Assessing the uncertainty of SMRU CTD-SRDL dive profiles abstracted using the broken-stick algorithm

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1 INTRO

Using animal-borne satellite-linked sensors such as SMRU Conductivity-Temperature-Depth Satellite Relay Data Loggers (CTD-SRDL) is an effective way of studying the behaviour of wide-ranging, deep diving marine predators, such as pinnipeds. The collection and delivery of longitudinal telemetry data is constrained in its quantity and resolution. The two constraints that dictate the need for abstraction are the limited of bandwidth and high energy requirements of attempting satellite transmissions. Behavioural and environmental data collected by CTD-SRDLs are therefore, received for analysis in an abstracted and compressed form.

2 DIVE PROFILE ABSTRACTION: THE BROKEN-STICK ALGORITHM

The algorithm used to abstract dive profiles on board these instruments is the broken-stick (BS). The final product of an efficient abstraction method should minimize the departure of the abstracted time-depth dive profile from the detailed dive profile.

The BS model achieves this by

- producing a dive profile made up of *n* line segments
- this is an iterative process, initialized by proposing a linear representation of the dive path, defined by the straight line joining the start and end point of the dive (Image 2 in Fig 1).
- at each iteration of the BS algorithm, the vertical distance between each pair of points, in the true path and proposed abstracted profile, is measured and stored.
- the point in the true profile which represents the greatest departure of the true path from the current incarnation of the piece-wise linear abstracted profile is then added to the abstracted profile.

Under the current abstraction regime for phocids, time-depth dive profiles are made up of six points; two at the surface, and four at depth, at irregular intervals. This process is illustrated in Fig 1 for n=5, producing an abstracted profile made up of 6 time-depth points and 5 line segments.

Once the BS points have been selected, they are stored for transmission at a resolution of 4sec and 1dm, while the rest of the time-depth points are discarded. Depths and times are digitized before transmission and compressed using a mantissa and exponent coding scheme.

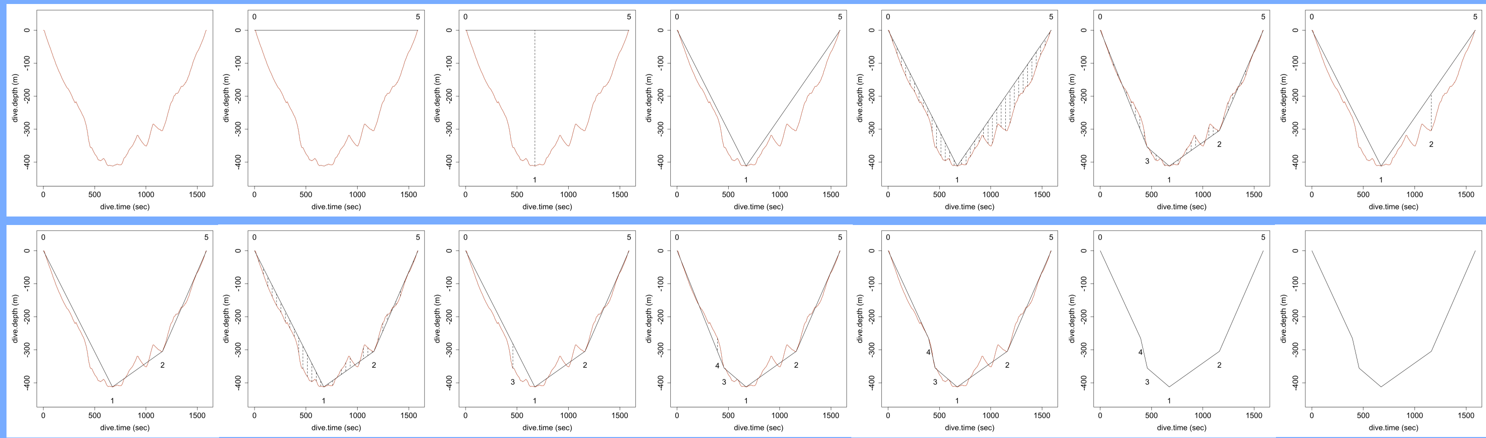

Fig 1. Illustration of the dive profile abstraction routine, using the broken-stick model, implemented onboard SMRU CTD-SRDLs. Images 1-14 from left to right.

