



Computer Vision Applications - Underwater Vision

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- Distortion

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- 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

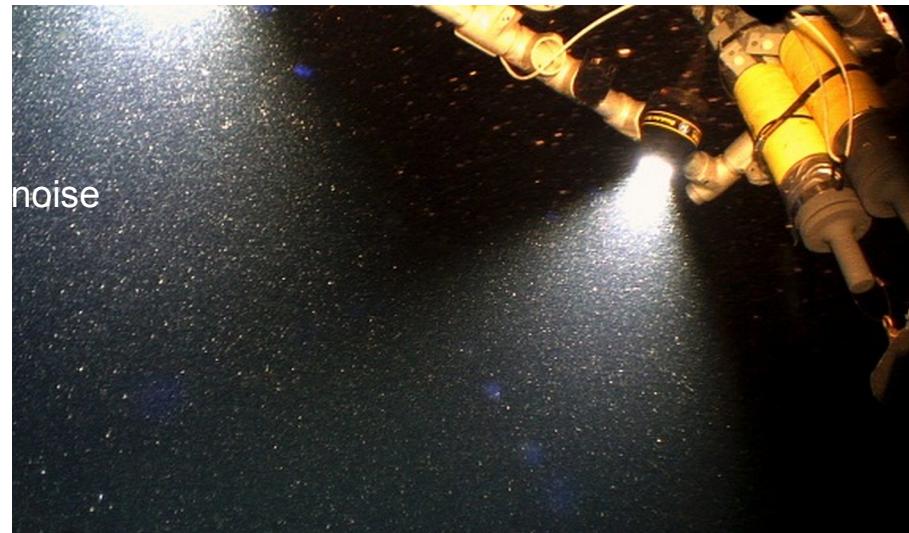
Strong light sources create secondary sources

- 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



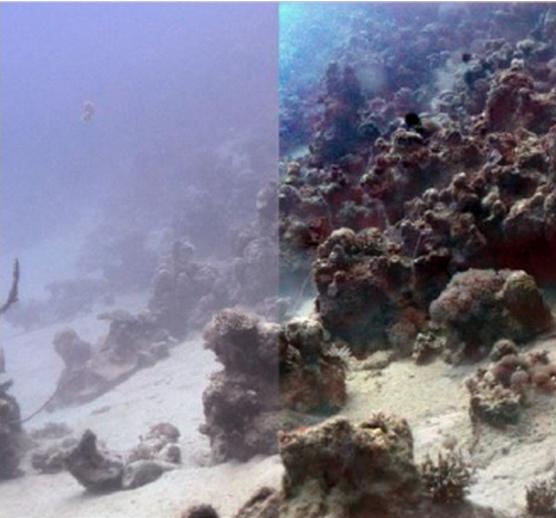
Let's talk about the problems first

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

(further slides will cover this)

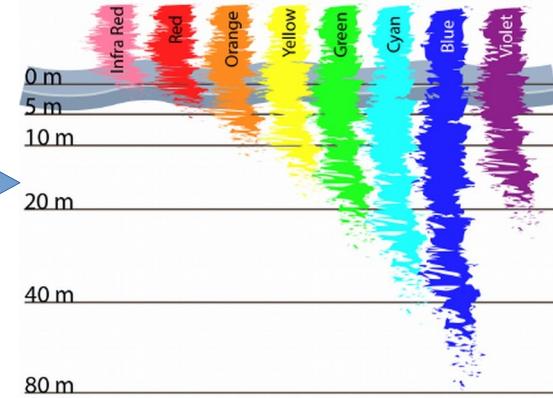
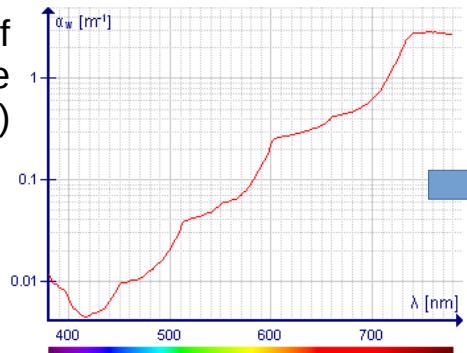
- Marine fouling

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

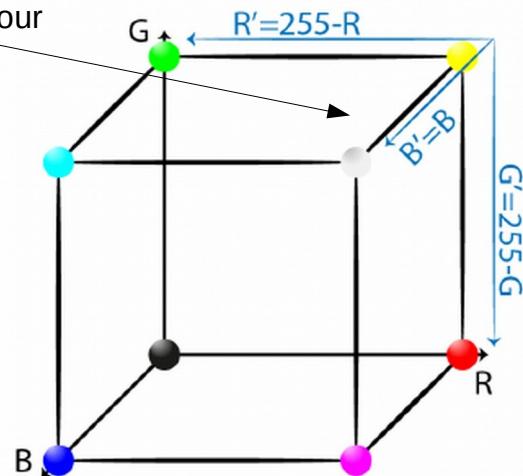
- Estimate the spectrum of the ambient light
 - We can easily guess it will usually blue-green!
- Correct for transmission losses
 - Colour modification
 - Intensity modification
- Physics-based solutions using polarising filters
- Algorithms like Dark Channel Prior have been adapted to work underwater
 - 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

