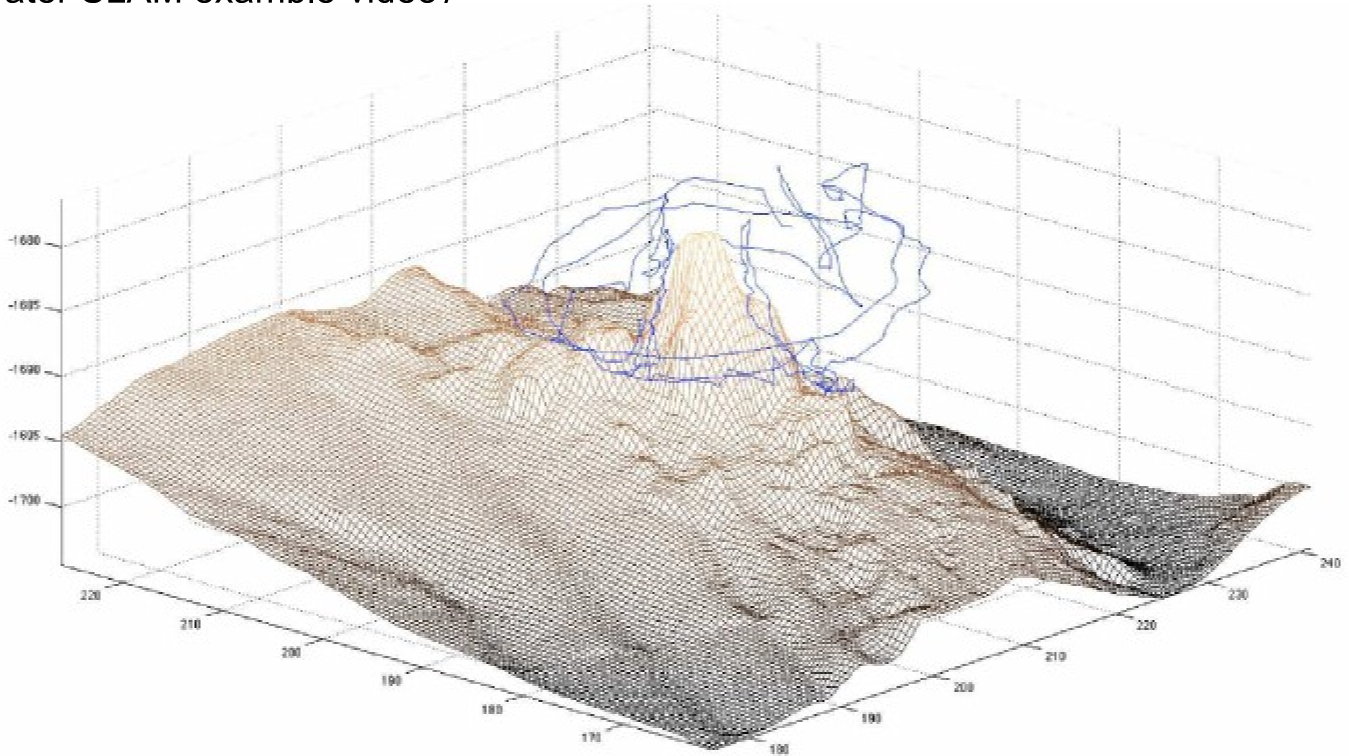


Figure 19: Results of refractive 3D reconstruction of a black smoker at the middle Atlantic ridge. Top row: Sample images from video sequence. Bottom row: 3D point cloud with camera path (left), sample depth map (center) and textured 3D model (right)

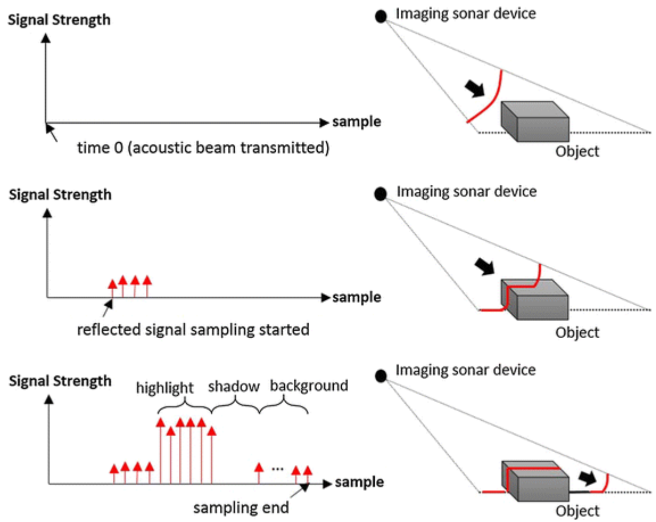
Positioning based on visual mapping

- (Underwater SLAM example video)

