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3D reconstruction of underwater scenes using image sequences from acoustic camera

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Introduction

- Climate change is gradually affecting the underwater environment :
  - Temperature increases, chemistry modifications
  - Ocean circulation perturbation
  - etc.

- Influencing:
  - Resources, population dynamics
  - Underwater structure stability

➢ Monitoring and observation of underwater environment is a necessity to: describe, understand, model ... in order to protect the marine resources and structures and to prevent climate changes

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Introduction

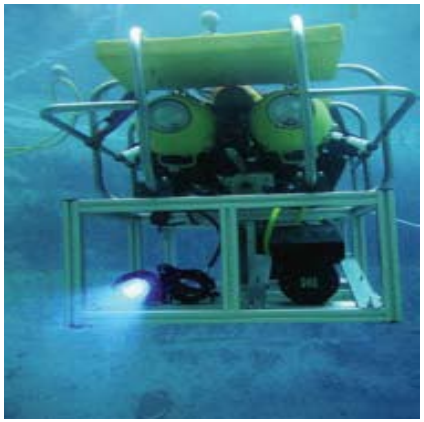
- Underwater observation is currently carried out using imagery systems:
  - **Optical systems:**
    - Provides physical properties (color, reflection, geometry)
    - Image quality depends on underwater conditions
    - Limited range
  - **Acoustical systems**
    - Image quality less affected by turbid water
    - Long range

KLEIN sidescan sonar
Source: www.usinenouvelle.com

➢ Acoustical imaging: the most reliable observation mode in the underwater environment

Introduction

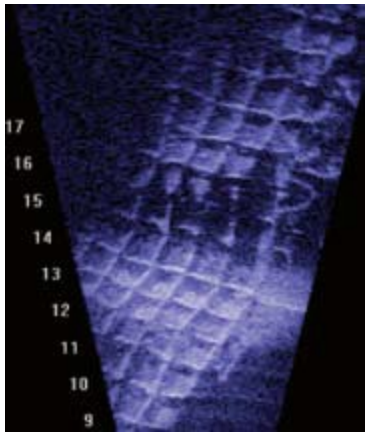
Acoustical Cameras



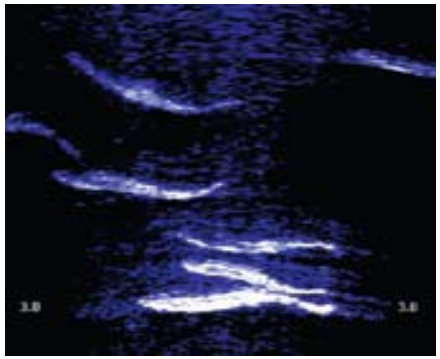
DIDSON on RAUVER ROV

Dual frequency IDentification SONar
http://www.soundmetrics.com

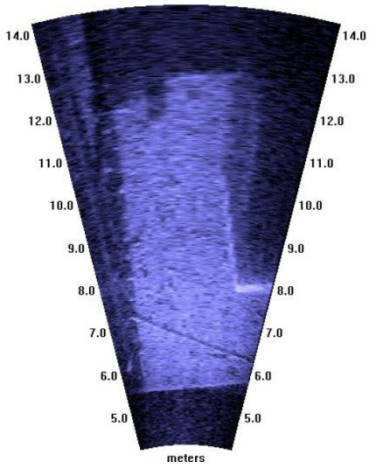
Underwater structure
900 KHz 2D BlueView imaging sonar
http://www.blueview.com/2d-Imaging-Sonar.html



Damaged concrete mats
DIDSON
http://www.soundmetrics.com



Salmon swimming
http://www.soundmetrics.com



Bridge Pier
http://www.soundmetrics.com

DIDSON Diver with Complete
Diver-Held System

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Introduction

- **But..**

  Acoustical cameras provide 2-D image, they do not resolve the altitude of the observed scene →*this is a limitation when monitoring and to observing the underwater environment*

➢ ***Purpose of this work*: designing and developing a method that enables 3D reconstruction of underwater scenes**