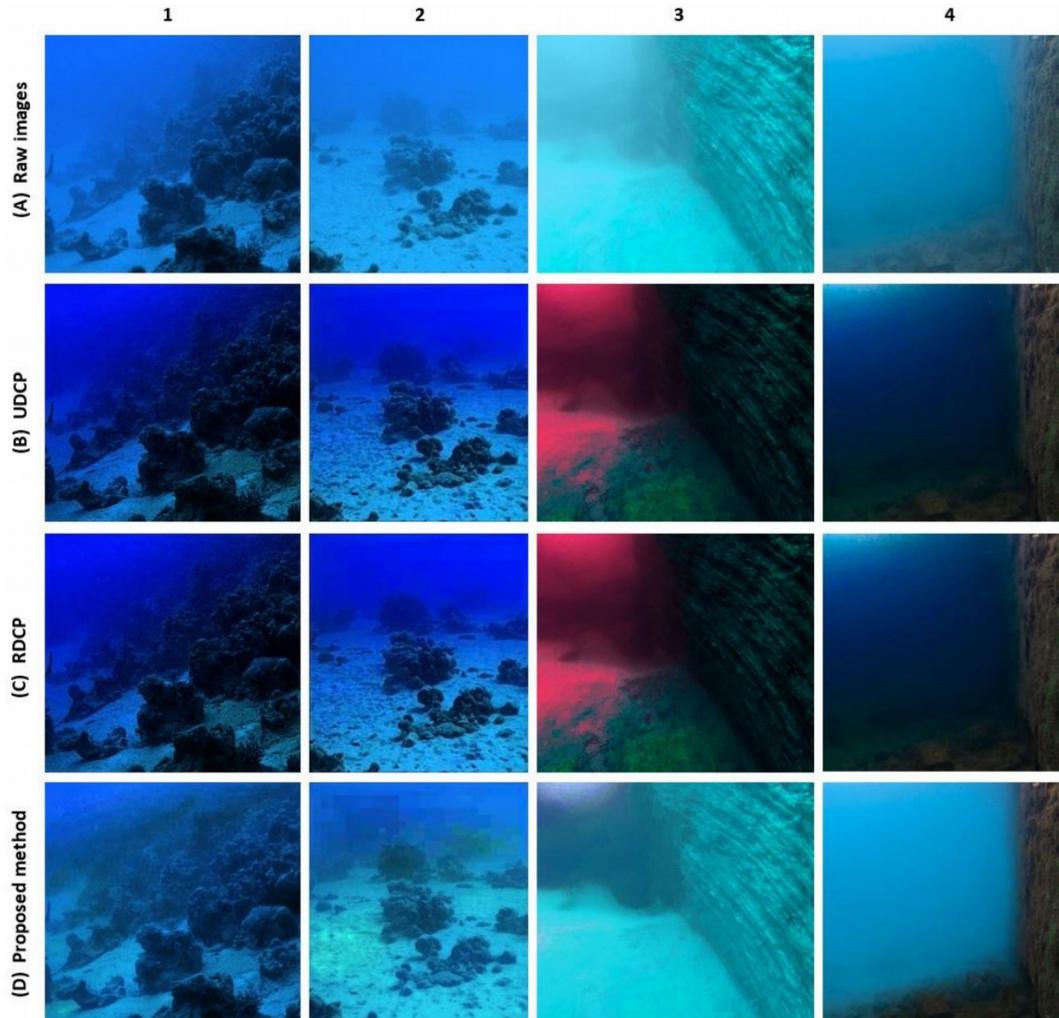
Blue does not need to be corrected since it's the least attenuated colour

$$R' = 255 - R$$

$$G' = 255 - G$$

$$B' = B$$





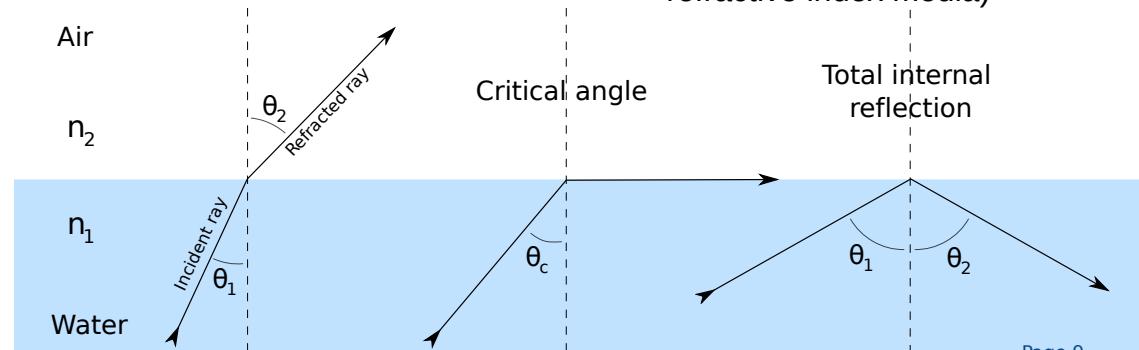
Distortion

- 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: $n_{\text{air}} = 1.00029$
 - Water: $n_{\text{H}_2\text{O}}=1.33$
(salinity and temperature can modify it)
 - Glass: $1.5 < n_{\text{glass}} < 1.7$
 - Can be partially compensated by adjusting the focal length of the objective
 - Also: the housing...

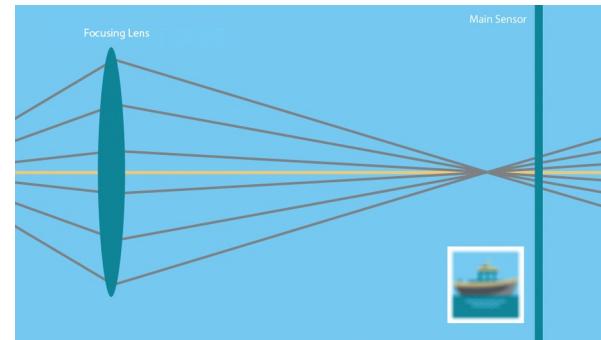
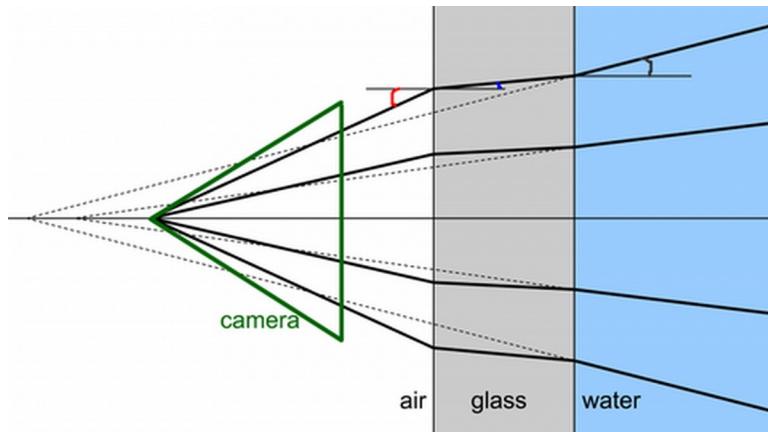


