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Tools to Compare Diving-Animal Kinematics with Acoustic Behavior and Exposure

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LONG-TERM GOALS

Intense international concern has arisen over the potential effects of anthropogenic sound on protected marine wildlife. To study this issue presents a challenge, however, because research animals in captivity form a limited sample set that may not always be appropriate to extrapolate to wild populations, and because most marine species spend the majority of their time submerged and out of sight of researchers. Thus instrumentation capable of monitoring free-ranging marine animals is an essential foundation for research on sound and marine wildlife.

Tags, attached to marine mammals are being increasingly used to understand their underwater behavior. Typically these tags contain a package of instruments including accelerometers, magnetometers, a pressure sensor and a hydrophone. *The goal of this project is to make the interpretation of this data more straightforward for scientists studying marine mammal behaviors.*

OBJECTIVES

TrackPlot is a software package developed at the University of New Hampshire designed for the kinematic analysis of data from tags attached to marine mammals, such as Johnson's DTAG[1]. At the starting point of the grant, however, the software was little more than a promising prototype. The task for the UNH component of this project has been to transition this software into a general purpose tool for dive and kinematic pattern analysis, add integrated capabilities for acoustic analysis, and add support for multiple tags, especially the new Acousonde from Greeneridge Sciences [2]. In addition, we also proposed to make TrackPlot software robust, improve its user interface, properly document it, and release it. All of these basic objectives have been met. In some respects the accomplishments far exceed the initial objectives.

APPROACH

The approach used is a spiral software development model. Software is continuously developed and refined to meet the needs of both marine mammal researchers and tag hardware developers. Most of the development discussed here has been possible because of the PI's participation in the 2009,2010

Antarctic MISHAP cruises (Nowacek, PI) This project used DTAGs rather than Acousondes, but because the instrumentation package is essentially identical, development for one platform for the most part directly applied to the other. UNH took delivery of an Accusonde tag, on Sept 1, 2010 and some field data has been acquired, although, unfortunately never with the UNH PI present. Also, the planned testing with captive animals was not accomplished.

In order to make the software capable of dealing with data from multiple tag types, and multiple, the grantee has offered assistance to researchers working with a variety of tags attached to a variety of marine mammal species.

WORK COMPLETED

This report covers work completed in the approximately 18 months since project inception. *New capabilities implemented in the last year include: support for two tracks, acoustic playback, support for multiple tag models (DTAG, Acousonde, Wildlife Computers, Critter Cam) and support for image saving. These are described principally at the end of this section.*

Integration of acoustic data handing. TrackPlot now has the capability to display an acoustic spectrogram along with the pseudo-track, and has an integrated capability of providing an estimation of the animal's speed, using the method of Goldbogen [3]. See Figure 2 for examples. This work was instrumental in a paper that is currently in press in Marine Mammal Science [4].

Graphical user interface development. Previously TrackPlot user commands were given by individual keystrokes on a qwerty keyboard. Different keys allowed the user to advance forward and backwards, and zoom in or out. TrackPlot has now been given an interactive control panel as well as on-screen buttons for some of the more common interactions. Various features of this user interface are illustrated in Figure 1. These include the ability to advance forward and backwards along the track as well as rotate relative to the viewpoint. The play button results in the animal smoothly advancing along the track. The zoom widget magnifies and minifies the view depending on the level of detail that is required.

