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BICA*AI 2023

BICA VPS 2023

A Prediction Model for the Equivalent Parameters of an Acoustic Transducer Based on DPSD and LSTM Neural Network.

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SUMMARY

This paper uses digital phase-sensitive detection (DPSD) and long shortterm memory (LSTM) neural network to predict the equivalent parameters of underwater acoustic transducers, and verifies through MATLAB simulation experiments that LSTM is more accurate and stable than gated recurrent unit(GRU) neural network.

INTRODUCTION

This paper uses DPSD and LSTM neural network to predict the equivalent parameters of underwater acoustic transducers. DPSD can extract the amplitude and phase information of the transducer from noise, and LSTM can predict the equivalent model and parameters of the transducer by classification and regression. This paper constructs five RLC equivalent models of the transducer, and generates a large amount of transducer data with different RLC parameters by MATLAB simulation, which are used for training and testing LSTM neural network models.

APPROACH

This paper uses digital phase-sensitive detection (DPSD) to extract the amplitude and phase information of the transducer, generates the amplitude and phase data of the transducer with different RLC parameters by MATLAB simulation, and uses long short-term memory (LSTM) neural network to classify and regress the transducer model and parameters.

METHODS

1.Digital Phase-Sensitive Detection.

This paper uses an improved digital phase-sensitive detection method, which uses FFT to calculate the cross-correlation operation in digital phase-sensitive detection, and improves the calculation accuracy and operation efficiency of digital phase-sensitive detection.

2. Long Short-Term Memory(LSTM)

the LSTM can automatically learn the characteristics and rules of input data , which performs well in regression prediction

RESULTS

Device Under Test	Theoretical Phase Difference	Original Phase Difference	Improved Phase Difference	Theoretical Amplitude	Original Amplitude	Improved Amplitude	Test Frequency
A	3.59	3.72	3.63	10.02	10.08	10.07	100KHz
B	12.52	12.68	12.58	158.87	155.46	160.02	100KHz
A	10.67	10.85	10.74	10.18	9.94	10.19	300KHz
B	-25.38	-25.45	-25.52	365.64	367.13	364.23	300KHz
A	17.44	17.70	17.55	10.92	10.72	11.06	500KHz
B	-77.72	-77.94	-77.88	111.75	108.40	110.62	500KHz
A	32.14	32.76	32.24	11.81	12.32	11.88	1MHz
B	-88.72	-90.40	-89.29	70.41	70.09	70.24	1MHz

Fig.1:Comparison of Transducer Phase and Amplitude Measurement Results

ANALYSIS

the FFT-based digital synchronous detection generally has higher calculation accuracy than before the improvement. When we use the time-domain-based method for cross-correlation calculation, we have to calculate the product at each time point and add all the results to obtain the final result. This requires a very large amount of calculation, especially for longer signal sequences. Using the FFT method, however,we can transform a signal into the frequency domain and perform calculations in the frequency domain. This means that we only need to perform one FFT to obtain the cross-correlation results at all time points.

DISCUSSION

TM	PM	R'TV (Ω)	LSTM R'PV (Ω)	GRU R'PV (Ω)	L'TV (10^{-4}H)	LSTM L'PV (10^{-4}H)	GRU L'PV (10^{-4}H)	C'TV (10^{-9}F)	LSTM C'PV (10^{-9}F)	GRU C'PV (10^{-9}F)
A	A	333.30	332.16	336.12	2.39	2.45	2.49	1.16	1.19	1.24
A	A	63.42	64.22	60.22	2.21	2.26	2.32	19.7	20.0	18.9
B	B	271.74	274.18	278.25	1.54	1.57	1.42	21.2	21.9	23.4
C	C	79.39	80.45	77.92	8.13	8.34	8.63	21.4	22.2	23.5
D	D	343.56	349.68	348.52	3.80	3.91	4.35	27.0	27.3	27.9
D	D	237.92	238.05	240.34	1.20	1.22	1.31	4.86	4.91	4.62
E	E	112.27	114.20	108.76	0.590	0.603	0.642	26.2	26.4	25.6

Fig.2:Comparison of transducer model and para meter prediction results

The partial data given in the Fig.2 can prove that the prediction accuracy of the LSTM neural network model is higher than that of the GRU neural network model when predicting parameters for the heat exchanger.

CONCLUSIONS

This article proposes a method for predicting the parameters of a hydrophone using an improved digital phase-sensitive detection algorithm combined with a LSTM neural network model. The neural network only needs amplitude and phase data from 10 frequency points to complete the prediction.

ACKNOWLEDGMENTS

This research was funded by the Ningbo Natural Science Foundation(2022J138).