Snell's Law:
 $n_1 \sin \theta_1 = n_2 \sin \theta_2$

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



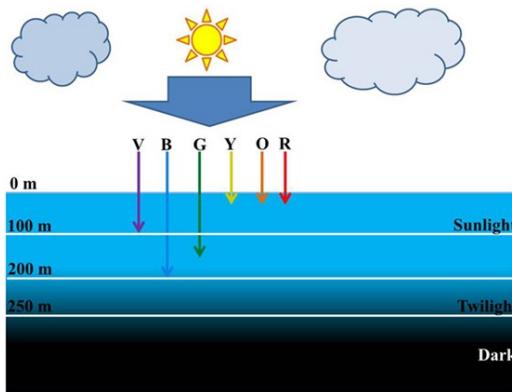
Distortion: influence of the pressure housing



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



- 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



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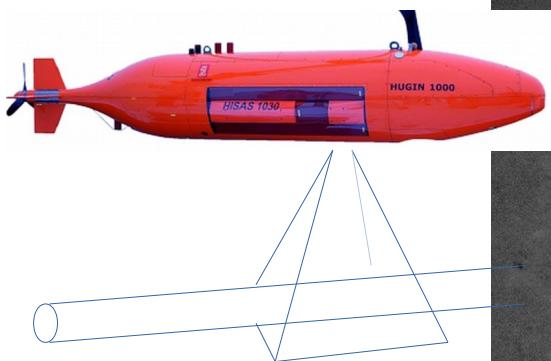


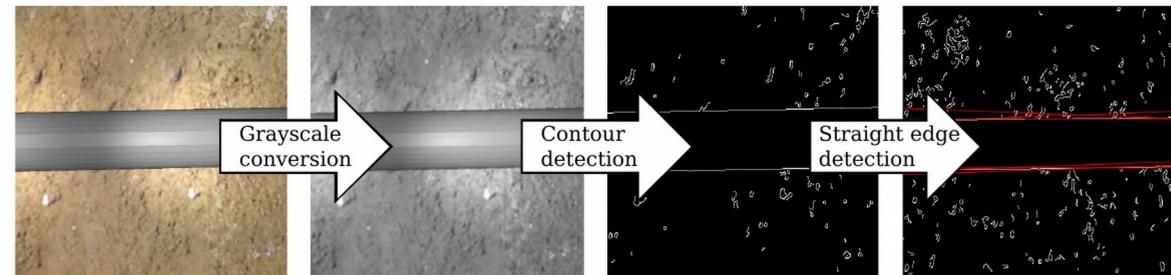
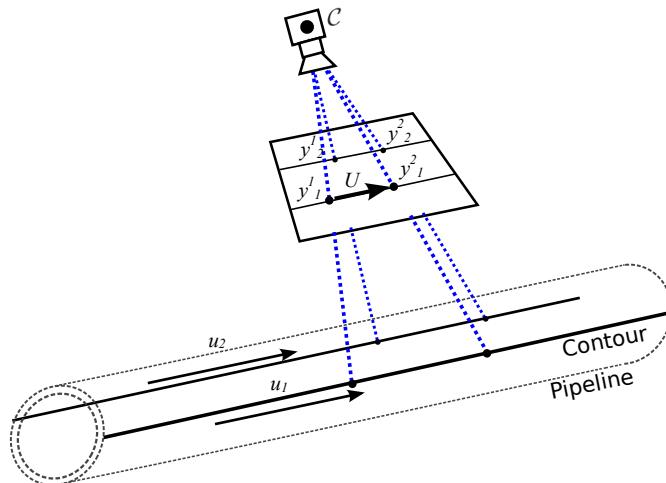
Image taken by an autonomous vehicle moving above the pipeline (in the centre of the image) with a down-looking still image camera

