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HAUSDORFF DISTANCE OPTIMIZATION USED FOR UNDERWATER PASSIVE SOURCE LOCALIZATION WITH REAL DATA EXPERIMENT

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Introduction

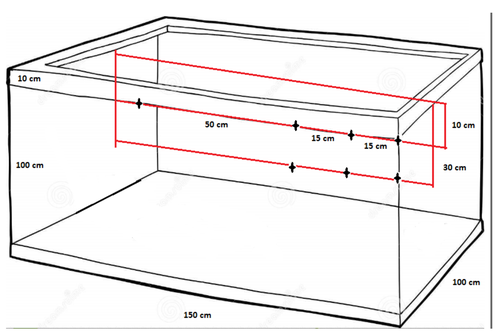
Passive source localization remains one of the major problems in underwater warfare. It allows detecting, classifying, locating and tracking hostile forces during an underwater operation keeping its main goal, being stealthy. Through this new approach proposed in this work, it becomes possible, with two proposed processing techniques, to detect not only the target in horizontal direction of arrival, but also in range of the source and in depth. Those results are based on Ray Path propagation, that has been used since early 1960s, used commonly for high frequencies and deep water, because it is only valid if the magnitude distances order involved are much greater than the wavelength (BREKHOVSKIKH, 2003).

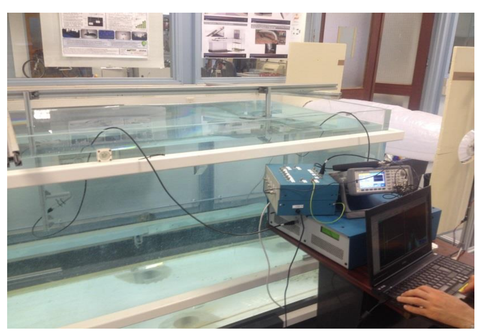
Objectives

- Localize a real signal in a tank in range and in depth, in order to define the best approach for localization problem.
- Test two techiniques, Hausdroff Distance, and Sum of minimum distance), to compare the TDOA recorded in the tank and simulated in Matlab using a ray propagation code, in order to find the minimum error that correspond the correct position.

Experiment in the Tank (GIPSA-LAB)

This experiment was conducted on 14.07.2016 in Grenoble - France, in the tank of the laboratory of GIPSA-LAB at University of Grenoble, whose size is 1.5 meters length by 1 meter width by 1 meter height, (shown in Figure 4).





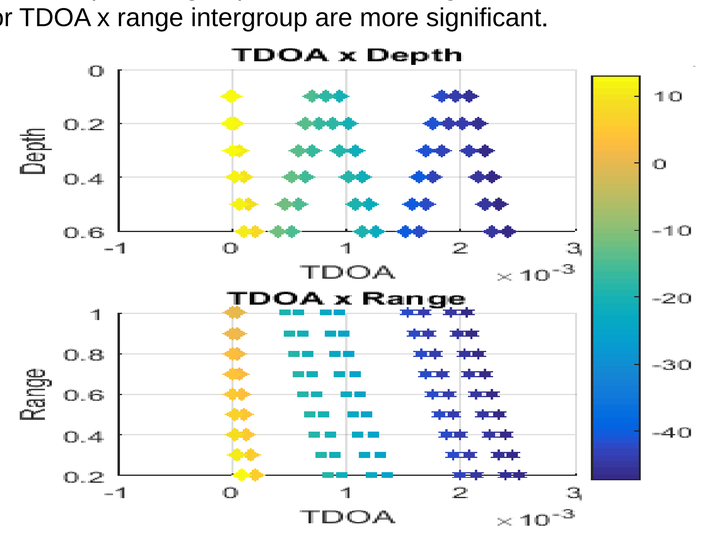
Measurement setup

For the transmission, the sensor was located at 0.1 m deep,. For the reception, the sensor was located at 0.3 m deep and 0.7 m range, centered horizontally in the tank. Given that the sensors Technisonic ISL-0104-GP were very directive with bandwidth of 7 degrees and a frequency range of 500 KHz - 1.5 MHz, for each set of signals we had to write a package containing 10 different take off angles, in order to record all the different ray paths.

Two signals were transmitted in this experiment:

Trasmitted signal		
type	Time (s)	Frequency (Hz)
Impulse	1/25MHz	---
Chirp	100µs	500KHz-1.5MHz

The TDOA was simulated with step variation, in depth and in range, of 0.1 m, the references for this plots were 0.7 m range and 0.3 m Deep. we only consider 3 different groups, which differ by the reflection number on the bottom, first group, zero bottom reflection (yellow), second group, one bottom reflection (green) and third group, two bottom reflections (blue). The variation of TDOA x Depth intragroup become more significant due to the dispersion, and for TDOA x range intergroup are more significant.



