SOUND AND THE SEAFLOOR

Determining Bathymetry Using Student-Built Acoustic Sensors

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SUPPLEMENT S2

Activity Extensions

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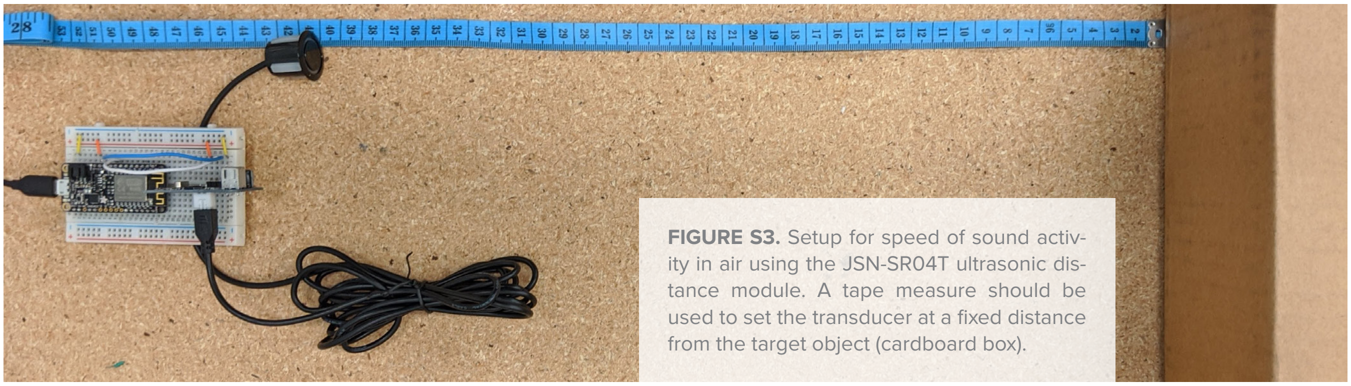

FIGURE S3. Setup for speed of sound activity in air using the JSN-SR04T ultrasonic distance module. A tape measure should be used to set the transducer at a fixed distance from the target object (cardboard box).

1. SPEED OF SOUND

As described in the Alternative Approaches and Extensions section of the activity, students can use their sensors to identify the speed of sound in air or water by recording observations at a known fixed distance and appropriately varying the speed of sound in order to approach the correct distance in their measurements. We recommend conducting this activity in a prior class period as an opportunity for students to assemble and explore their sensors by collecting repeat measurements.

1. Assemble the sensors according to the instructions provided in the Sensor Assembly Guide (S1). In addition to the materials necessary for assembly, students will need a tape measure.
2. Using a tape measure and a large object with a flat side such as a book or box, set up the sensor at a fixed distance (>5 cm) away from the object.
3. Collect 10 measurements, starting with a speed of sound *c* of 100 m s^{-1}, increasing *c* by large steps (50 m s^{-1}) with each measurement. Record and plot the values.
4. Collect another 10 measurements, this time beginning at the value of *c* from Step 3, which was the closest to the known distance without going over, and increase *c* by 5 m s^{-1} with each measurement. Record and plot the value.
5. Collect another 10 measurements, this time beginning at the value of *c* from Step 4, which was the closest to the known distance without going over, and increase *c* by 1 m s^{-1} with each measurement. Record and plot the value.

Students should now be able to approximate the speed of sound in air by incrementally increasing the resolution of their measurements with respect to *c*. When plotting the values, indicate the known distance as a horizontal line to help identify the closest measurements (**Figure S4**).