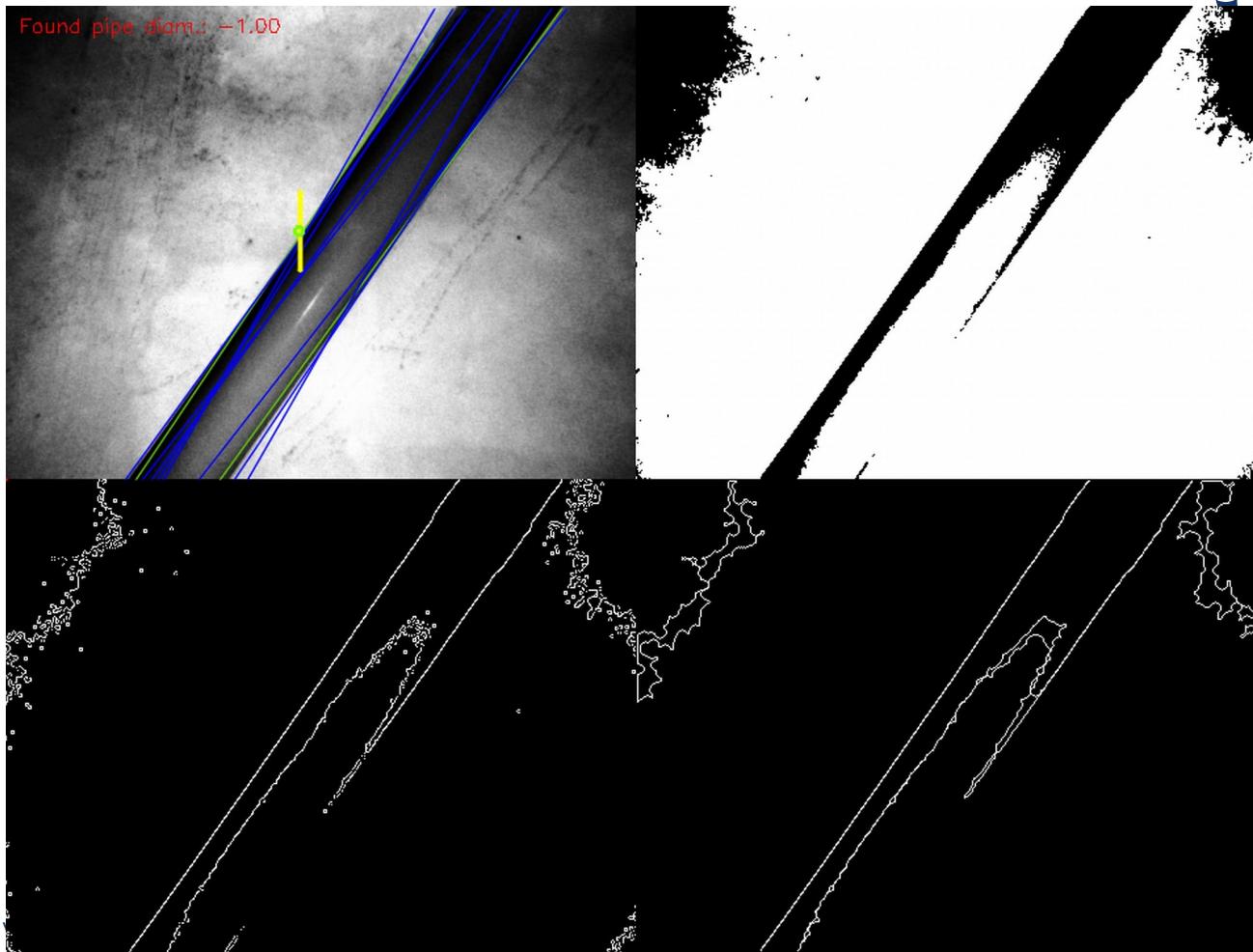


(You would probably never guess what the object next to the pipeline is using sonar...)

Underwater inspection + control

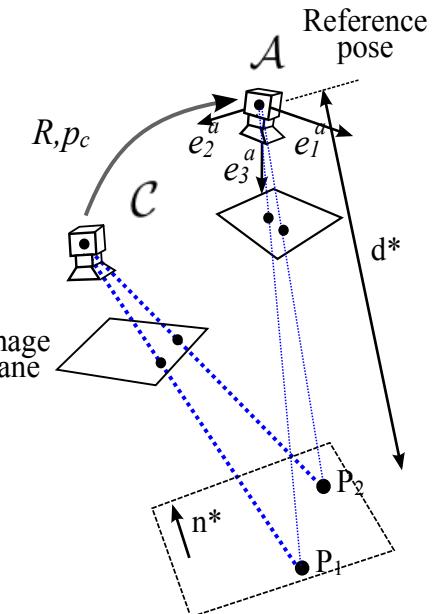
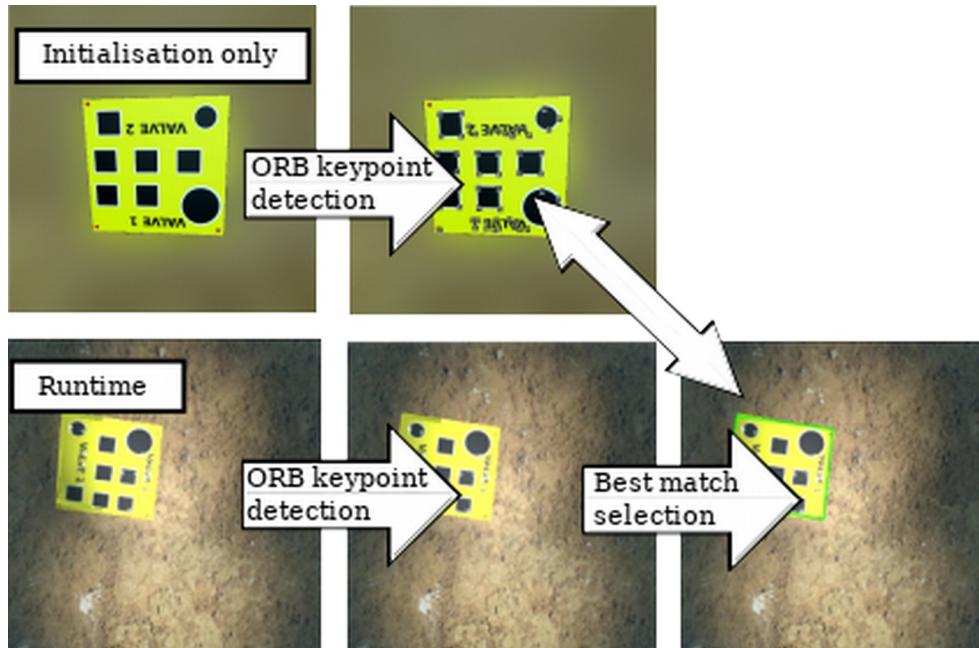
- Idea: use objects visible in the image as reference points for vehicle guidance
- Use line detection for pipeline following (control input computed directly from line coordinates + inertial sensor information)