3D reconstruction methodology

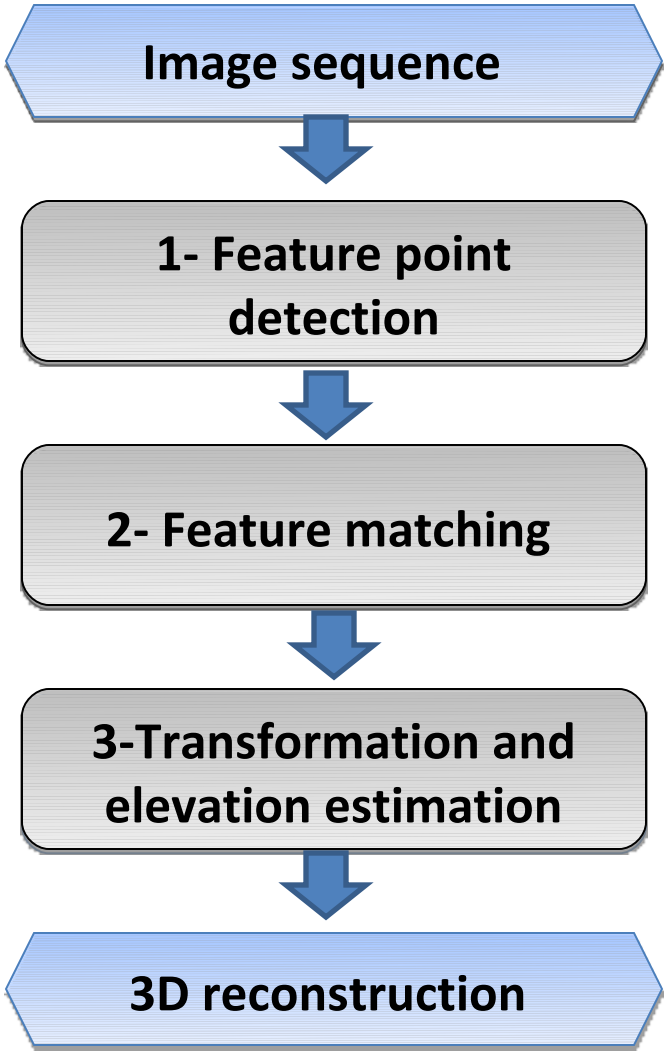
- Multiple acquisition of the same underwater scene over an image sequence under different points of view

➢ Exploitation of this information redundancy to reconstruct in 3D the observed scene

➢ The developed methodology is inspired from ***stereovision techniques***

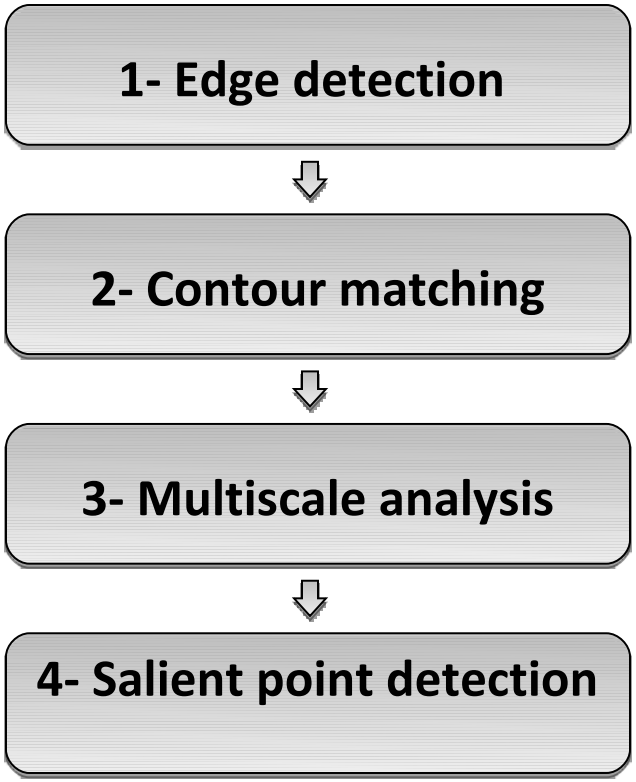
3D reconstruction methodology

Global methodology



Feature point detection

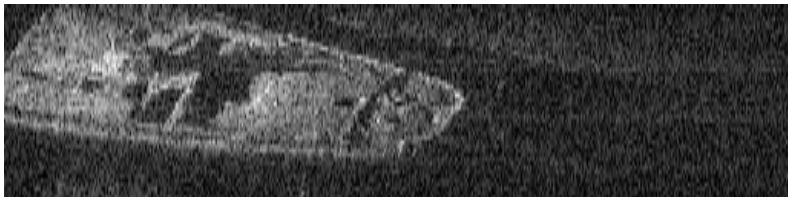
General approach



1- Edge detection

- Robust feature points clearly belong to object edges in the collected images
  - Application of Canny filter to detect contours

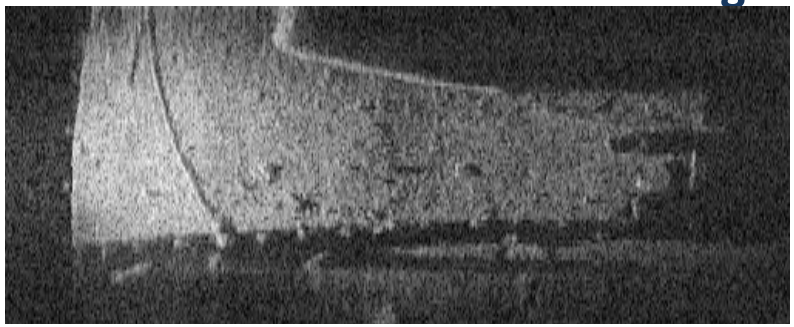
Ship sequence



Original image

Image filtered by Canny filter

Bridge sequence



Original image

Image filtered by Canny filter

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2- Contour matching

- **Purpose**: Remove false contours and preserve object contours

  Hypothesis: Small camera movement between two successive images

- Determining the percentage of contour points present in successive image frames within a small neighborhood

$$\mathcal{M}_k^{1\to 2} = \frac{\sum_{p\in\mathcal{C}_k^1} \mathbb{1}_{\eta(p)\in\mathcal{C}^2}}{\ell(\mathcal{C}_k^1)}$$

