Recognition of man-made objects in underwater videos

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ISEN école d'ingénieurs

THALES

Outline

Outline

ISEN Brest research laboratory (L@BISEN)

13 researchers, 3 HDR, 8 PhD students

- Acoustic instrumentation

  Gilles Keryer: gilles.keryer@isen.fr

- E-learning

  Jean Pierre Gerval: jean-pierre.gerval@isen.fr

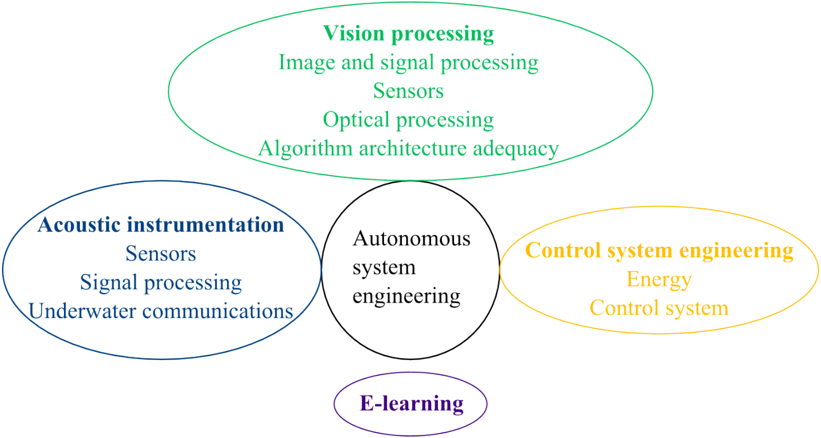
- Control systems engineering

  Emmanuel Delaleau: emmanuel.delaleau@isen.fr

- Vision processing

  Ayman Alfalou: ayman.al-falou@isen.fr

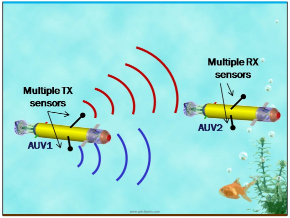
ISEN Brest research laboratory (L@BISEN)



Acoustic research

Underwater acoustic communications

- ➢ Underwater channel modeling
- ➢ Multi-input multi-output (MIMO) techniques are considered to overcome the bandwidth limitation of under-sea channel



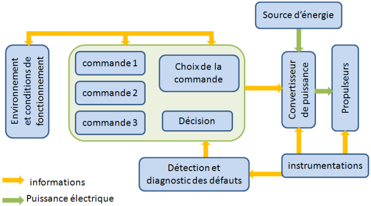
contact: Gilles.Keryer@isen.fr

P.J. Bouvet, A. Loussert , "An analysis of MIMO-OFDM for shallow water acoustic communications," OCEANS 2011 , vol., no., pp.1-5, 19-22 Sept. 2011

Robotic research

Control Systems Engineering

- ➢ Energy management to increase robot autonomy
- ➢ Fault diagnosis
- ➢ Data fusion for robot navigation

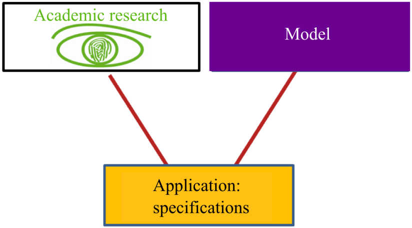


contact: laure.amate@isen.fr

V. Choqueuse, M.E.H. Benbouzid, Y. Amirat and S. Turri, "Diagnosis of three-phase electrical machines using multidimensional demodulation techniques," IEEE Transactions on Industrial Electronics, vol. 59, p.2014-2023, 2012

Vision research

- ➢ Low-level processing
- ➢ High-level processing
- ➢ Algorithm architecture-adequacy



contact: ayman.al-falou.@isen.fr

9 journal articles in 2012

Outline

1. Research at ISEN

2. Context
   - Mine warfare
   - Scenario
   - PhD subject

3. Preprocessing

4. Detection

5. Identification

Context

Mine warfare

Underwater mines are used in sea warfare
⟹ For instance, Gulf wars (1980-1988, 1990-1991)

Asymmetrical threat:

- Cheap weapons
- Considerable damage

Psychological threat

⟹ Specific means are needed to handle this threat

Figure: Spherical mine (http://jdb.marine.defense.gouv.fr)

