DIRECTIONAL DESCRIPTORS USING ZERNIKE MOMENT PHASES FOR OBJECT ORIENTATION ESTIMATION IN UNDERWATER SONAR IMAGES

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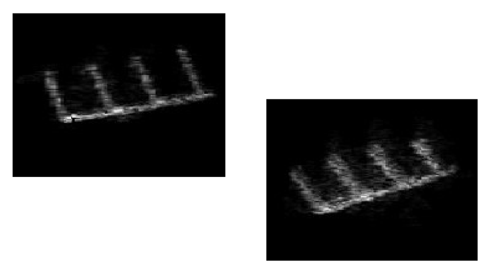
Orientation Estimation

Problem

Estimate the angle of rotation between similar objects in two different sonar images.



Other Approaches

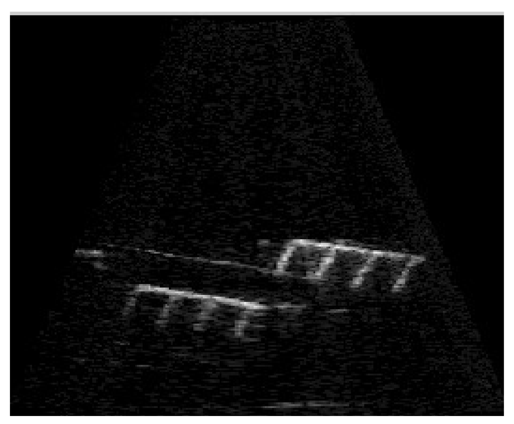
- SIFT- Scale Independent Feature Transform
- Generalized Principle Axes
- Other Zernike Phase based approaches.[2] [3]

Imaging Sonar

Issues

Uncertainties in object appearance due to nature of sonar imaging, resulting from :

- Hardness/Texture of the object
- Characteristics of the local medium
- Grazing angle of sonar beam
- Heavy clutter around objects of interest



A sample frame showing objects of interest

Object Descriptors need to be **compact** so that they can be used onboard an AUV which has limited bandwidth capabilities and **robust** to changes in this imaging modality.

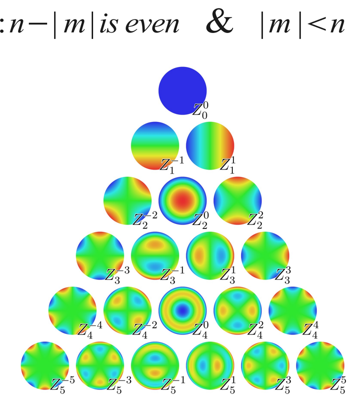
Zernike Basis Functions

Zernike Polynomials : $V_{nm}(x,y) = V_{nm}(\rho,\theta) = R_{nm}(\rho)e^{-jm\theta}$

$$R_{nm}(\rho) = \sum_{s=0}^{\frac{n-|m|}{2}} (-1)^s \frac{(n-s)!}{s!\left(\frac{n+|m|}{2}-s\right)!\left(\frac{n-|m|}{2}-s\right)!}\rho^{n-2s}$$

$$\forall (n,m): n-|m| \text{ is even} \quad \& \quad |m|<n$$

- Orthogonal Basis Functions
- Only a few allowed m,n values. (36 polynomials for n<=10)



Zernike Moments

$$A_{nm} = \frac{n+1}{\pi}\int\int_{x^2+y^2\le 1} \underbrace{f(x,y)}_{\text{Image}} V^*_{nm}(\rho,\theta)\,dx\,dy$$

- Lower order Zernike moments contain coarser shape descriptions that generalize well.
- Zernike moments upto the 10th order were used. (n<=10)

Rotation by an angle α

$$A^{\alpha}_{nm} = A_{nm}e^{-jm\alpha}$$

- The **magnitude** of Zernike moments is rotation invariant [1] .
- The rotation information is stored in the **phases** of the zernike moments [3].