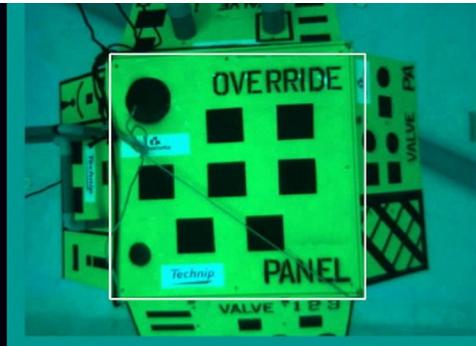
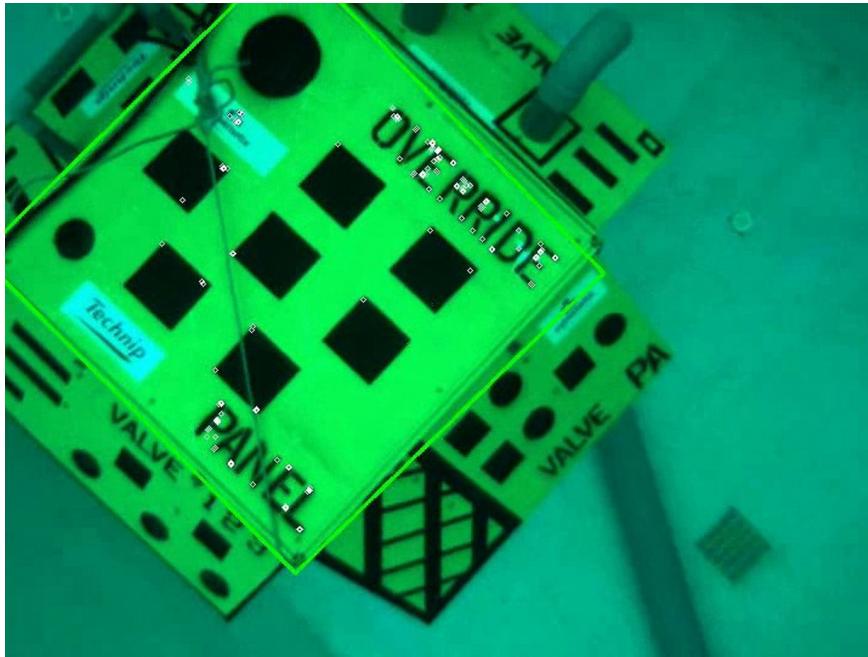
Underwater inspection + control

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



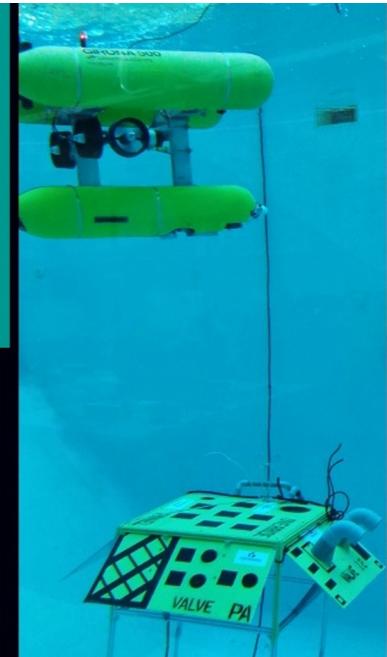
Here is an example how it can work on a square panel with some easy to detect features