$\ell(\mathcal{C}_k^j)$: Length of contour $\mathcal{C}_k^j$

p : stands for location (i, j) in image 1 and 2

$\eta(p)$: defines a small neighborhood around the location p in image 2

$\mathbb{1}_x$: equal 1 if x is true, 0 if not

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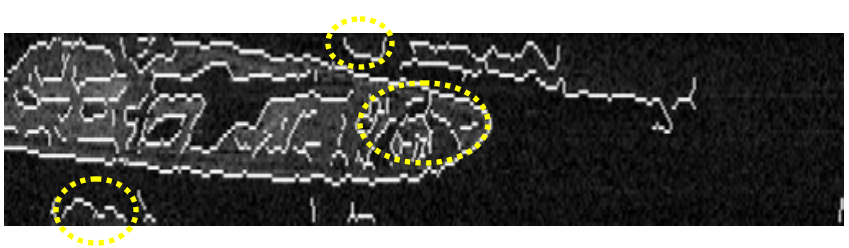
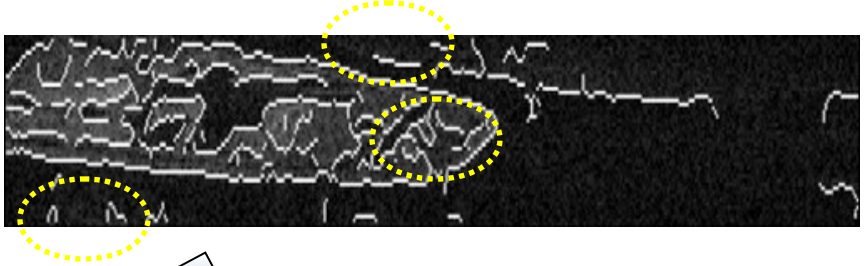
2- Contour matching

Ship sequence

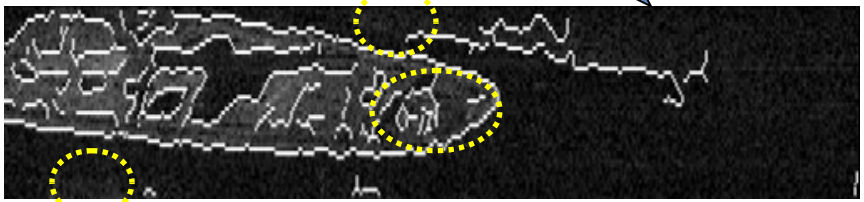


frame i

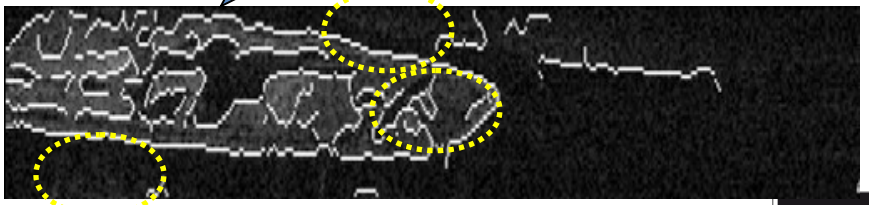


frame i+1

Contour matching process



frame i



frame i+1

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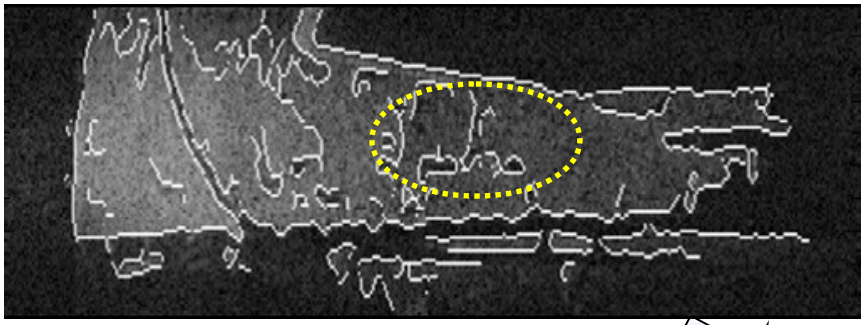
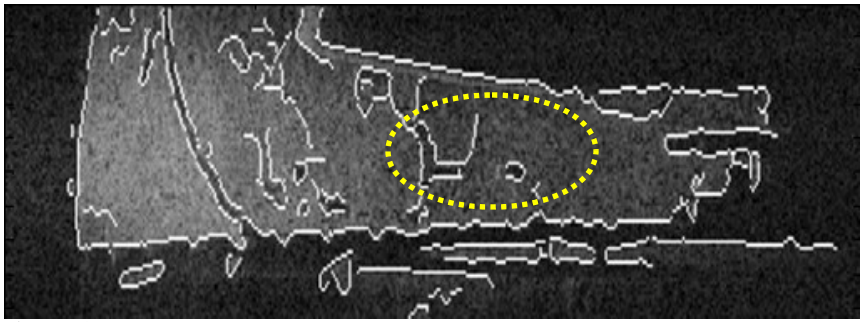
2- Contour matching