Context
Scenario

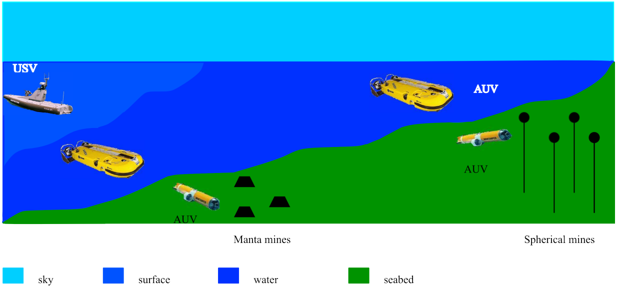


Figure: Scenario, adapted from [1]

AUV: Autonomous Underwater Vehicle

USV: Unmanned Surface Vehicle

"Guerre des mines: à l'heure de la robotique," *Mer et marine*, vol.1, p.51, 2010

Context
PhD subject

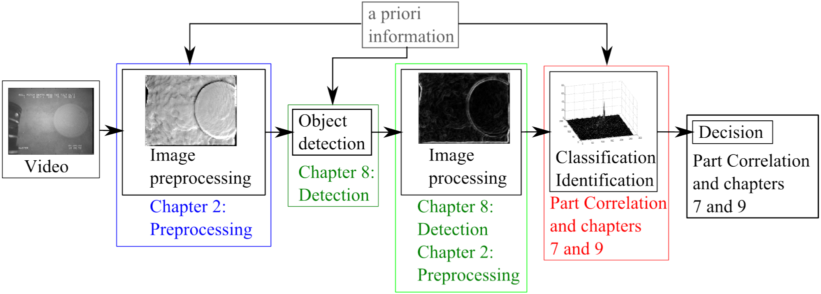


Figure: Proposed workflow

Outline

Preprocessing

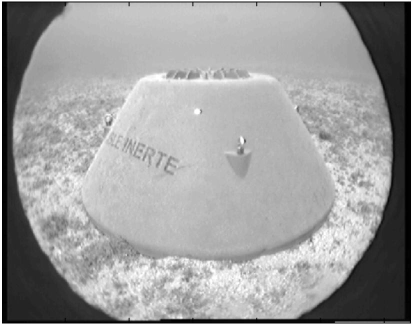


Figure: Manta mine

Preprocessing

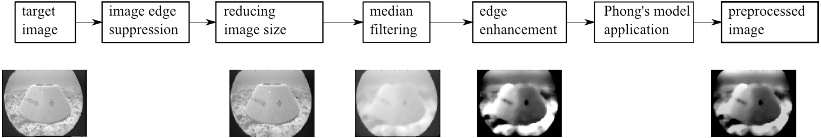


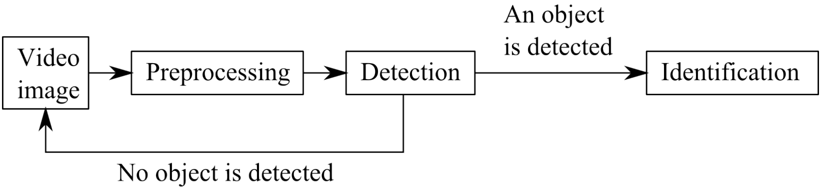
Figure: Image preprocessing

I. Leonard, A. Arnold-Bos, A. Alfalou, and N. Mandelert, "Improvement of automatic man-made object detection in underwater videos by use of navigational information," in ICoURS'12, octobre 2012.

Outline

Object detection
Why?

Algorithm embedded on AUV
⟹ Processing time should be close to real time

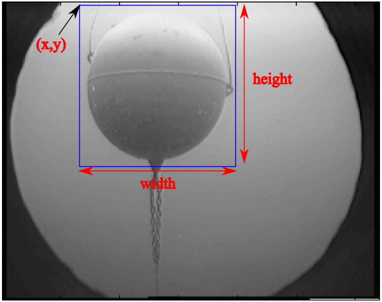


⟹ Processing results should be quantified (probabilities)

Object detection
Result quantification

Results quantification = comparison of detected object position and real object position