Underwater inspection + control



△ Current target view

Downward-looking camera



Mosaicking and 3-D reconstruction

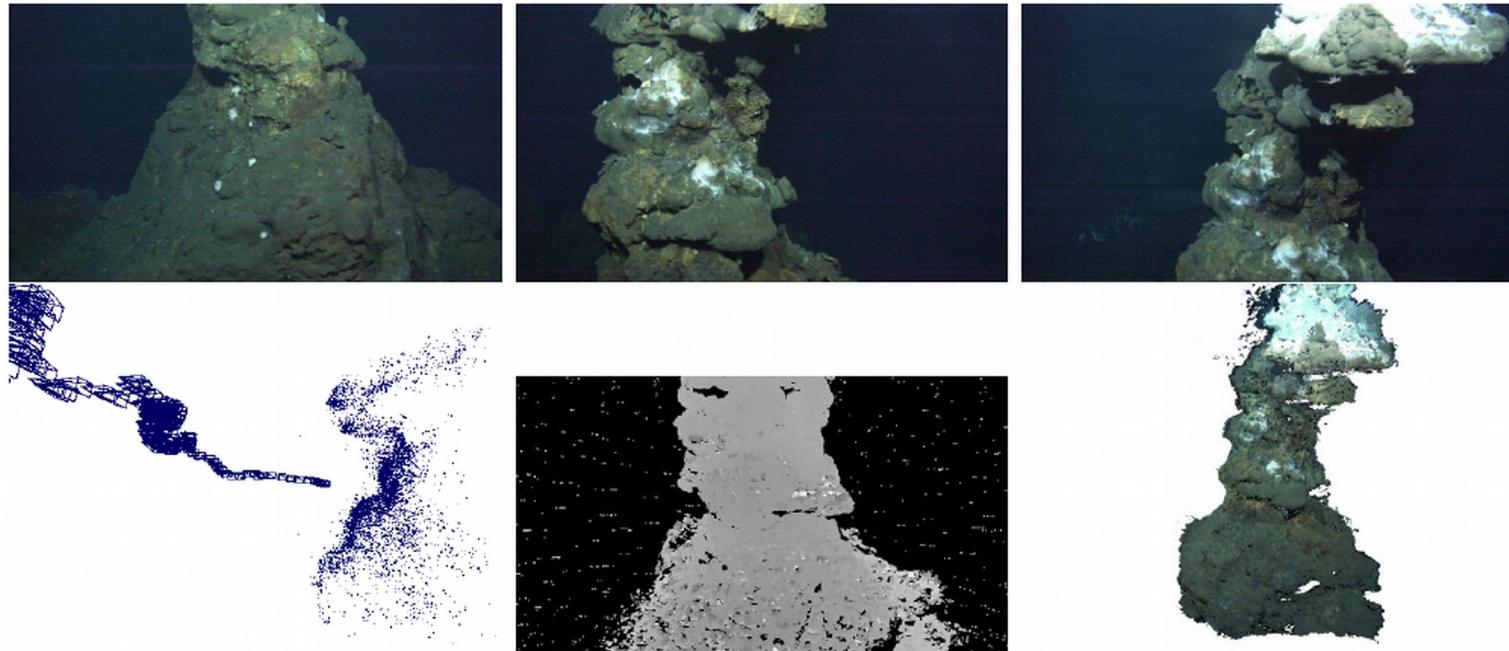
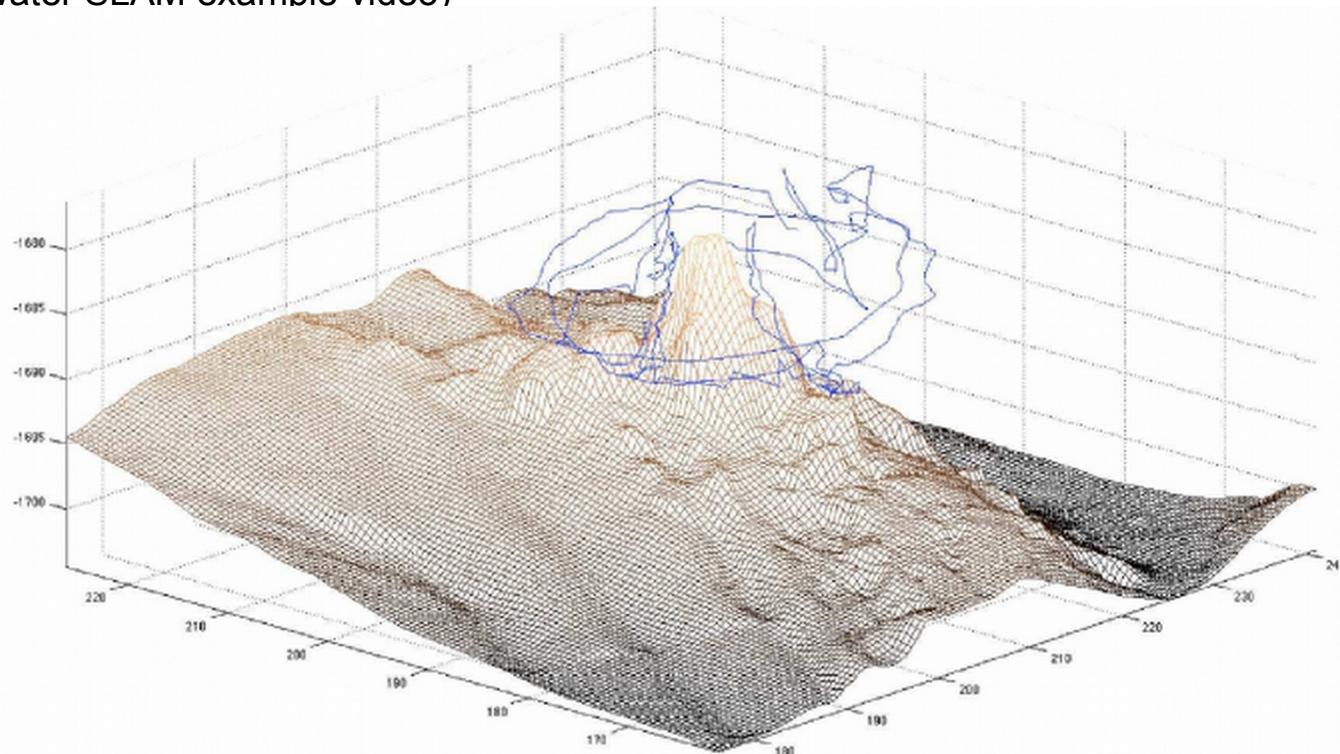


Figure 19: Results of refractive 3D reconstruction of a black smoker at the middle Atlantic ridge. Top row: Sample images from video sequence. Bottom row: 3D point cloud with camera path (left), sample depth map (center) and textured 3D model (right)

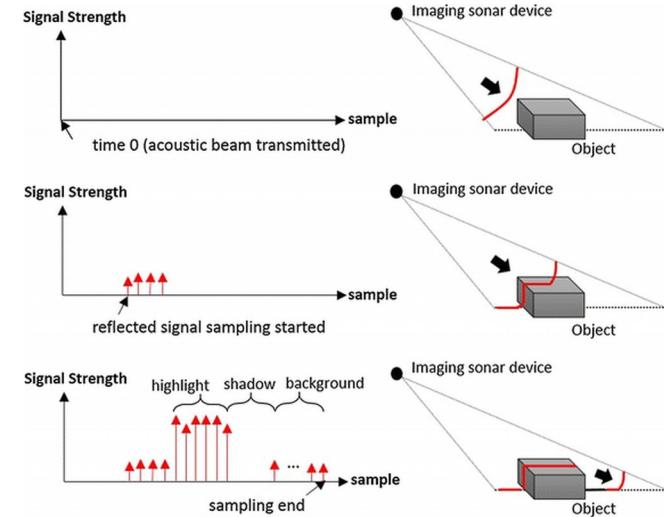
Positioning based on visual mapping

- (Underwater SLAM example video)