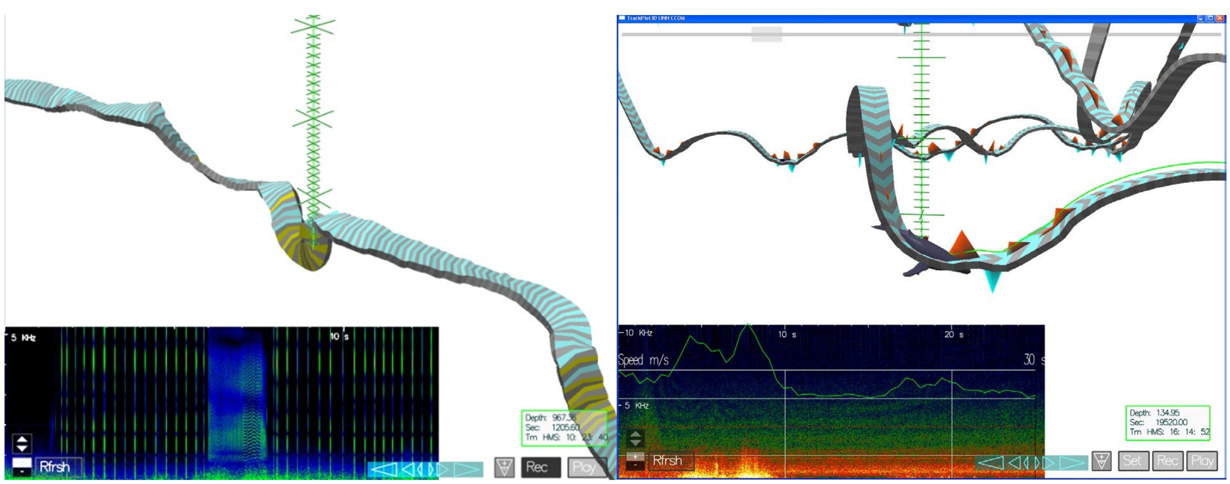

Figure 2. Left: The acoustic spectrogram from a beaked whale foraging at 967m depth revealing clicks and buzzes. Data courtesy of Brandon Southall. Right: The typical acoustic signature of a lunging humpback feeding on krill. The overlaid plot shows speed estimated from flow noise.

Integrated analysis and plotting capabilities. In addition to the acoustic spectrogram plots TrackPlot can display a variety of time series plots facilitating a greatly speeded analytic process. Illustrated in Figure 3(left) is a plot showing data from a Florida manatee (data courtesy of Douglas Nowacek). The insert plot shows the results of a Fourier analsis of the residual accelerations, once g has been subtracted. This gives an accurate indication of the fluke rate for a Florida Manatee with a tag attached to its peduncle. TrackPlot can also estimate fluke rates from differentiated pitch changes and this has been found to be effective for humpbacks. In addition, TrackPlot can display residual accelerations directly, as well as rate of descent and estimated speed from flow noise as shown in Figure 3(right).

Basic dive statistics. On loading a pseudo-track, TrackPlot automatically generates a depth histogram for the entire dive giving the percentage of time the animal spent at different depths. In addition, TrackPlot enables the user to save data from individual point or selections of track for more detailed analysis. For example, depth histograms can be generated for selected sections of track.

Automatic kinematic feature finding. A number of approaches to automatic feature finding have been explored. The most successful of these to date has been the development of a feature detector to automatically find humpback lunges from the flow noise signatures. This has been validated against human judges and been used to automatically find lunges in the tracks of 6 animals foraging in and around Wilhemena Bay in the West Antarctic Peninsula [4].