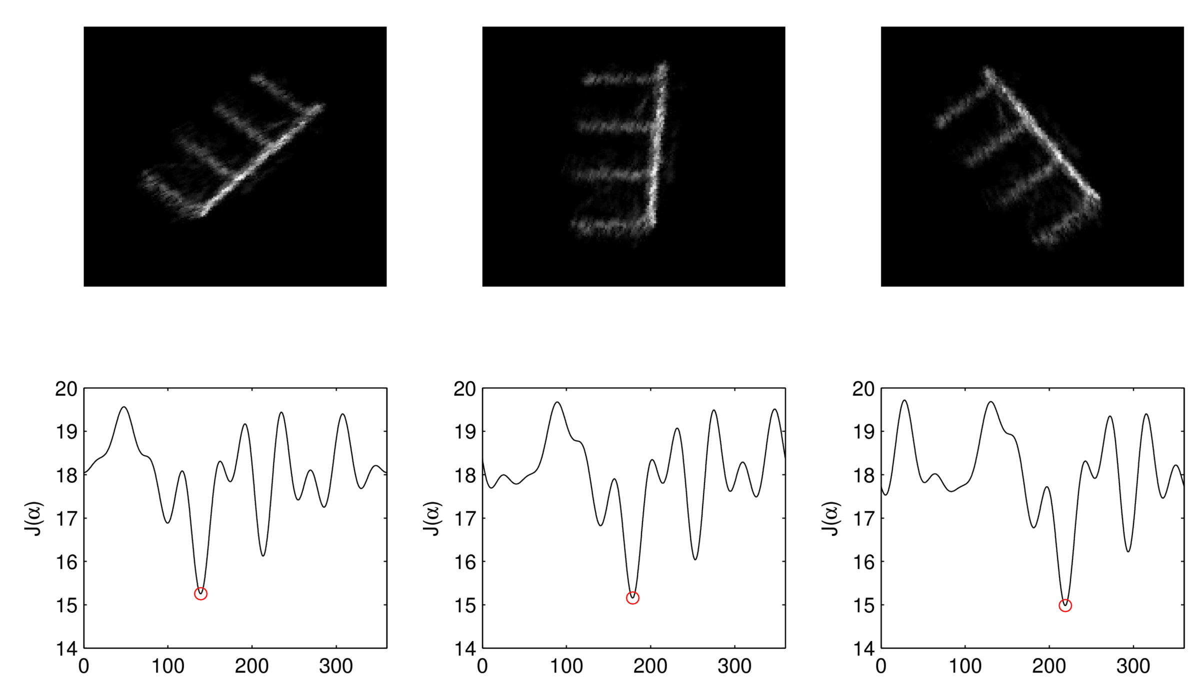
$$\phi^{\alpha}_{nm} = \phi_{nm} - m\alpha$$

Proposed Directional Descriptor

$$J(\alpha) = \sum_{n=0}^{N}\sum_{m}\sin^2\left(\frac{\phi_{nm}-m\alpha}{2}\right) \quad \text{for } \alpha \in (0, 360^\circ)$$

Properties

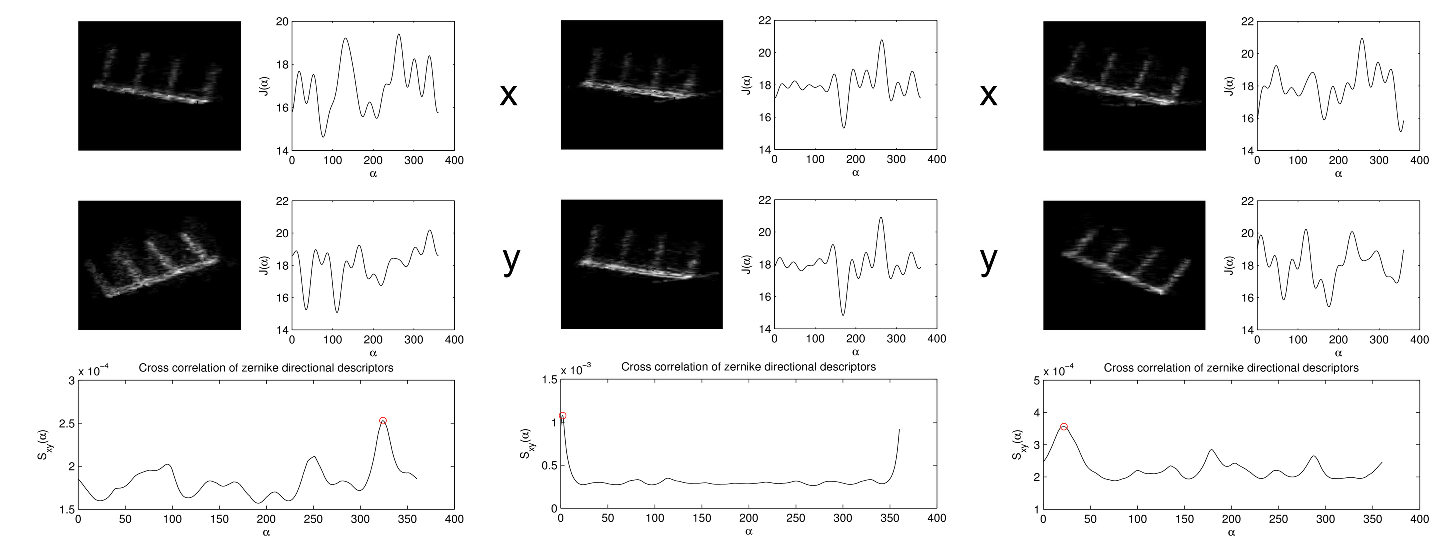
- Equivalent to rotating the object at different angles and computing J.
- J gives a “theoretical” curve describing the object from different directions.
- Matches the intuition of periodicity for rotation.