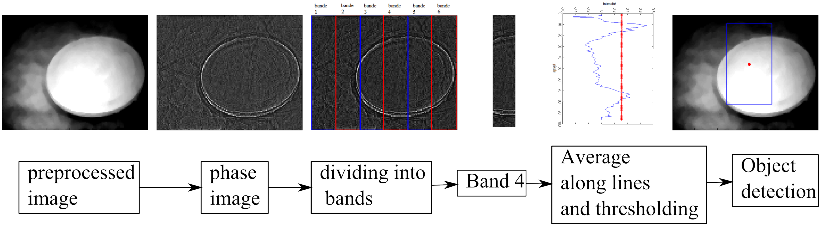
Creation of files containing top left angle position, width and height



		Reality	
		Mine	Nothing
Results	Mine	Pd detection	Pfa false alarm
	Nothing	Pndf false negative	Pndv true negative

Object detection
Phase image algorithm

Detection of change in phase image



Object detection

Phase image algorithm

Results on two image sets

On highly contrasted images:

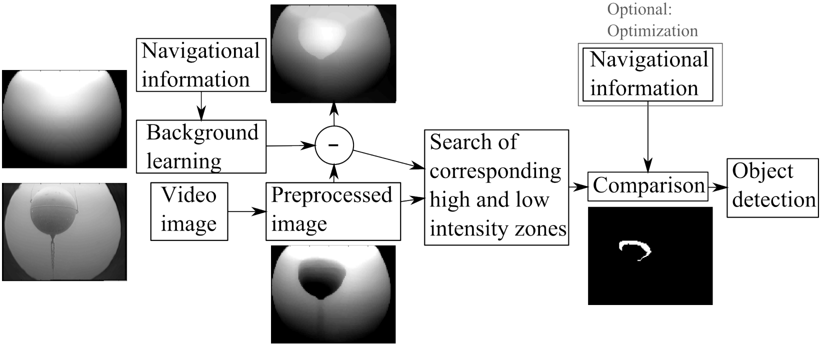
Detection probability higher than 60%

On poorly contrasted images:

Very low detection probability

$\Longrightarrow$ Need for a method without edge detection

Object detection
Background subtraction algorithm



I. Leonard, A. Arnold-Bos, A. Alfalou, and N. Mandelert, "Improvement of automatic man-made object detection in underwater videos by use of navigational information," in ICoURS'12, octobre 2012.

Object detection

Optimized background subtraction algorithm: results

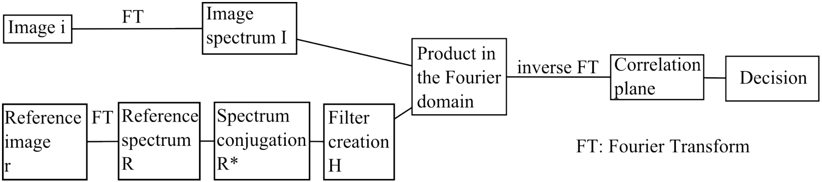
Mine	Number of tested images	Number of mine images	Ptp	Pfp	Pfn	Ptn
Manta	25205	18275	32.86%	20.83%	26.19%	96.61%
Cylinder	49251	37564	49.41%	62.37%	16.48%	31.61%
Sphere	11376	7919	43.23%	2.1%	56.41%	99.4%
Other objects	13905	10222	46.82%	71.94%	34.72%	13.96%
Empty	17389	0		4.13%		95.87%

Outline

Object identification

What is correlation?

Vanderlugt correlator



Correlation filter: Phase only filter (POF)

$$H(\mu,\nu) = \frac{R^*(\mu,\nu)}{|R(\mu,\nu)|}$$

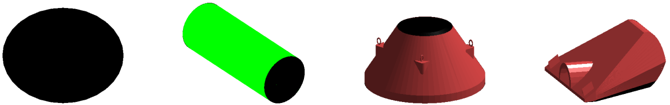
Decision criterion: Peak to correlation energy (PCE)

$$PCE = \frac{\sum_{x=x_0-t}^{x=x_0+t} \sum_{y=y_0-t}^{y=y_0+t} |C(x,y)|^2}{\sum_{x=1}^{x=N} \sum_{y=1}^{y=M} |C(x,y)|^2}$$