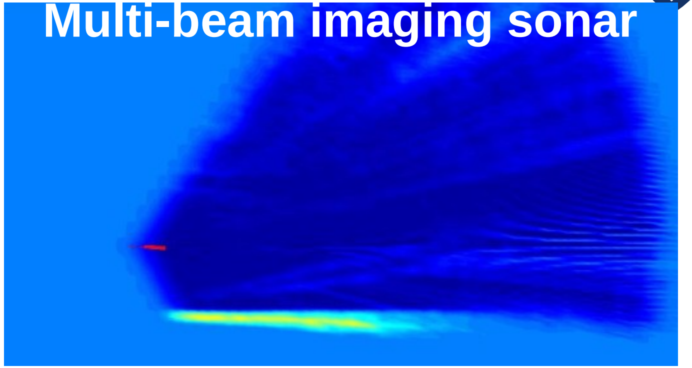


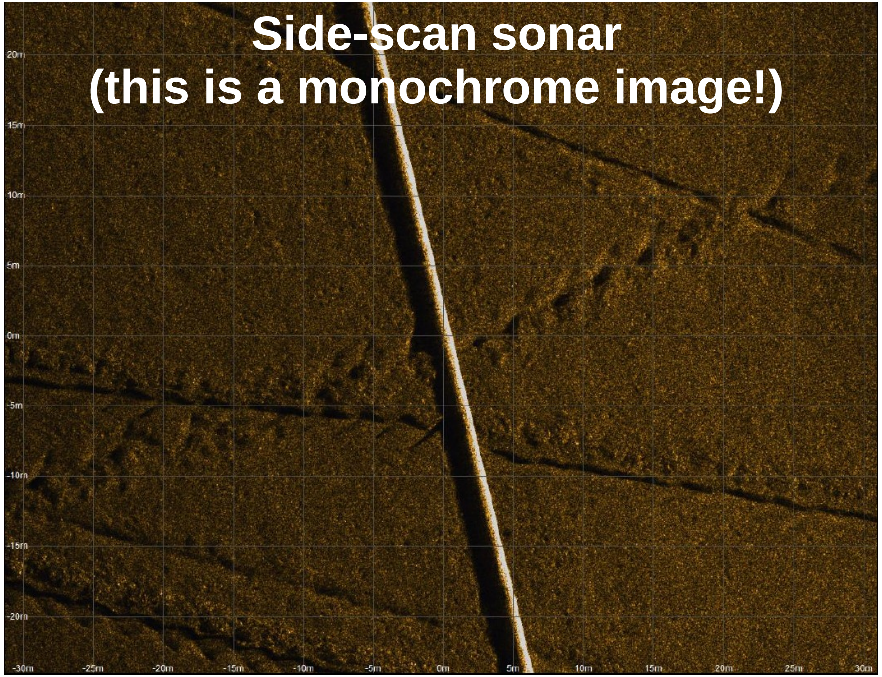
Computer vision and sonar imaging

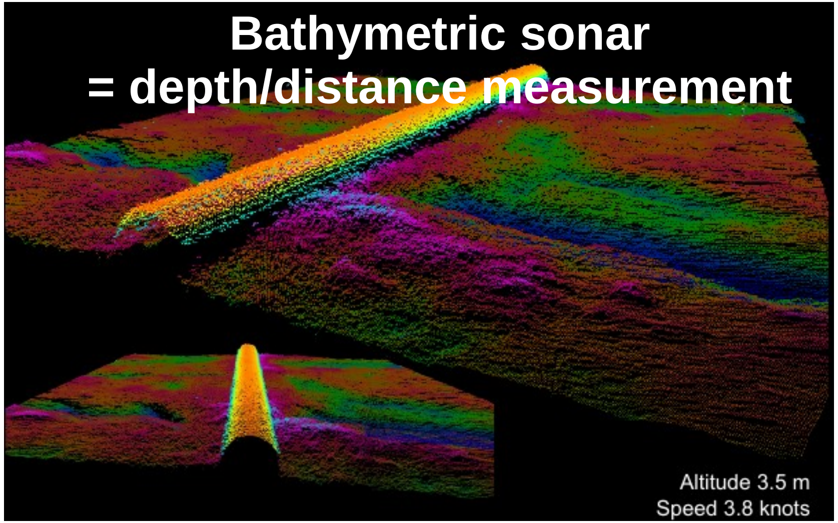
- Sonar is an acoustic sensor where the principal information are:
  - Time of flight of the reflected wave
  - Intensity of reflection
  - (phase of reflection)
- <u>This information can be used to constitute an image</u>
- Image can be processed using computer vision techniques!
- Always grayscale images
- More noise, compared to a well exposed photo