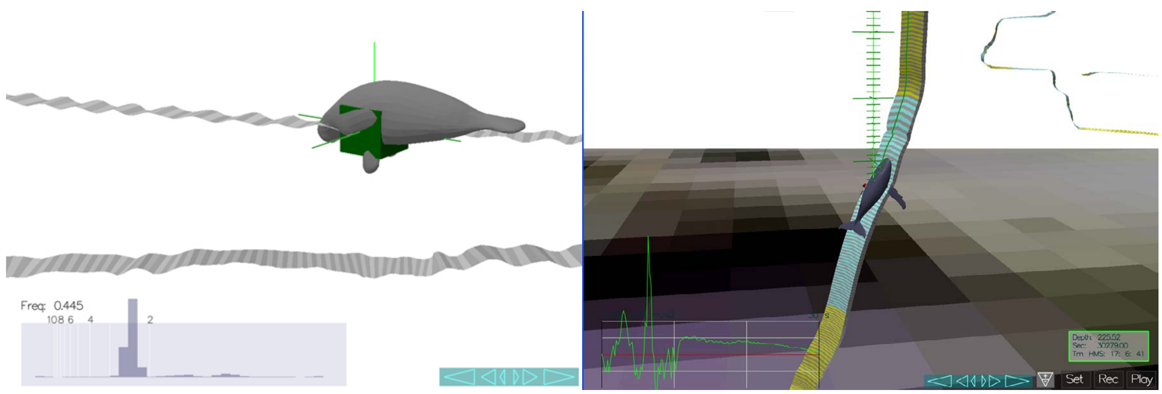

Figure 3. Left: A TrackPlot image of a Florida manatee. The insert shows one of the plot options based on a fourier analysis of the residual accelerometer data. Right: The inset plot shows the residual acceleration attributable to a vertical lunge by a humpback.

Pseudo-track creation: TrackPlot now has the ability to import raw data from a set of accelerometer, magnetometer and pressure sensors and to construct a pseudo-track using an intuitive interactive technique. The user only has to specify a section of track where the animal can be assumed to be horizontal, and a section of track containing a deep dive and a pseudo-track is automatically created.

This class of tag inherently is incapable of providing direct estimates of speed. (The accelerometer information is used to determine the animal's attitude and it cannot also be used to estimate accelerations, except under special circumstances.) Nevertheless, under some circumstances, speed can be inferred from the available data. First, when the animal is ascending or descending steeply, if we assume that the animal is traveling a rostral direction, we can then simply divide the rate of ascent by the sine of the pitch angle to get speed. This method is used in pseudo-track creation.

We have also developed a correction to obtain a better estimate of pitch angle, acceleration in the rostral direction, and speed in the rostral direction.

Georeferencing Pseudo-Tracks: A basic pseudo-track is essentially a sequence of dead-reckoned positions constructed relative to a starting point. Basic georeferencing can therefore be accomplished by tying the starting point to a geographic location. In many instances, however, a set of fixes may be available, obtained from laser range finders relative to a GPS position, or simply from visual estimates of range and bearing. It is straightforward to tie a pseudo-track to a set of fixes, using linear interpolation, but because of inaccurate speed estimation this often results in a severely distorted track.

In order to improve the quality of a geo-referenced pseudo track, relative to a set of fixes we implemented a simple dynamic model of animal speed with two parameters. Using the fluking estimated from pitch accelerations, we drive the animal model forward with a force proportional to the amplitude of the strokes. A second force slows the animal proportional to the square of the speed. TrackPlot attempts to optimize this model by adjusting two parameters, one controlling the acceleration, the other the deceleration, using a simple hill-climbing method. Finally, small adjustments, of a few cm/sec at most are added to "drift" the animal towards the fixes. This deals with inaccuracies due to currents and other unaccounted for factors.

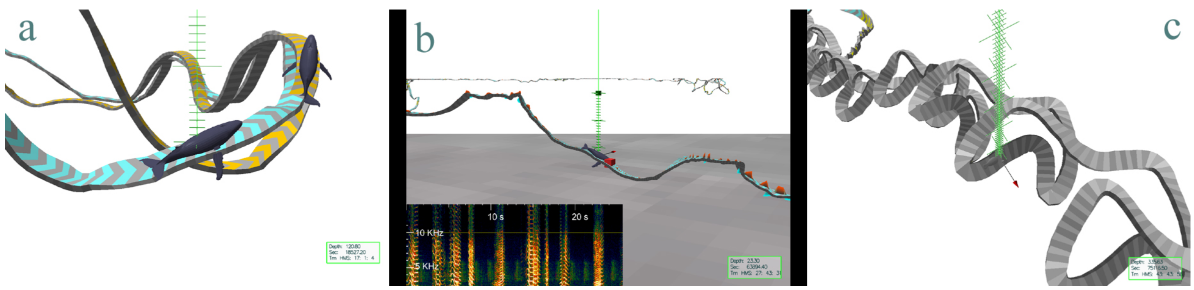

Figure 4. New in 2010. (a) Two tracks. (b) Sound playback. A singing humpback. (c) Track from a wildlife computers tag attached to an elephant seal.