Bridge sequence





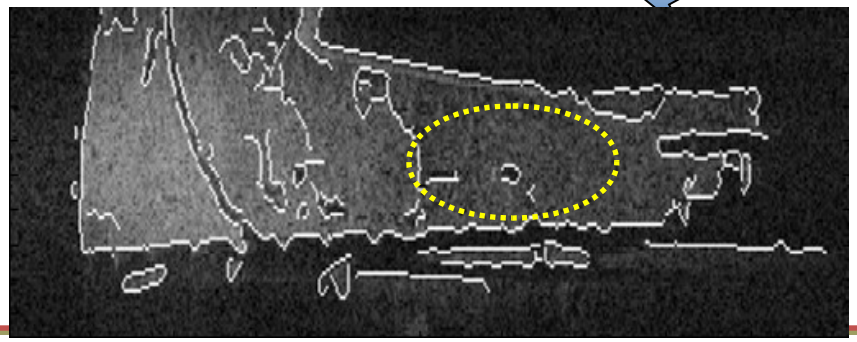
frame i

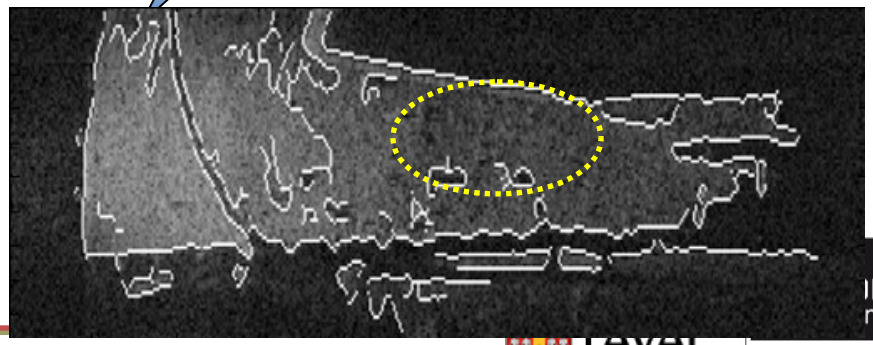
frame i+1

Contour matching process

frame i

frame i+1





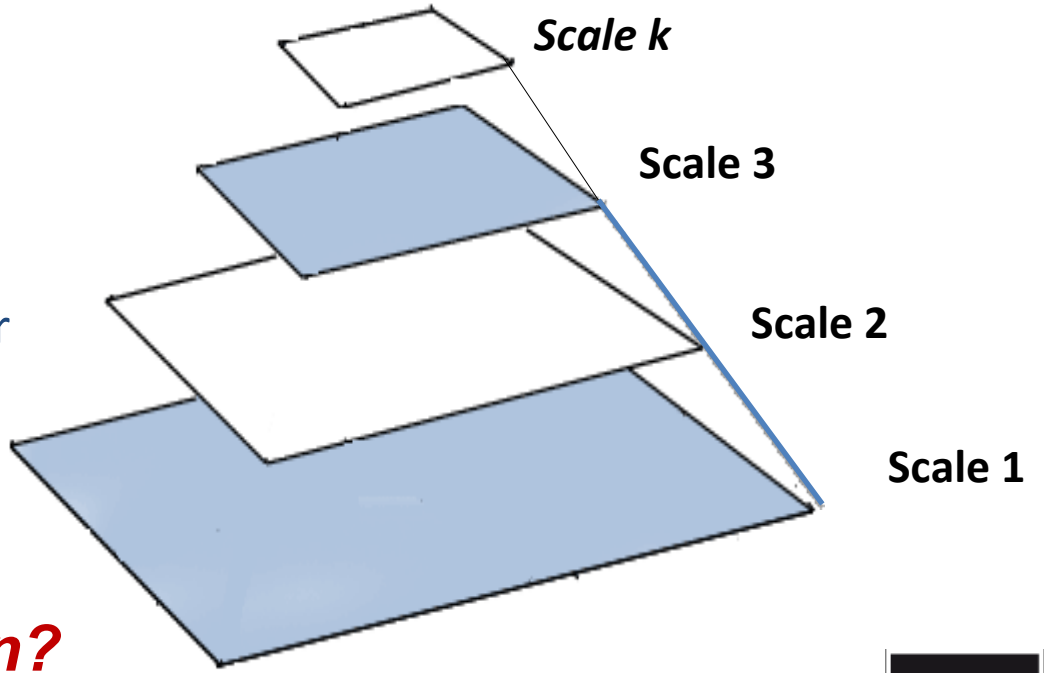
3- Multi scale analysis

- Preserve only robust contours that will yield to robust corners and accurate camera pose estimation

➢ Analyze corresponding contours through a multi-scale approach

➢ *At each scale:*

1. Gaussian filter
2. Edge detection
3. Contour matching
4. Computation of the number of corresponding contours in two successive frames



