IMAGE PROCESSING BASED STRATEGY FOR ADAPTIVE WIDEBAND ECHOLOCATION

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ABSTRACT

Wideband bio-inspired sonar allows to study echo structure over a broad range of frequencies. The emitted wideband pulses have a linear chirp design. The structure of reflected pulses from the object provides information about a target's content. Dips and peaks in the echo structure provide information about the target characteristic. The echo is highly dependent on the emitted pulse. Therefore classification result can be improved by an adaptive approach where the emitted pulse is being refined based on echo processing. This research presents a novel approach of wideband pulse adaptation for better object characterisation. The paper describes an adaptation of a pulse's slope values. Image processing techniques are applied to localize peaks and dips in the Time-Frequency Representation of the echo signal.

***Index Terms*—** Wideband sonar, Time-Frequency Representation, chirp, object characterisation, adaptive sensing

1. INTRODUCTION

Most sonars use narrow bandwidth pulses and measure timing of the returned ping. The wideband sonar is a relatively new technology, which brings the possibility to study broadband echo structure. The sonar works over the same frequency range as dolphins' echolocation. It can emit signals from 30 to 160 kHz. The pulses used have a chirp-based structure and are inspired by dolphin echolocation systems. For object identification the animals use wideband and high intensity double chirp pulses, also called clicks. The complex structure of the pulses provides the animals with information about the object's size, shape and even internal content. Dolphins vary some parameters of the clicks during the recognition process. It allows them to "tune" the pulse for the particular task, target, environment and achieve better results in object identification [1].

The generated bio-inspired wideband pulse is not exact duplicate of the dolphins' clicks. It can be presented as a combination of one or more chirp components. The wideband sonar echoes provide information about the pulse-object interaction. The echo structure can be studied through energy distribution in the frequency and time-frequency domains. The energy distribution will be different for different objects' material and content, which allows discrimination between object with the same form, but different shells and filling materials. Gaunaurd in [2] uses a recording of the dolphin clicks and consider spacing between the resonance peaks for the target classification. Comprehensive research and practical work on object identification and classification was performed by Pailhas *et al* [3]. They considered peaks and dips in the echo spectrum, which caused by resonance phenomena and identifies a target by evaluation of the positioning of the peaks and dips.

There is a strong dependency between emitted pulse structure and echo interpretation [4]. The target identification can be improved by using adaptive pulses. Dolphins transmit a set of pulses and change the pulse structure from pulse to pulse, which supports the idea of the adaptive echolocation system. The emitted pulses can be changed based on the returned echo's structure of the reflected pulse. This way the emitted pulse structure can be adapted for different targets and the surrounding environment [5].

The PhD research is focused on the adaptive approach in bio-inspired wideband echolocation for better object characterisation. The presented work, as part of the research, shows an adaptation of the chirp's slope value based on the representation of the echo structure.

The targets used were spherical objects submerged in a 3m x 4m x 2m water tank. The pulses are single chirp pulses with constant frequency range and different slope values. The slope of the signal was changed by varying the duration of the pulse. Frequency range of the pulses was from 30 kHz to 160 kHz. The pulse duration was varied from 0.1 msec to 3 msec in 0.1 msec increments.

The echo is presented in the Time-Frequency Domain (TFD) and some image processing technique are applied to evaluate the peaks and dips locations. The paper presents a methodology of the approach and early stage results.

2. METHODOLOGY

The aim of the approach is to choose a pulse with the best distinction of the dips and peaks in echo structure from a set of pulses with different slope values. The position of the dips and peaks is stable for the different values of the chirp slope, but the depth of the dips and intensity of amplitude

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of the peaks vary depending on the slope. The concept is based on the evaluation of the peak-dip ratio. A set of pulses with different slopes was processed and pulse with the highest peak/dip ratio in the received echo was chosen for the object characterisation.