Computer vision and sonar imaging



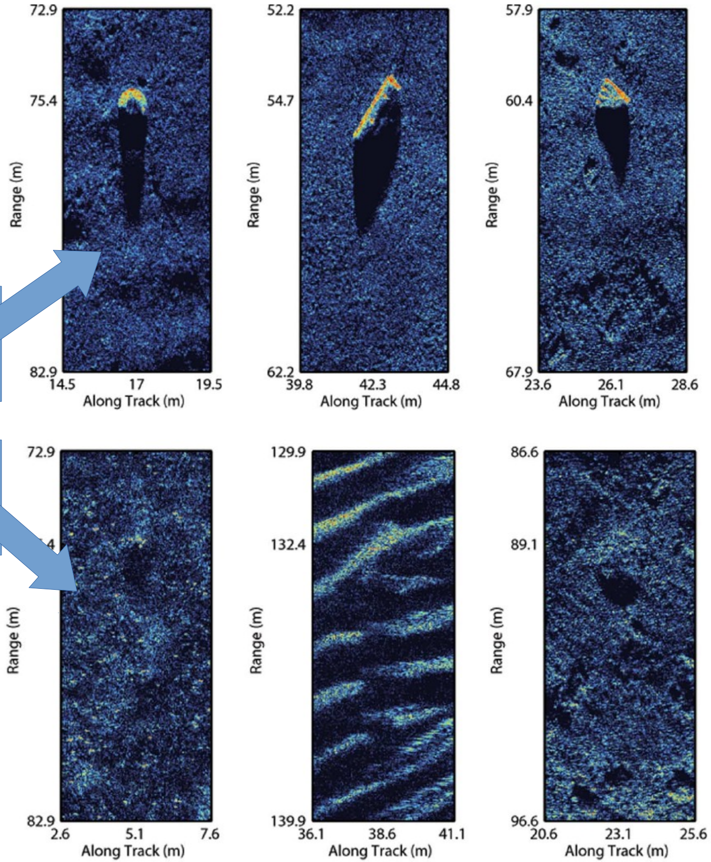


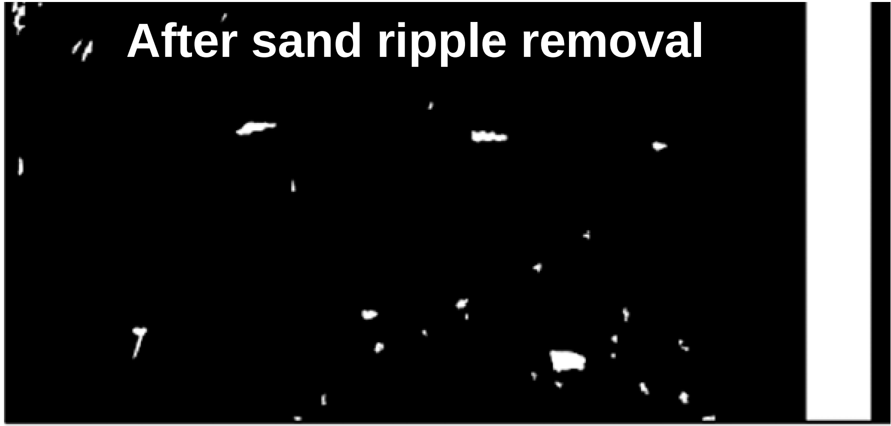


Computer vision and sonar imaging

Rather obvious

Not so obvious!