➢ ***which scale allows robust contours extraction?***

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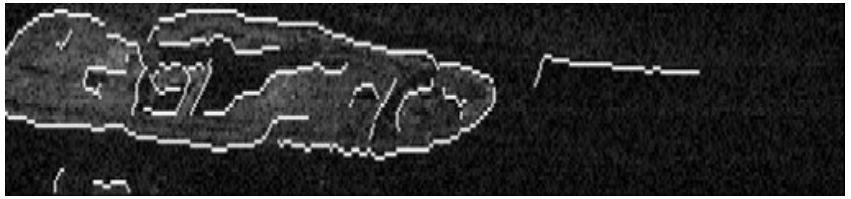
3- Multi scale analysis

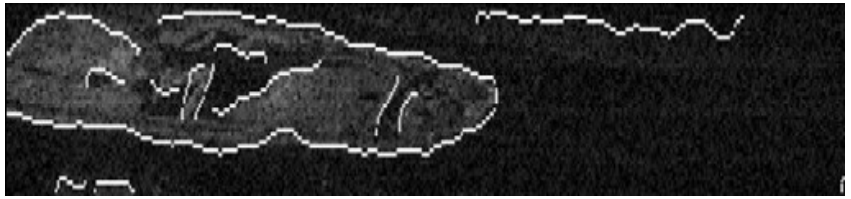
Relevant contours from ship sequence

Scale 1 (original contours)

