Machine Learning for Transcranial Narrowband Ultrasound Propagation Delay Estimation

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I. ABSTRACT

II. INTRODUCTION & BACKGROUND

Focused Ultrasound (FUs) is a non-invasive treatment for various disorders that can concentrate mechanical energy on specific volumes within the body. This energy can have various effects based on ultrasound parameters, such as intensity and frequency. For example, it can allow larger particles through the blood-brain barrier (BBB)[1], thermally ablate[2] tissue, or neurostimulate[3].

To ensure the accuracy of a target region within the brain, computer models[2,4] simulate the transcranial propagation of narrowband ultrasound pulses. The comparison of the simulated signal's onset to that of the experimental signal is a benchmark to validate a computer model.

Time delay estimation techniques are often used in literature[4] to identify onset delay, yet they are not ideal for this situation. The onset of multi-pulse signals in the presence of strong aberrations, such as the skull, is difficult to identify due to echoes which distort and delay the rest of the signal. Cross-correlation is a robust choice for time delay estimation, but often miss-identifies the delay and requires human adjustment for the best results[5,6].

As signal generation techniques become more advanced, and therefore signals more complex, a new onset time delay estimator is required. The goal of my project is to implement a reliable algorithm to detect the onset time delay between the two signals and validate it against current methods. In this document, I will summarize my progress in identifying which algorithms to use, their relative merits, and the current status of my derivation and development of their python implementations.

III. PREVIOUS WORK

There have been several different techniques used in literature to detect the time delay between two signals. These techniques are split into four different classes[7]: time-delay approximation model, explicit time-delay parameter, area and moment, and higher-order statistics (HOS) methods. This research will primarily use HOS methods for their ability to remove noise with a symmetric probability distribution, though all classes will be reviewed for comparison.

Unfortunately, none of these techniques have shown the ability to accurately detect the onset of a signal – most find the best fit overall, even if the signal has become delayed further after echoes cause interference[4,5]. Most methods used today were introduced pre-2000[7], and therefore don‘t take into account these new acoustic complexities.

IV. METHODS

Sections here typically describe the data structures, the algorithms, the user interface and other technical details of your solution. If you do not have the answer to a technical problem explain how you are going about seeking a solution.

V. TIMELINE

give a plan for finishing the project by the end of the Fall term.

VI. CONCLUSION

This will be brief in the proposal, but expanded to summarise your results in the interim and final reports.

REFERENCES

[1] L. H. Treat, N. McDannold, N. Vykhodtseva, Y. Zhang, K. Tam, and K. Hynynen, Int. J. Cancer **121** (2007), 10.1002/ijc.22732.

[2] C. R. Hill, I. Rivens, M. G. Vaughan, and G. R. ter Haar, Ultrasound Med. Biol. **20** (1994), 10.1016/0301-5629(94)90066-3.

[3]H. J. Jang, J.-Y. Lee, D.-H. Lee, W.-H. Kim, and J. H. Hwang, Gut Liver **4** (2010), 10.5009/gnl.2010.4.S1.S57.

[4]S. Pichardo, C. Moreno-Hernández, R. Andrew Drainville, V. Sin, L. Curiel, and K. Hynynen, Phys. Med. Biol. **62** (2017), 10.1088/1361-6560/aa7ccc.

[5]S. Pichardo, personal communication (2018).

[6]S. Pichardo, V. W. Sin, and K. Hynynen, Phys. Med. Biol. **56** (2011), 10.1088/0031-9155/56/1/014.

[7]S. Bjorklund and Lennart Ljung, in *42nd IEEE International Conference on Decision and Control (IEEE Cat. No.03CH37475)*, Vol. 3 (IEEE, 2003).

* Citations in the AIP style, used by the Journal of Applied Physics.