The approach can be presented with a few steps: (1) Time Frequency Representation (TFR), (2) localisation of the peaks and dips, using Image Processing techniques and (3) calculation of a peak/dip ratio for the final decision about the slope value. The input of the adaptive scheme is a set of echoes with different slopes. The echo is represented in Time-Frequency Domain by Smoothed Pseudo Wigner Ville Distribution (SPWVD). The distribution provides fine resolution in time and frequency domain. Although it contains some cross terms, they are reduced by smoothing function and the applied windowing. Figure 1 presents an example the TFR of four echoes with different slope values. In all 4 plots in figure 1 (a-d) the first chirp is a specular reflection and the second chirp is a reflection from a back wall of the sphere. The visible line with the set of peaks and dips in between is a core component for this approach. The peaks and dips line (PDL) is formed by the resonance phenomena and also is influenced by the cross terms. The PDL representation is depending on the slope of the pulse. The overall aim of this work is to adapt a slope value of a chirp pulse to a different spherical objects (different sizes and materials) based on the representation of the PDL.

For the slope evaluation, the TFR is processed using image processing techniques. Firstly the TFR is thresholded around mean values in a way that only highest and lowest values are left. This allowed elimination of some of the cross terms and improves subsequent analysis. The next step is to use a canny edge detector and hough line transform to find the echo slope. In the next step the algorithm uses the slope value and moves through the image to find the PDL, using a supervised technique. The detected PDL is projected into the frequency axis. The separation of the peaks and dips provides a clearer picture of dips and peaks without interfering with the other components of the echo. The peak/dip values are calculated for each echo. The decision is made based on the calculated ratio values.

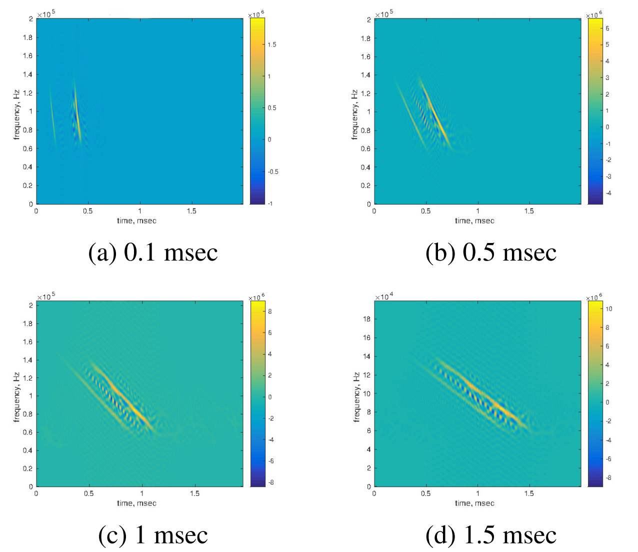
3. RESULTS

An aluminium sphere (8 cm diameter) was ensonified with a sequence of down-chirp pulses. Table 1 presents a selection of the echo parameters. The slope value is a measurement of a chirp slope in the TFD.

Table 1. Experiment results

duration, msec	0.3	0.5	1.0	1.5	2.0	2.5
slope	-1.65	-1.04	-0.51	-0.36	-0.27	-0.21
ratio value	0.74	0.74	0.75	0.94	0.86	1.04

The PDL first becomes visible in the 0.3 msec pulse, an overlapping effect limits the pulse duration to 2.5 msec so this limit is used. The ratio value significantly improved with the 1.5 msec pulse and should be chosen as a preferable value for the target and environment.



(a) 0.1 msec (b) 0.5 msec (c) 1 msec (d) 1.5 msec

Fig. 1. Example of echoes reflected from the same aluminium sphere with different slope values (different pulse duration).

4. CONCLUSION AND FUTURE WORK

This paper has presented work on the adaptive wideband echolocation with an image processing based strategy. The transmitted chirp pulse is adapted for the better object characterisation based on the representation of peaks and dips in the echo structure. The only one parameter that is being varied in the work presented here is the slope value of the chirp pulse.

The future work involves validation of the chosen parameters based on the classification result, as well as increasing number of the adaptive parameters.

5. REFERENCES

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