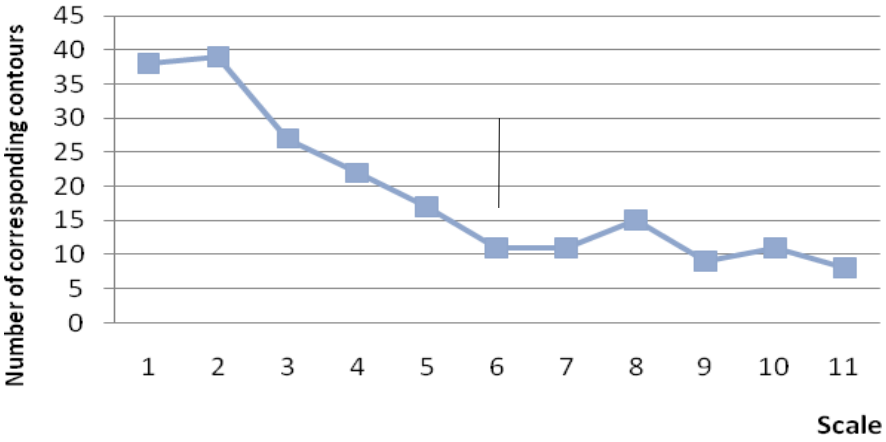


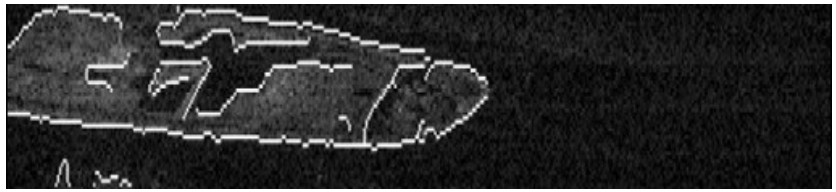
Scale 4

Scale 2



Scale 6

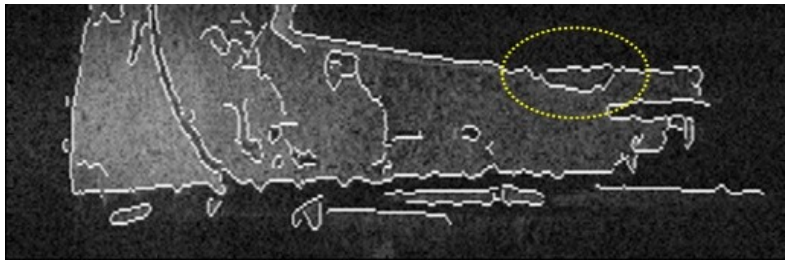




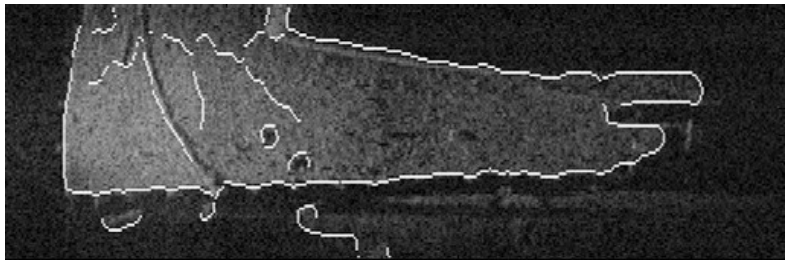
Corresponding contours from scale 1

3- Multi scale analysis

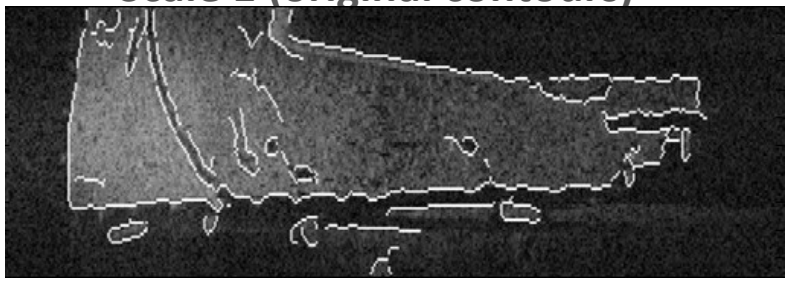
Relevant contours from bridge sequence



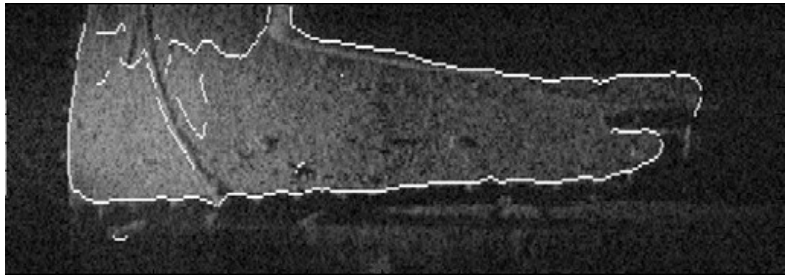
Scale 1 (original contours)



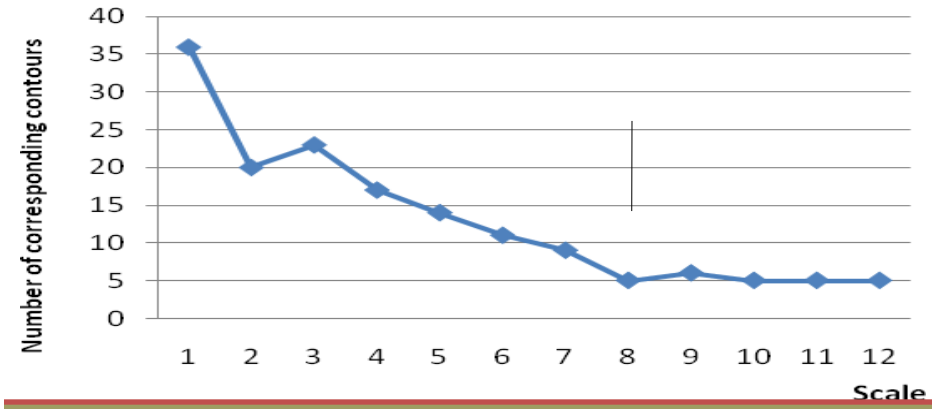
Scale 6

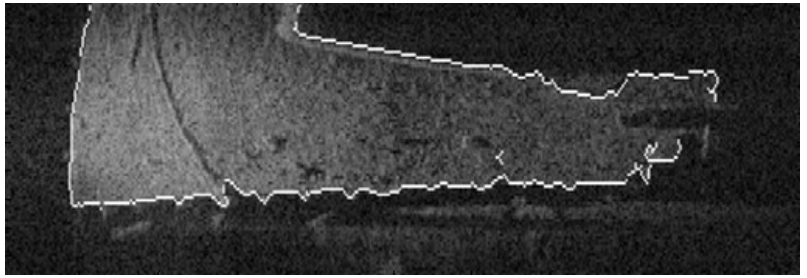


Scale 2



Scale 8





Corresponding contours from scale 1

4- Salient point detection

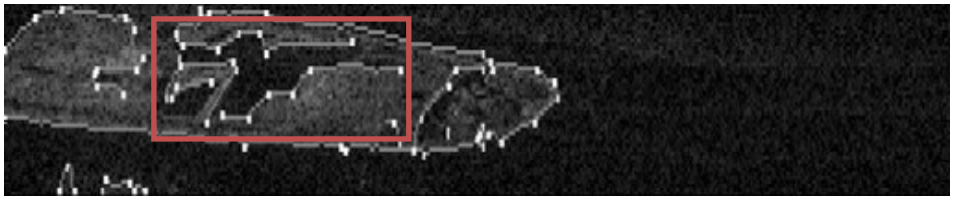
- Contour salient points : points with high curvature

➢ Corner Detector : *Douglas-Peucker algorithm*

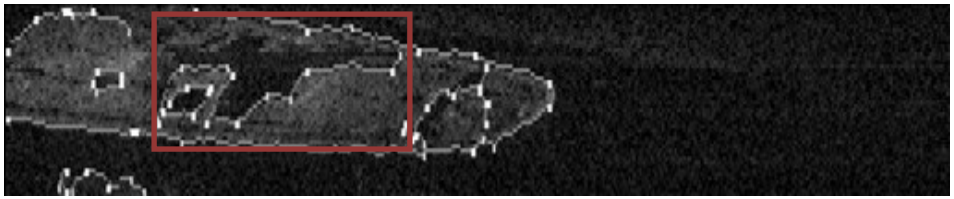
➢ Decrease the number of points in a curve, keeping only corner candidates → points with highest curvatures