Variation of TDOA in depth and range

Comparison Techniques

• Hausdorff Distance

The function h(TDOAs(d,r),TDOAr) is referred to as the directed Hausdorff distance from the simulated to the received. It categorizes each arrival time of the simulated according to its distance (difference of time) to the nearest arrival time of the received. The largest of these distances determines the value of h(TDOAs(d,r),TDOAr). (D. P HUTTENLOCHER, 1993)

$$\mathrm{h}(\mathrm{TDOA}_s(\mathrm{d},\mathrm{r}),\mathrm{TDOA}_r) = \max_{(\mathrm{d},\mathrm{r})}\{\min_i[|\mathrm{TDOA}_s(\mathrm{d},\mathrm{r})(\mathrm{i}) - \mathrm{TDOA}_r|]\}$$

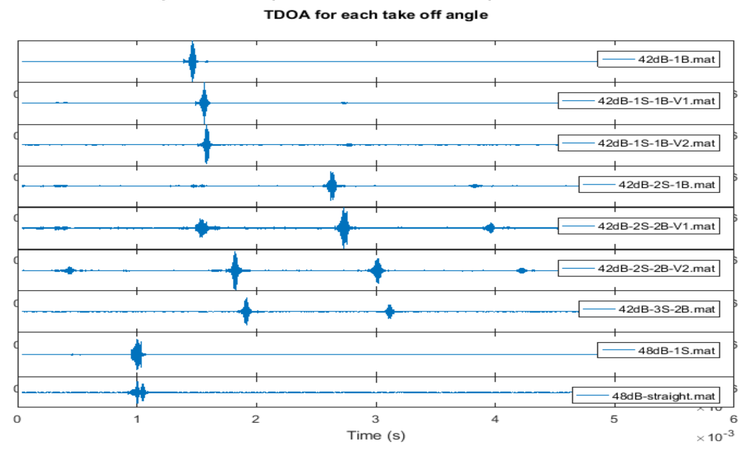
Sum of minimum distance

The function $SMD(\mathrm{d},\mathrm{r})$ take in count every difference between a set of points instead of only the maximum difference.

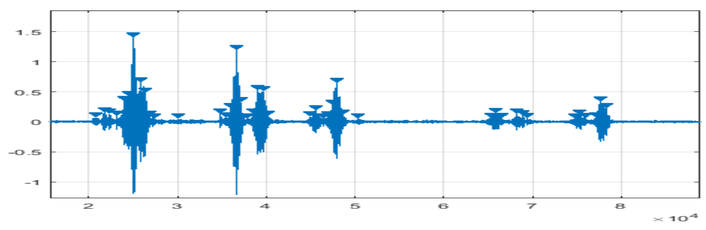
$$SMD(\mathrm{d},\mathrm{r}) = \sum_{i=1}^{n} \min_i[|\mathrm{TDOA}_s(\mathrm{d},\mathrm{r})(\mathrm{i}) - \mathrm{TDOA}_r|]$$

Results

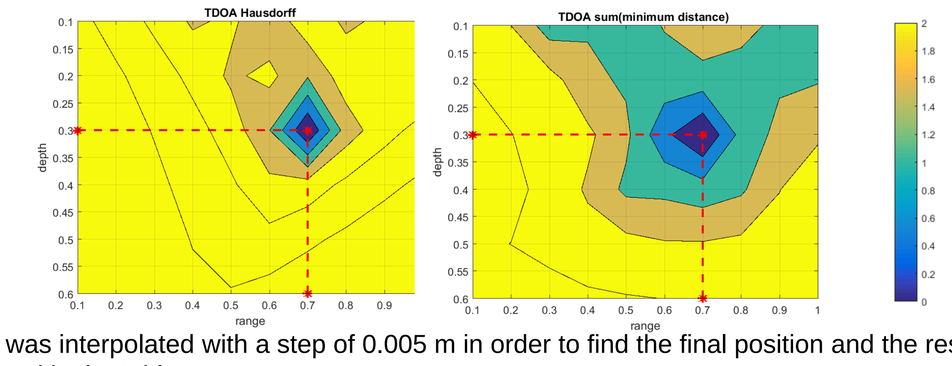
Each different take off angle correspond one different path with a different arrival time.



The sum of all those different take off angle give us the received signal, then we extract the final arrival time. The signal noise ratio for this measured is 23.69dB.



In order to compare the most accurate technique, the results of error was normalize and we kept the same scale after applying the logarithmic scale of the error. The dark blue means the error near to zero that correspond the best result, in both technique we can localize correctly our target with a small variation of error that corresponding the area of the dark blue surface, being the Hausdorff distance more accurate for this measure than sum of minimum distance



Both plots was interpolated with a step of 0.005 m in order to find the final position and the results are presented in the table.

		TDOA Hausdorff	TDOA SMD
estimated	range	0,645	0,645
	depth	0,285	0,29
error	range	0,055	0,055
	depth	0,015	0,01
Total error		0,057	**0,056**
area		**0,0023**	0,0029
Total error X area		**1,30E-04**	1,61E-04

Future Works

- Other signals (Stationary signal, real signals from the sea)
- Other hydrophones with a larger bandwidth (Beamforming)
- Combine the beamforming with the TDOA in order to improve the accuracy with a lower SNR
- Other environments (lake in Annecy, south sea of France)

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