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respdetect: A Matlab tool for detecting breath events from whale biologger data

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Statement of Need

Physiological investigations of free-swimming cetaceans have, historically, been limited because of these animals' large body size and fully aquatic lifestyle (Block, 2005; Hooker et al., 2007; Ponganis, 2007). Recent developments in digital biologging devices have enabled direct measurements of some physiological parameters in free-swimming cetaceans (Czapanskiy et al., 2022; Goldbogen et al., 2019; T. M. Williams et al., 2017), but such investigations remain challenging due to constraints on the design and deployment of these devices. Our ability to measure physiological parameters in free-swimming cetaceans is critical to understanding how these species will respond to disturbance and environmental change. Therefore, development of novel methods to extract physiological information from biologging sensors can advance the fields of vertebrate physiology and conservation biology.

Respiratory parameters, including respiratory rate, are of particular interest in understanding the diving physiology of cetaceans because of their role in determining gas exchange and, therefore, the oxygen supply that supports breath-hold diving. Previous studies have determined respiratory rate of free-swimming cetaceans by direct observation (Blix & Folkow, 1995; Christiansen et al., 2014; Sumich, 1983; R. Williams & Noren, 2009), from acoustic signals in tags equipped with hydrophones (Goldbogen et al., 2008), and from patterns in the pitch and depth signals in accelerometry tags (Goldbogen et al., 2008; Miller et al., 2010; Roos et al., 2016). These methods are viable in some species, particularly those for which a breath is taken during each surfacing event, but they are not applicable for others that exhibit long periods of time at the surface (i.e., logging) with multiple breathing events, such as short-finned pilot whales.

Summary

Here, I present `respdetect`, a set of Matlab tools to detect breathing events from high-resolution movement data recorded by digital acoustic recording tags (DTAGs). This novel method takes advantage of the high flow rates and large tidal volumes that are typical of cetacean breaths and detects the movement artifacts resulting from a breathing event. The method employs several signal processing steps followed by peak detection based on Czapanskiy et al. (2022)'s method for ballistocardiography from accelerometer data collected from blue whales to derive movement parameters from acceleration and pitch data and identify movement artifacts associated with respirations. The library of functions associated with `respdetect` allow users to identify all breaths in the tag record and export the timing of each breath.

`Respdetect` is intended to be used with existing DTAG processing tools developed by Mark Johnson (Johnson, 2013). These tools require the same folder structure necessary for DTAG data processing. A DTAG record should be processed by exporting the prh.m file which contains the accelerometer and magentometer data transformed into the whale frame, as well as the animal's pitch, roll, and heading. To use `respdetect` tools, the user is asked to specify the

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deployment prh files to analyze. After identifying dives and calculating movement parameters, the user then executes the breath detector which will identify all breathing events in the tag record.

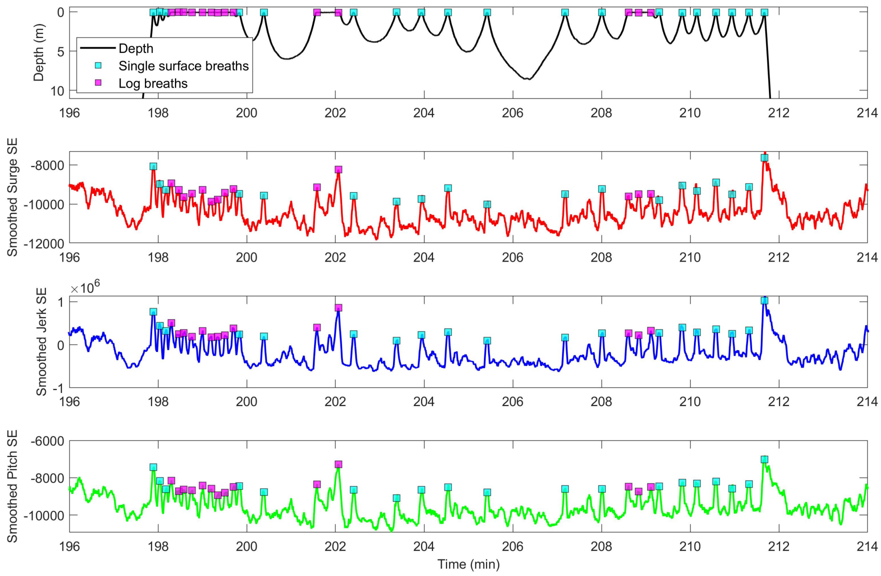

Figure 1: An example of `respdetect` breath detections from a short-finned pilot whale DTAG2 record. The first panel shows the time depth record (black line) for this segment of data with detected breaths plotted using squares. The next three panels show smoothed Shannon entropy derived from surge, jerk, and pitch, respectively, with corresponding squares at timepoints corresponding to each breath.

Following detection, the tools allow the user to visualize the respiratory rate time series before exporting the timing of each breath, in addition to several other relevant dive parameters, in a .mat file.

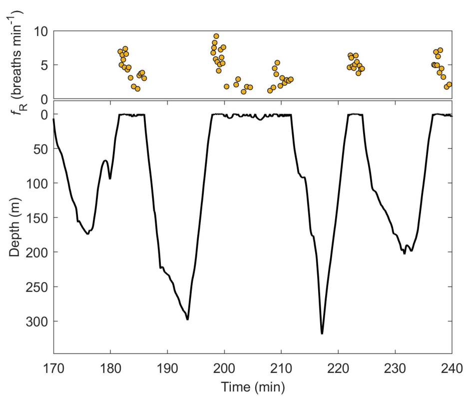

Figure 2: Continuous respiratory rate from breath detections by `respdetect` for a short-finned pilot whale before and after deep dives.

These tools were intially developed to detect breaths from DTAGs deployed on short-finned pilot whales, but should be useful for any DTAG or CATS tag record. The best use cases for `respdetect` are for tags that were deployed close to the blowhole.

There are two test datasets avaiable for users to validate nominal function of `respdetect`. The short-finned pilot whale record (*gm08_143b*) was collected in May of 2008 in Cape Hatteras, North Carolina, USA using a DTAG 2 (D2) and has been previously included in published studies including (Shearer et al., 2022). The humpback whale record (*mn17_310a*) was collected in November of 2017 of the coast of Brazil using a D2.

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