4- Salient point detection

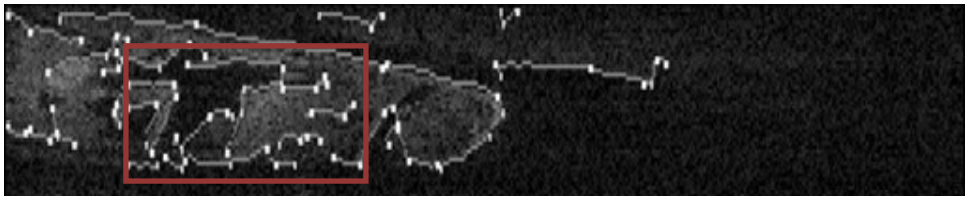
Ship sequence



Frame i

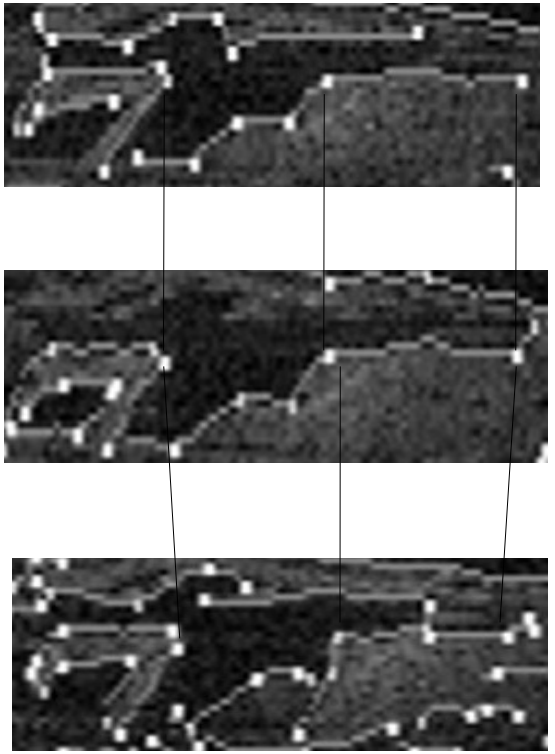


Frame i+1



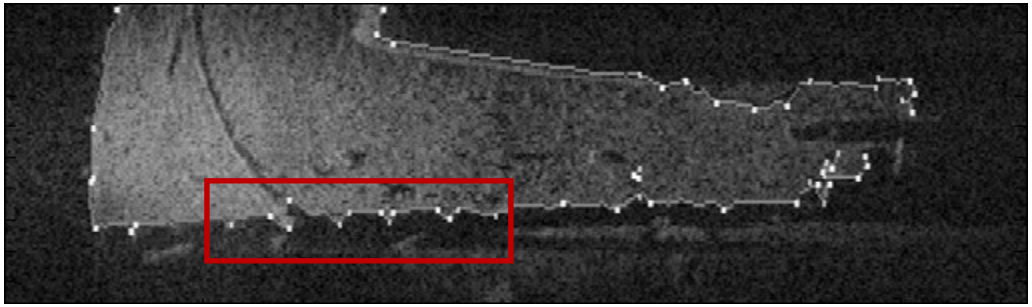
Frame i+15

Example of corresponding points

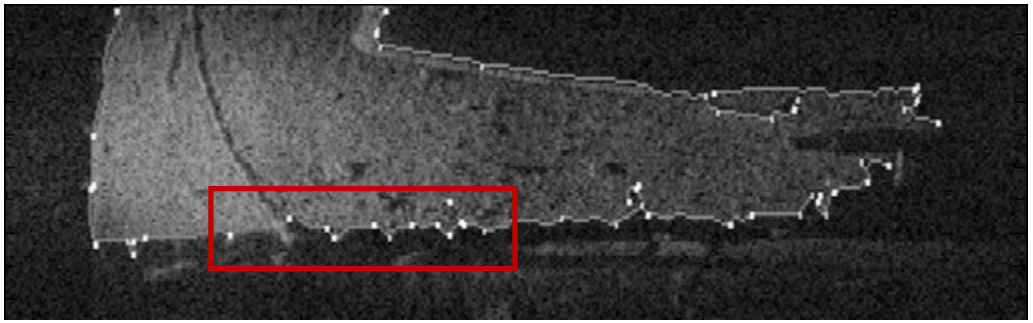


4- Salient point detection

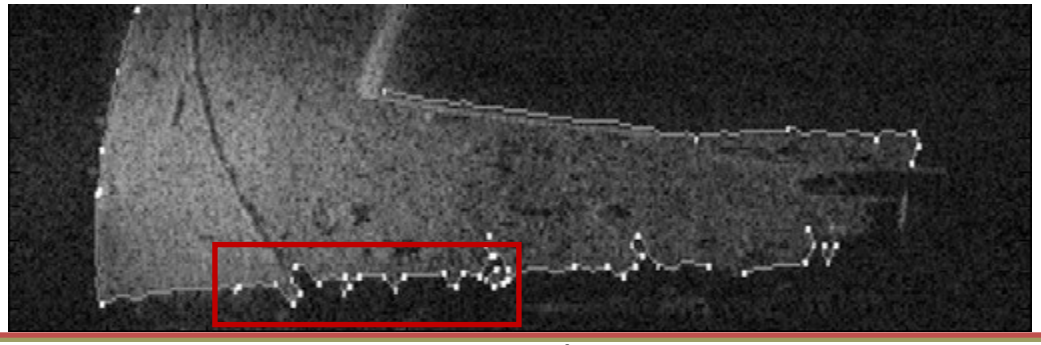
Bridge sequence



Frame i

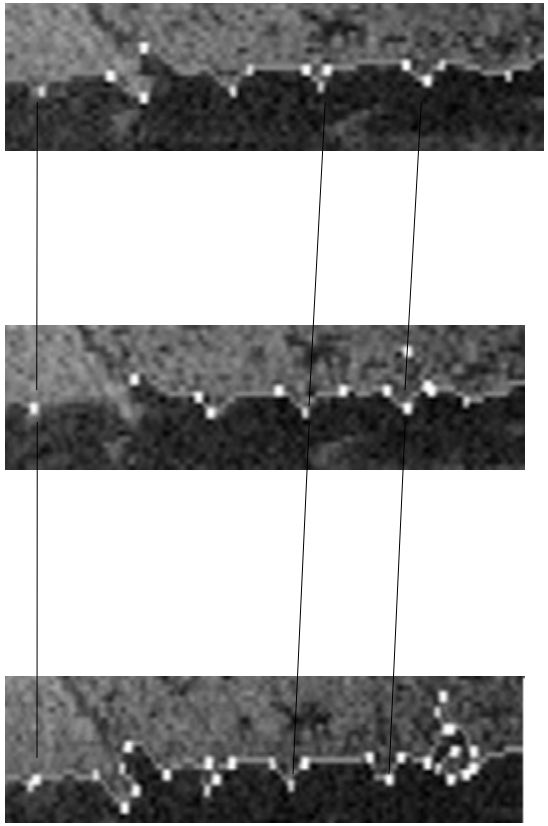


Frame i+1



Frame i+15

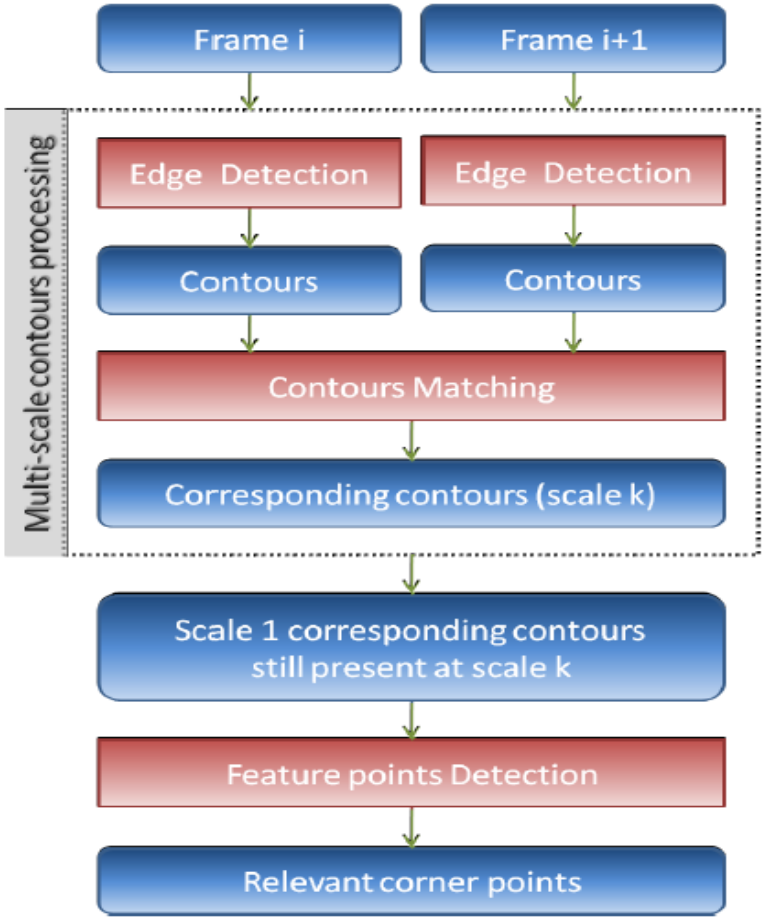
Example of corresponding points



Conclusion & future work

This research work proposes:

- A new methodology to extract robust feature points that enable 3D reconstruction of underwater scenes
- This approach is based on contour extraction, multi-scale analysis and corner extraction



Conclusion & future work

- The proposed method demonstrates good performances and promising results

- The next step will consist in devising the reconstruction methodology relying on these results:
  - Feature point matching
  - Computation of the camera movement
  - 3D reconstruction from corner points

Acknowledgement

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Questions ?

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