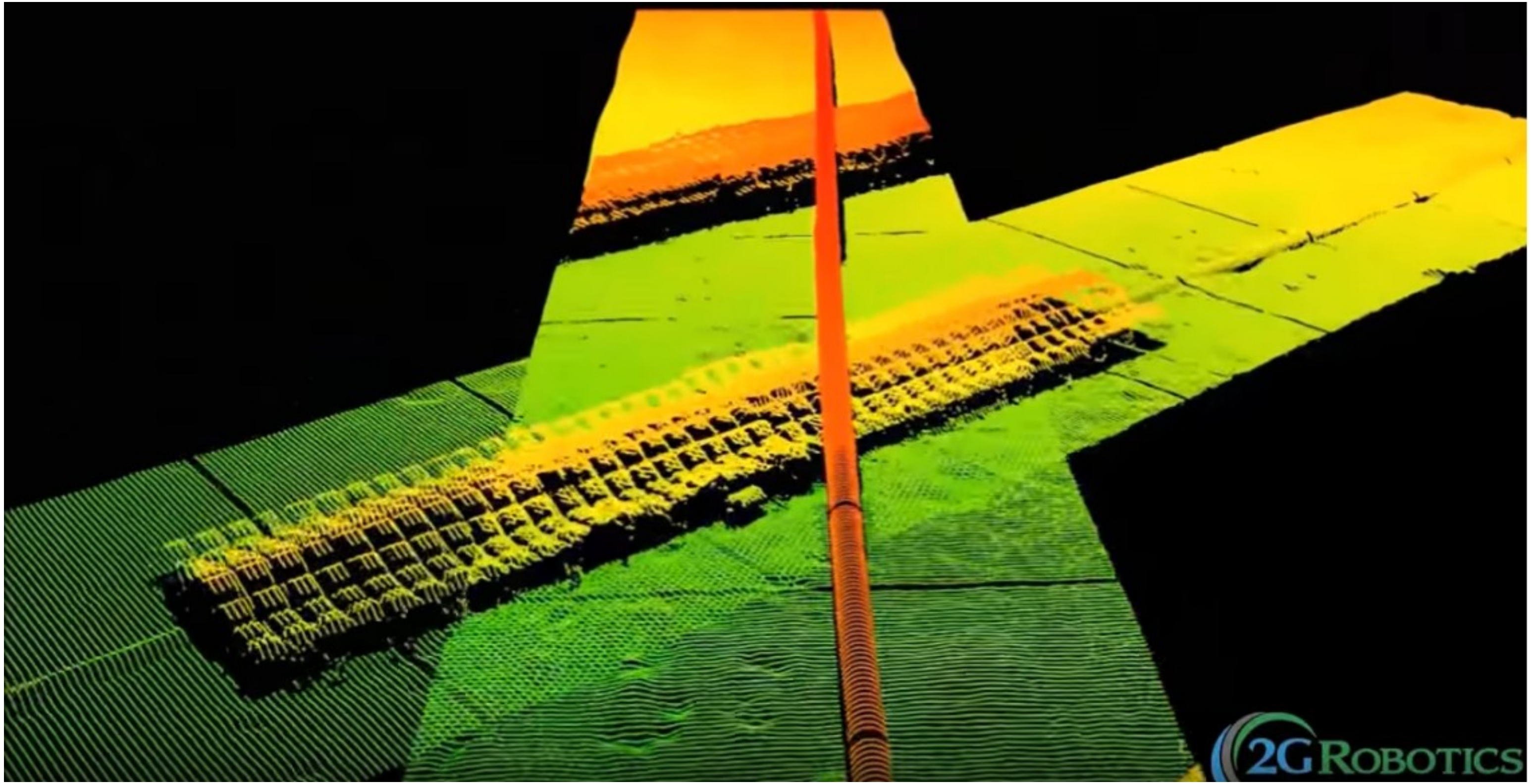


Examples of mine detection processing steps

Specialised computer vision: laserline sensor

- Recently quickly developing field
- The same method as in the air
  - Akin to structured light methods
  - Trigonometric basis for calculating the depth
  - Important factors: baseline, distance from the object
    (→ angle between the laser sheet and the detected beam axis)
  - Vision processing applied: detecting the laser line using chroma key
- Full 3-D reconstruction is obtained when the instrument or the object is moving!

Specialised computer vision: laserline sensor



Some literature

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Hope this lecture whetted your appetite to find out more!