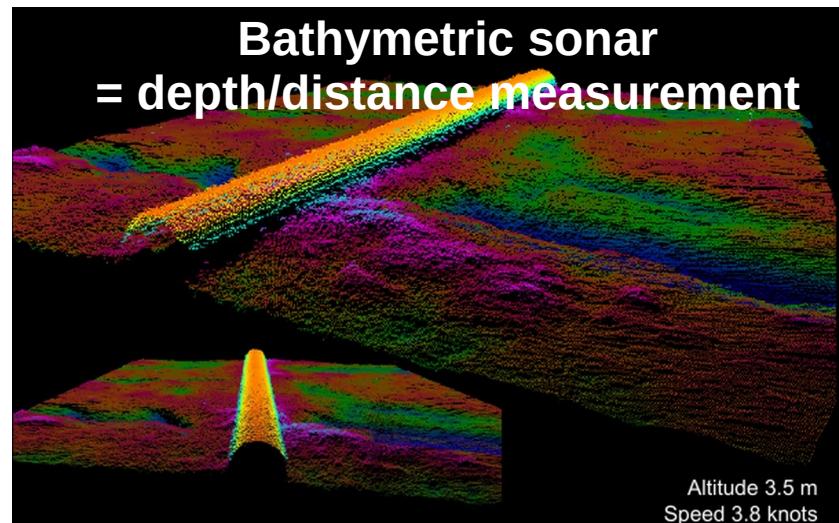
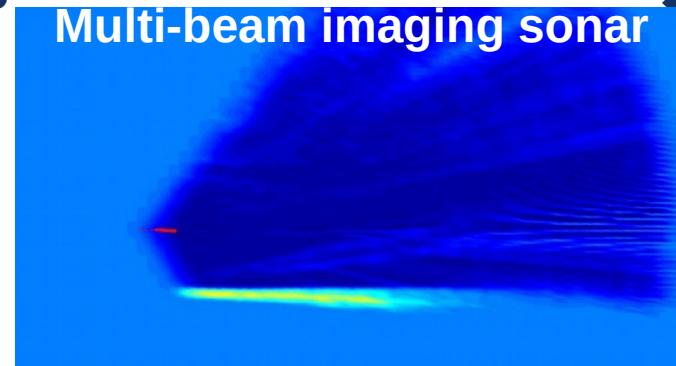
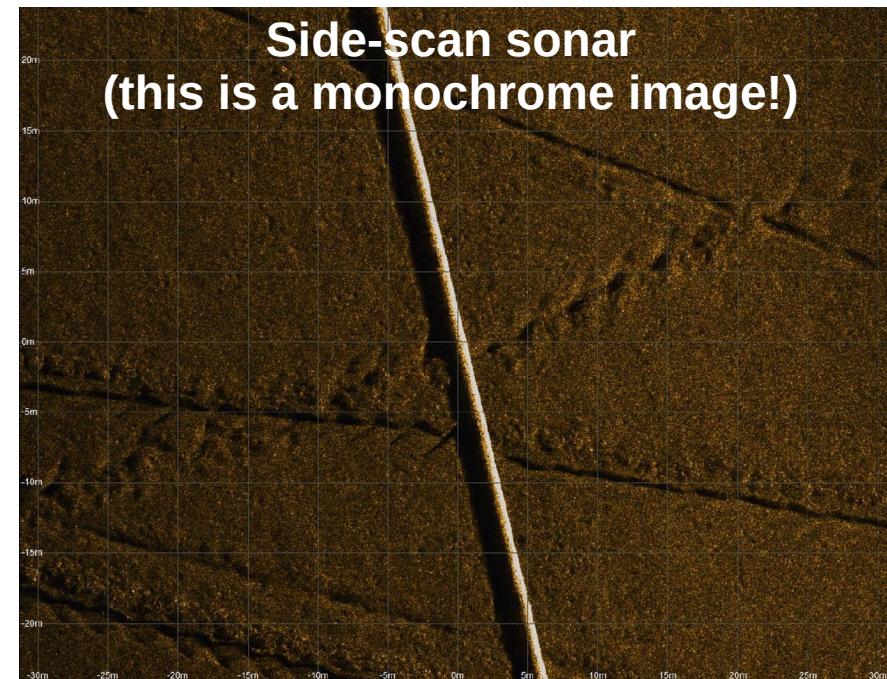


Computer vision and sonar imaging

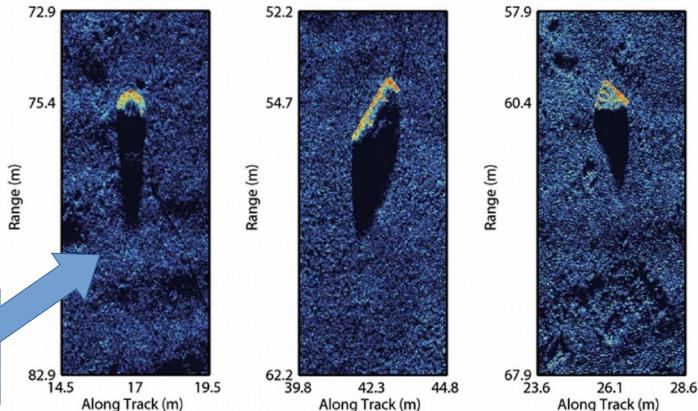
- Sonar is an acoustic sensor where the principal information are:
 - Time of flight of the reflected wave
 - Intensity of reflection
 - (phase of reflection)
- This information can be used to constitute an image
- Image can be processed using computer vision techniques!
- Always grayscale images
- More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



Computer vision and sonar imaging

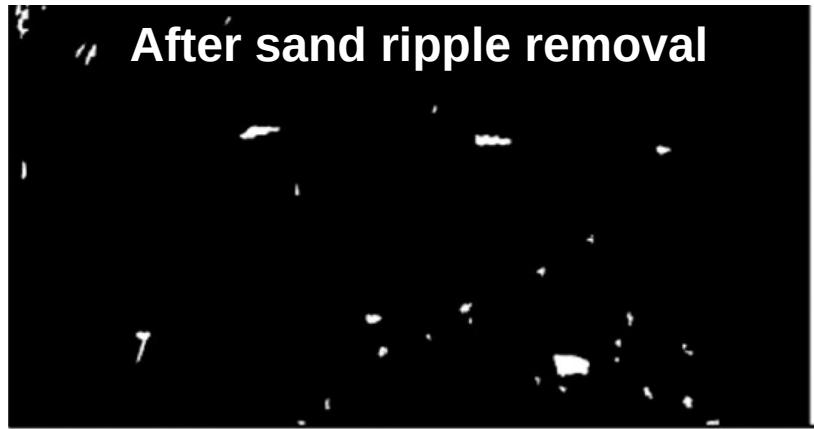
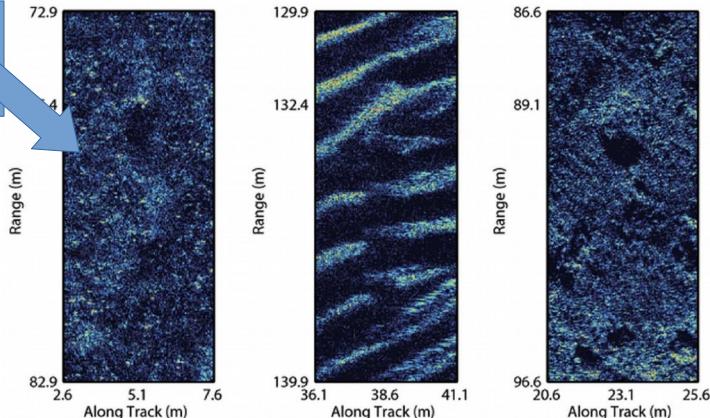