Support for two Tracks: One of the exciting results of the 2010 MISHAP Antarctic cruise was a record where both a mother and calf were tagged. This is allowing us to understand mother calf interactions just as the calf is beginning to learn to lunge feed. In order to support the kinematic analysis of two animal interactions, Trackplot has been used to georeference one animal to the other. Also, the capability of showing both tracks simultaneously has been added (Figure 4a).

Acoustic Playback: A number of researchers have suggested that they would like to be able to hear sounds recorded on a tag, as well as see the spectrogram. Sound playback has now been added to TrackPlot (Figure 4b).

Support for Acousonde, Wildlife Computers, Critter Cam.
Over the past year significant effort has been invested in expanding the capabilities of TrackPlot to support more types of tag. Work with National Geographic's Critter Cam (with Greg Marshall) revealed major problems with built-in calibrations and problems owing to the attachment that uses a freely rotating swivel. It did however, showed the potential of that device to create pseudo-tracks. An Acousonde tag was received at UNH in early September 2010 (from Bill Burgess). Preliminary

analysis of the data revealed the need for calibration of the magnetometers, but also that both magnetometers and accelerometers produced high quality, low noise data records. Little difficulty is anticipated in adding the capability to process Acousonde to TrackPlot. In addition, Jen Maresh of has provided a sample of data from a Wildlife computers archival tag, attached to an elephant seal. Preliminary work suggests that TrackPlot will be able to help with analysis of this data also (see Figure 4c).

At the time of this report the data pathways from DTAG are well established and there are a number of users. The data pathways from Acousonde have been developed and tested but more work is needed especially for the handling of sound files. Some work has also been done with data from a Wildlife computers tag. But the data pathways are still rudimentary.

Image saving
TrackPlot now has the capability of saving images. When an image is saved, a smaller version is saved also. The small image has proven useful in data analysis because it provides a convenient way of recording various behavior snippets.

RESULTS

As a result of this grant TrackPlot is a far more capable and robust piece of software. The most important new capabilities are: (1) a method to construct a pseudo-track from raw data, using a straightforward graphical interface; (2) its ability to read acoustic files and display spectrograms referenced to track locations; (3) its ability to georeference a pseudo-track to a set of surface fixes; (4) its ability to find features, in particular, lunges; (5) a graphical user interface and written documentation. These features have been field tested in an extensive Antarctic cruise using data from tagged humpbacks, as well as with data from pilot whales, blue whales, florida manatees, elephant seals and mediterranean beaked whales. A paper currently in press reports on Antarctic humpback lunges finding based on an automatic filter that is built into TrackPlot [4].

The user base of TrackPlot is developing. It is being used by researchers are Duke, SBNMS and Penn State. Preliminary work has been done with a number of other researchers. The number of species is also continuing to increase.

IMPACT/APPLICATIONS

The larger goal of this project has been to make the interpretation of tag data more straightforward for scientists studying marine mammals by increasing the capabilities of TrackPlot and making it more widely available. To date, TrackPlot analysis has been applied to humpback whales, right whales, beaked whales, manatees, and elephant seals. The results have been part of at least six abstracts and four papers with more in preparation.

The project is now essentially unfunded. Over the next year an attempt will be made to find a software company willing to support the work. Also, support for users will be provided as time permits. Ware intends, especially to continue to work with Greeneridge on improving the interface to Acousonde tags.

RELATED PROJECTS

The present work is a collaborative effort with William Burgess, the creator of Acousonde, separately supported under Award number N00014-09-C-0406

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