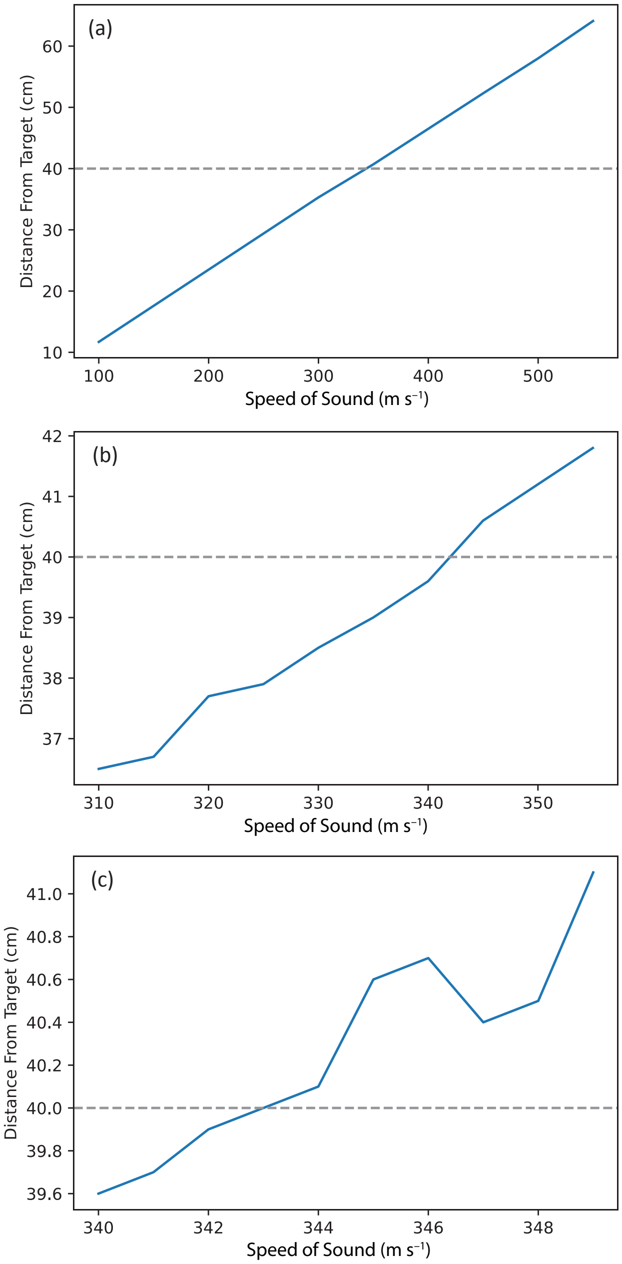

FIGURE S4. Example figures showing distance as a function of sound speed *c* in intervals of (a) 50 m s^{-1}, (b) 5 m s^{-1}, and (c) 1 m s^{-1}. Measurements produced by the sensor are shown in blue, with the known distance to the object indicated by the dashed horizontal line.

2. BATHYMETRIC CONTOURS

As described in the Alternative Approaches and Extensions section of the activity, students can use the sensor to take measurements at multiple fixed angles along the original transect. Measurements taken at an angle perpendicular to the transect demonstrate the operation of side-scan and multibeam echosounder systems and can be used to investigate more advanced data processing and visualization methods. While performing this activity, students could consider:

- How does the apparent depth/distance vary as a function of angle?
- What is the maximum angle at which a return echo is received?

At each sampling location along the transect, students should take measurements of the seafloor perpendicular to the transect, with the transducer face positioned at a known angle (**Figure S5**). As with the primary activity, repeat measurements should be collected at each location and angle position to account for potential errors and outliers.

1. Measure the depth with the transducer in a vertical position (0°) at the sampling site, collecting multiple measurements. The depth (z_1) of the seafloor is the distance reported by the sensor (d, **Figure S6a**).
2. Setting the transducer face at a fixed angle (such as with a protractor shown in **Figure S5b**), collect three distance measurements.
3. Calculate the depth (z_2, **Figure S6b**) at the location where the sound wave reflected off the seafloor. The depth can be calculated as $z_2 = d \sin(a)$, where d is the reported distance and a is the angle of the transducer relative to the surface of the water.
4. To map the measurements, determine the distance between z_1 and z_2 (**Figure S6b,c**) as $x = d \cos(a)$.