Object identification

Reference images

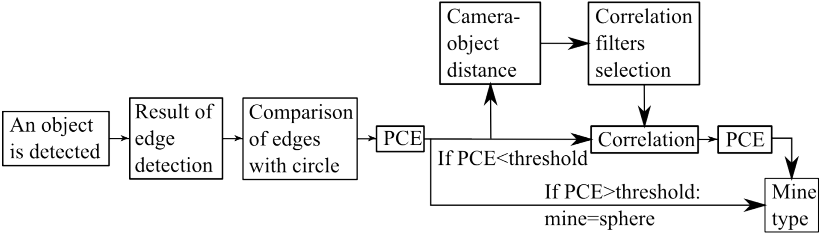
- Problems of using real images as reference images:
  - Mine points of view
  - Images are perturbed by underwater noise
- Proposed and validated solution:
  - Computer generated images
  - Group reference images according to viewer position



I. Leonard, A. Arnold-Bos, and A. Alfalou,Interest of correlation-based automatic target recognition in underwater optical images: theo-retical justification and first results,Proc. SPIE7678, 767800 (2010)

Object identification

Identification with composite POF filters

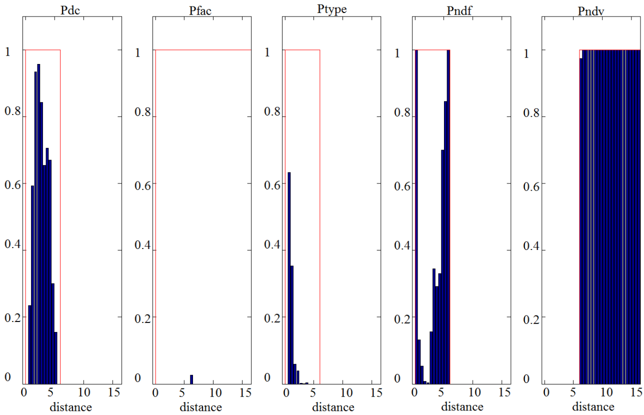


Object identification

Identification with composite POF filters

Spherical mine identification

Pdc=50.37%
Ptype=9.08%
Pfac=0.001%
Pndf=40.54%
Pndv=99.8%



Outline

Future prospects

Use of light polarization

- Study the impact of image quality on preprocessing needs

Use of numerical devices: GPU and FPGA

- Real time algorithm
- Algorithm embedded on autonomous underwater vehicle

M. Dubreuil, P. Delrot, I. Leonard, A. Alfalou and C. Brosseau,"Imaging polarimetry and optical correlation-based techniques for improved underwater target detection," Applied Optics (2012) (revisions)

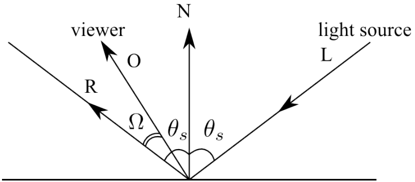
Y. Ouerhani, "Contribution à la définition, à l'optimisation et à l'implantation d'IPs de traitement du signal et des données en temps réel sur des cibles programmables," Thèse de doctorat, Université de Bretagne Occidentale, 2012

Thank you for your attention!

Questions?

Preprocessing
VAMA preprocessing

Phong's model:



$$I_{\text{transmitted by object}} = I_{\text{ambient}} + I_{\text{diffuse}} + I_{\text{specular}}$$

In the underwater medium:

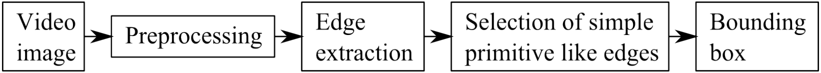
$$I_{\text{transmitted by object}} = e^{-cz}(I_{\text{ambient}} + I_{\text{diffuse}} + I_{\text{specular}})$$

B. Phong, "Illumination for computer generated pictures," in *Communications of the ACM*, vol.18, n.6, p.311-317, 1975.

Comparison with a reference algorithm

Reference algorithm

Algorithm developed by Cybernetix and Thales



N. Mandelert and A. Arnold-Bos, "Joint sonar and video sensing for a fire-and-forgot underwater mine disposal munition," in *Proc. 3rd conference on maritime systems and technology*, 2008

Comparison with a reference algorithm

Result comparison

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Empty videos	17389	0		4.13% 8.57%		95.87% 91.43%

Table: Blue: Proposed algorithm. Red: reference algorithm