An object synthetically rotated at angles of 30°, 70°, 110° and the corresponding directional descriptors.

Note the circular shift in directional descriptor J due to rotation!

Estimate circular shift



(a) Clockwise Rotation (b) No Rotation (c) Counter-Clockwise Rotation

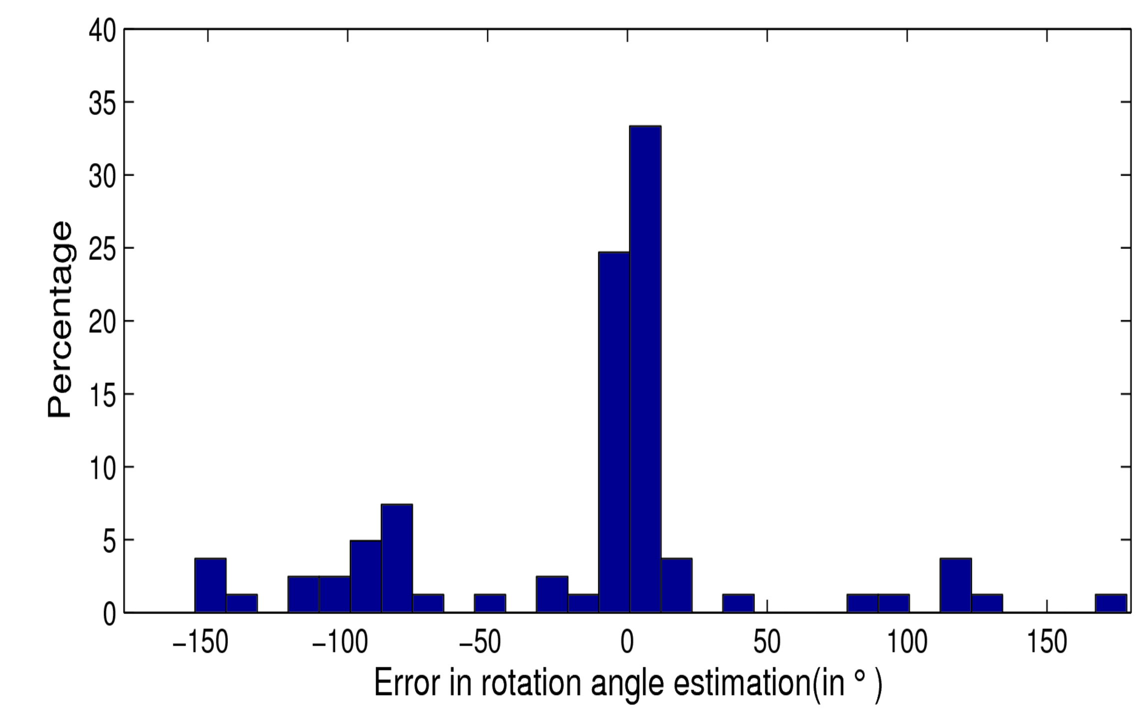
$$S_{xy}(\alpha) = \frac{CCF(x,y)}{AMDF(x,y)}$$

CCF : Circular Cross Correlation Function

AMDF : Circular Average Magnitude Difference Function

Rotation angle estimated by the peak

Results



- Tested on 81 objects from MIT DIDSON [4] forward looking sonar database.
- Median absolute error = 6°
- Z-test for estimator $(H_0 : \mu = 0)$ was significant (p-value=0.9762)

References

(1) A. Khotanzad and Y.H. Hong. "Invariant Image Recognition by Zernike Moments" *IEEE Transacions on Pattern Analysis and Machine Intelligence.*

(2) W.Y. Kim and Y.S. Kim, “Robust Rotation Angle estimator”, *IEEE Transaction on Pattern Analysis and Machine Intelligence.*

(3) J. Revaud, G. Lavou´e, and A. Baskurt, “Improving zernike moments comparison for optimal similarity and rotation angle retrieval,” *IEEE Transactions on Pattern Analysis and Machine Intelligence.*

(4) E. Belcher, W. Hanot, and J. Burch, “Dual-frequency identification sonar (DIDSON),” in Underwater Technology, 2002.*Proceedings of the 2002 International Symposium on. IEEE,*

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