International Student Challenge Problem in Acoustic Signal Processing 2023

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The Acoustical Society of America (ASA) Technical Committee on Signal Processing poses international student challenge problems in the discipline of acoustic signal processing (Ferguson and Culver, 2014; Ferguson et al., 2019). The International Student Challenge Problem for 2023 involves the student (or team of students) processing real acoustic sensor data to extract information about the source from the sound that it radiates.

For the present problem, the acoustic sensors are three hydrophones, N, O, and P, located 1 m above the seafloor in water 20 m deep. The hydrophones are distributed along a straight line, with a separation distance of 14 m between adjacent hydrophones (i.e., the uniform interelement spacing of the three-element horizontal line array is 14 m). Hydrophone O is the middle sensor at the center of the array. The output of each hydrophone is sampled at the rate of 250,000 samples per second (i.e., the sampling period is 4 μs). The sampled data time series for the three hydrophones are recorded in Waveform Audio File (WAV) format. The files are Hyd N.wav, Hyd O.wav, and Hyd P.wav and can be downloaded as .wav files at acousticstoday.org/iscpasp2023.

The source is an open-circuit scuba diver swimming at constant speed and altitude along a straight-line trajectory (i.e., a line vertically above and parallel to the axis of the horizontal line array). The acoustic signature of an open-circuit scuba diver consists of a sequence of regularly spaced broadband-pulsed acoustic emissions linked to the inhaling phase of the diver's breathing cycle. The pulses are generated by the scuba equipment's high-pressure regulator where expansion of the compressed air from the tank produces turbulent airflow pressure fluctuations that excite structural vibrations of the regulator's valve and channels (Donskoy et al., 2008; Gemba et al., 2014). The student is invited to undertake two tasks.

Task 1

(a) Display the output spectrogram (frequency versus time) for one of the hydrophones (e.g., the middle hydrophone O). Comment on the spectral properties of the scuba diver's acoustic signature.

(b) Estimate the breathing rate of the diver in hertz.

Task 2

Assume that the isospeed of sound travel in the underwater environment is 1,520 m/s.

(a) Estimate the time (in seconds) when the diver is at the closest point of approach to the middle hydrophone O.

(b) Estimate the diver's altitude (i.e., the distance vertically above hydrophone O, when the diver is at the closest point of approach).

(c) Estimate the diver's swimming speed in meters per seconds.

Your solution should detail your approach, signal-processing methods, and reasoning to solve the problem as well as your best estimates of the above parameters.

The deadline for student submissions is October 31, 2023. Submit your solutions, along with your contact details and proof of student status, to asa@aip.org with the subject line "Entry for International Student Challenge Problem in Acoustic Signal Processing 2023." The finalists and prize winners (monetary prizes: first place, $500; second, $300; and third, $200) will be announced by November 30, 2023.

References

Donskoy, D. M., Sedunov, N. A., Sedunov, A. N., and Tsionskiy, M. A. (2008). Variability of SCUBA diver's acoustic emission. *Proceedings of Optics and Photonics in Global Homeland Security IV*, SPIE Defense and Security Symposium, Orlando, FL, March 16-20, 2008, vol. 6945, pp. 272-282.

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