Computer vision and sonar imaging



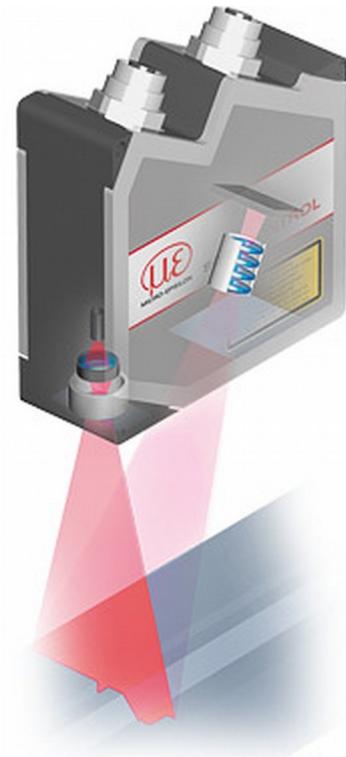
Rather
obvious

Not so
obvious!

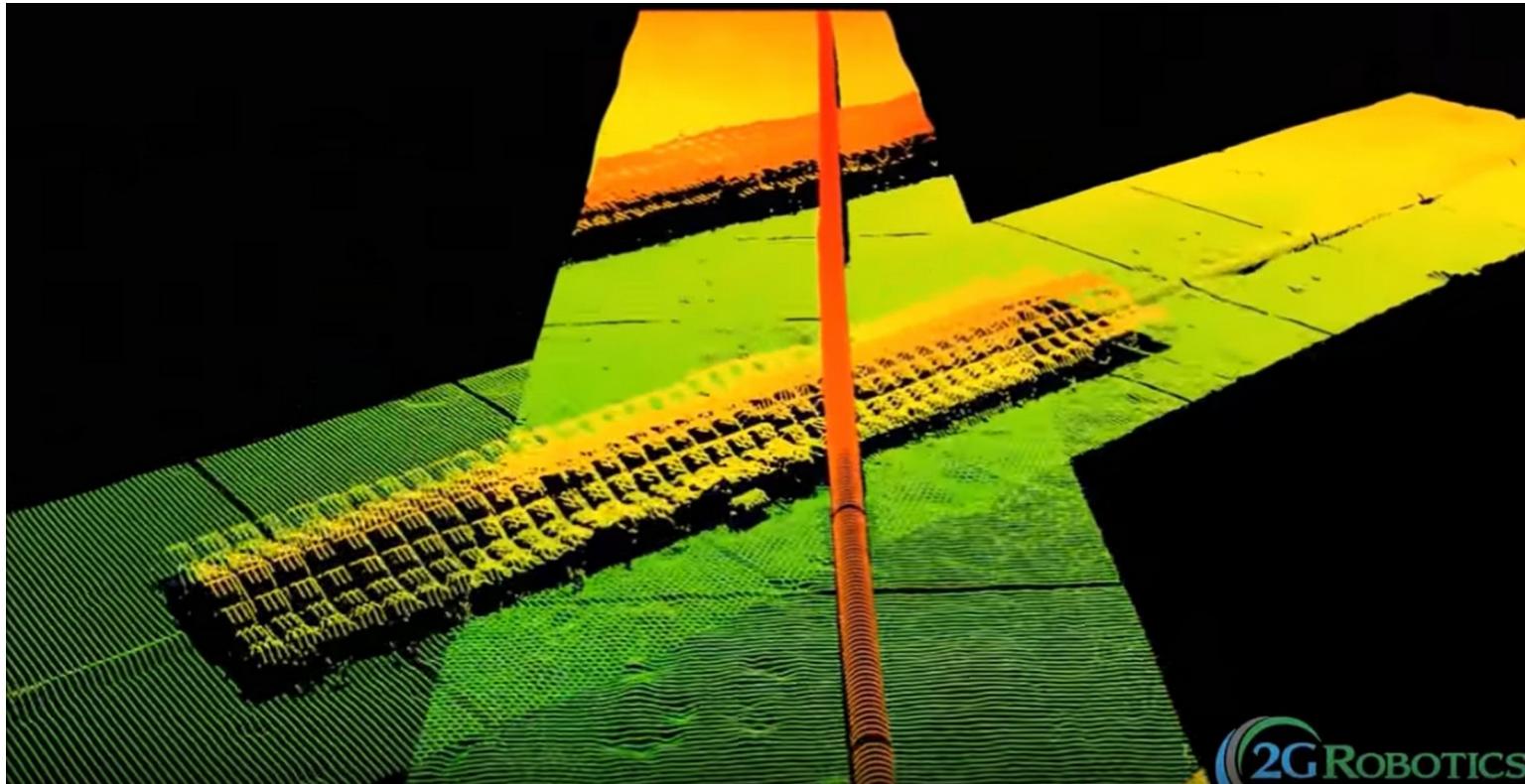


Specialised computer vision: laserline sensor

- 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



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Hope this lecture whetted your appetite to find out more!