3 DIVE ZONE RECONSTRUCTION: REVERSE ENGINEERING THE BROKEN-STICK ALGORITHM

Since we know how the BS points were obtained, we can work backwards, and reconstruct a zone around two-dimensional dive profiles by reverse engineering the abstraction algorithm.

Even though the order in which the BS points were added to the profile is not retained, we can work this out. We know that the first point that is added is always the deepest point in the profile (Image 3 Fig 2). And we know which three subsequent points were added. All we need to do is compare the vertical residuals at each iteration (Fig 2) and continue to add points to the profile.

The fourth and final residual, R4 (Image 8 Fig 2) represents the maximum amount of information we can extract from abstracted profiles, with respect to the detailed dive path. At this stage we know with 100% confidence that all other points in the true time-depth profile, as recorded by the instrument, lie no more than R4 above or below time-depth point 3 (Image 9 Fig 2). We also know the depth at BS points with higher precision than R4 so the zone around the dive contracts at BS points (Image 10 Fig 2).

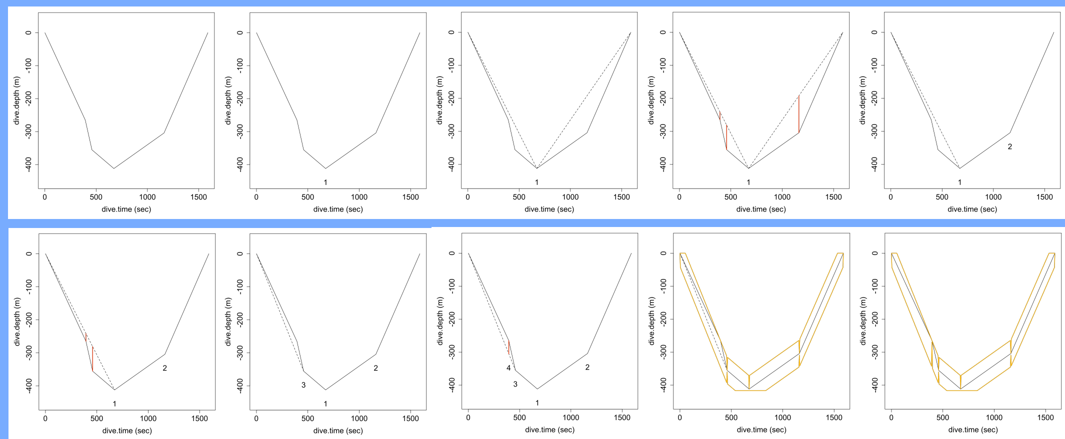

Fig 2. Illustration of the dive profile reconstruction routine by reversing the broken-stick model. Images 1-10 from left to right.

4 SUMMARY AND FUTURE WORK

Detailed dive data used to test this method came from a prototype archival accelerometer tag manufactured by SMRU and deployed on a northern elephant seal (*Mirounga angustirostris*) at Ano Nuevo, California. The construction of a confidence zone around abstracted dives is being used as the first of a two-part mechanistic model whereby data abstraction and compression/decompression procedures represent the observation model which link observed dives to the true, underlying diving process, as defined by known physiological constraints and behavioural characteristics of diving, obtained from more detailed data. A quantitative measure of fit for abstracted profiles, valid across dives, irrespective of depth and duration, is something we would like to develop in the future as part of this work.

I'm sorry I was not able to attend this conference! I am just finishing a stint of Antarctic fieldwork and cannot make it to Hobart in time. If you would like to know more about this work, please ask Mike Fedak. Don't hesitate to contact me at tp14@st-andrews.ac.uk. Thanks!

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