With the data collected, students can create scatter or contour plots using distance away from the dock (x), sampling location (y), and depth (z) for each of their measurements.

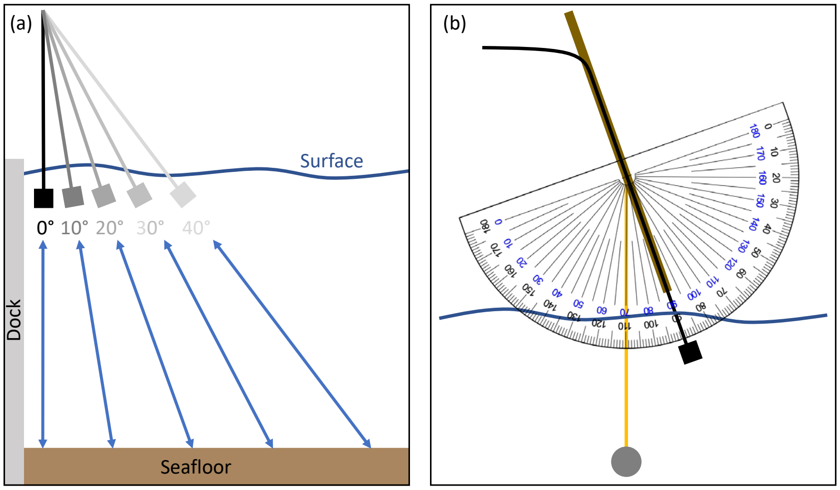

FIGURE S5. (a) By increasing the angle relative to a vertical measurement, students can collect distance measurements at positions further away from the dock. (b) Example sensor assembly. The transducer (black) is fixed to a pole at the 90° position on a protractor, with a weighted line attached (yellow/gray) used to indicate the angle.

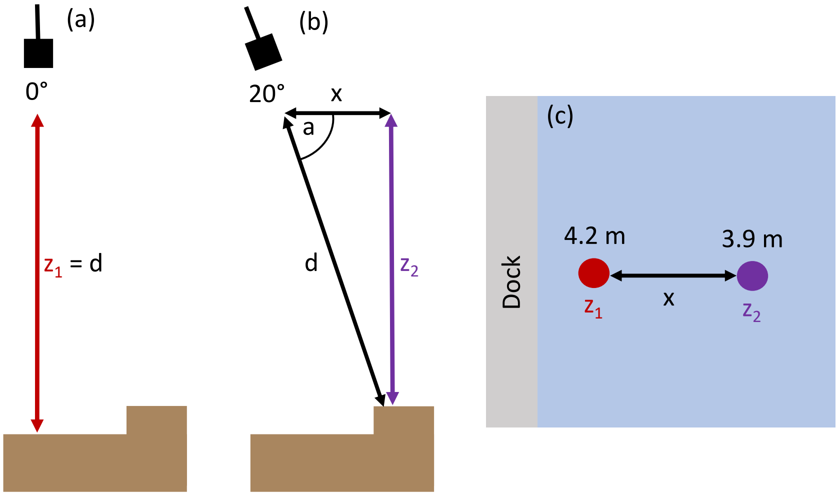

FIGURE S6. (a) Initial measurement of depth at the sampling location with transducer in the vertical position. Water depth is the sensor-reported distance (z_1). (b) A measurement taken at the same sampling position with the transducer rotated 20°. Water depth (z_2) can be calculated from the sensor-reported distance d and the angle relative to the water's surface a using basic trigonometry. (c) Aerial view to compare locations of depths measured in (a) and (b). Using the geometry set up in (b) students can solve for x to determine the distance between the downward and angled measurement.

3. ADDITIONAL EXTENSIONS

For additional extensions, see the associated GitHub repository. These materials will be updated with activities and community suggestions.