diveMove: dive analysis in R

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Contents

1 Introduction

Dive analysis usually involves handling of large amounts of data, as new instruments allow for frequent sampling of variables over long periods of time. The aim of this package is to make this process more efficient for summarizing and extracting information gathered by time-depth recorders (TDRs, hereafter). The principal motivation for developing `diveMove` was to provide more flexibility during the various stages of

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Table 1. Sample TDR file structure.

date	time	depth	light	temperature	speed
16/02/2004	14:30:00	12	200	8.4	1.44
16/02/2004	14:30:05	15	180	8.0	1.75
16/02/2004	14:30:10	19	170	7.6	1.99
...	...	...	...	...	...

analysis than that offered by popular commercial software. This is achieved by making the results from intermediate calculations easily accessible, allowing the user to make his/her own summaries beyond the default choices the package provides. The following sections of this vignette illustrate a typical work flow during analysis of TDR data, using the `sealMK8` data available in `diveMove` as an example.

2 Starting up

As with other packages in R, to use the package we load it with the funtion `library`:

```
> library(diveMove)
```

This makes the objects in the package available in the current R session. A short overview of the most important functions can be seen by running the examples in the package's help page:

```
> example(diveMove)
```


3 Reading Input Files

Input files must be simple, comma-delimited text files[1]. The order of columns is not significant, as the column numbers indicating the variables of interest can be supplied as arguments. Table 1 shows the file structure that readTDR assumes by default, which is a standard structure of files from common TDR models.

Depending on the TDR model, speed may be omitted. Currently, light, temperature and any other variables beyond column 6 are ignored.

To read the file into R , use the function `readTDR`:

```
> sealX <- readTDR(system.file(file.path("data",
+     "sealMK8.csv"), package = "diveMove"))
```

[1]The extension does not matter, but conventionally these files have a .csv extension

Read the help page for `readTDR` using `?readTDR` following common R help facilities. Thus, data could have been subsampled at a larger interval than that in the original file, so that the time interval between readings is 10 s:

```
> sealX <- readTDR(system.file(file.path("data",
+     "sealMK8.csv"), package = "diveMove"), subsamp = 10)
```

But since the original 5 s interval (which is the default value for *subsamp*) is what will be used for the subsequent sections, it is recreated it here:

```
> sealX <- readTDR(system.file(file.path("data",
+     "sealMK8.csv"), package = "diveMove"))
```

The format in which date and time should be interpreted can be controlled with the argument *dtformat*. If the data are already available in the R session, e.g. as a `data frame`, then the function `createTDR` can be used to convert it to a form that facilitates further analyses.

Both of these functions store the data in an object of class *TDR* or *TDRspeed*, which hold information on the source file and sampling interval, in addition to the variables described above. Which of these objects is created is determined by the name of the input file. All files should contain the letter sequence "mk" followed by a number, as these correspond to the names of common TDR models. If the number following this sequence is 8, then a *TDRspeed* object is created, otherwise the function returns a *TDR* object.

4 Extraction and Display of Information from TDR and TDRspeed Objects

For convenience, extractor methods are available to access the different slots from objects of these classes. The standard *show* method will display the usual overview information on the object:

```
> sealX
```

```
Time-Depth Recorder data -- Class TDRspeed object
  Source File            : sealMK8.csv
  Sampling Interval (s)  : 5
  Number of Samples      : 34199
  Sampling Begins        : 2002-01-05 11:32:00
  Sampling Ends          : 2002-01-07 11:01:50
  Total Duration (d)     : 1.979
```

Other extractor methods are named after the component they extract: *getTime*, *getDepth*, *getSpeed*, and *getDtime*, where the latter extracts the sampling interval. The *plot* method brings up a plot of the data covering the entire record, although a `tcltk` widget provides controls for zooming and panning to any particular time window. Alternatively, the underlying function `plotDive` provides the same functionality, but takes separate *time* and *depth* arguments, rather than a *TDR* object.

At any time, TDR objects can be coerced to a simple data frame, which can later be exported or manipulated any other way:

```
> sealX.df <- as.data.frame(sealX)
> head(sealX.df)
```

```
                 time depth speed
1 2002-01-05 11:32:00    NA    NA
2 2002-01-05 11:32:05    NA    NA
3 2002-01-05 11:32:10    NA    NA
4 2002-01-05 11:32:15    NA    NA
5 2002-01-05 11:32:20    NA    NA
6 2002-01-05 11:32:25    NA    NA
```

5 Zero-Offset Depth Correction and Summary of Wet/Dry Periods

One the first steps of dive analysis involves correcting depth for shifts in the pressure transducer, so that surface readings correspond to the value zero. Although some complex algorithms exist for detecting where these shifts occur in the record, the shifts remain difficult to detect and dives are often missed, which a visual examination of the data would have exposed. The trade off is that visually zero-adjusting depth is tedious, but the advantages of this approach far outweigh this cost, as much insight is gained by visually exploring the data. Not to mention the fact that obvious problems in the records are more effectively dealt with in this manner.

That personal rant aside, zero offset correction (ZOC) is done in `diveMove` using the function `zoc`. However, a more efficient method of doing this is by using the `calibrateDepth` function, which takes a *TDR* object (or inheriting from it) to perform three basic tasks. The first is to ZOC the data, using the `tcltk` package to be able to do it interactively:

```
> dcalib <- calibrateDepth(sealX)
```

This command brings up a plot with `tcltk` controls allowing to pan and zoom in or out of the data, as well as adjustment of the `depth` scale. Thus, an appropriate time window with a unique surface depth value can be displayed. It is important to make the display such that the `depth` scale is small enough to allow the resolution of the surface value with the mouse. Clicking on the ZOC button waits for two clicks:

1. the coordinates of the first click define the starting time for the window to be ZOC'ed, and the depth corresponding to the surface,
2. the second click defines the end time for the window (only the x coordinate has any meaning).

This procedure can be repeated as many times as needed. If there is any overlap between time windows, then the last one prevails. However, if the offset is known a priori, there is no need to go through all this procedure, and the value can be provided as the argument *offset* to `calibrateDepth`.

Once depth has been ZOC'ed, `calibrateDepth` will identify dry and wet periods in the record. Wet periods are those where a depth reading is available, dry periods are those without a depth reading. Records often have abherrant missing depth that should not be considered dry periods, as they are often of very short duration. Likewise, there may be periods of wet activity that are too short to be compared with other wet periods. This can be controlled by setting the arguments *landerr* and *seaerr*.

Finally, `calibrateDepth` identifies all dives in the record, according to a minimum depth criteria given as its *divethres* argument. The result (value) of this function is an object of class *TDRcalibrate*, where all the information obtained during the tasks described above are stored. Again, an appropriate *show* method is available to display a short overview of such objects:

```
> dcalib

Depth calibration -- Class TDRcalibrate object
  Source file                        : sealMK8.csv
  Number of dry phases               : 4
  Number of aquatic phases           : 3
  Number of dives detected           : 317
  Dry threshold used (s)             : 70
  Aquatic theshold used (s)          : 3610
  Dive threshold used (s)            : 4
  Speed calibration coefficients     : a = 0 ; b = 1
```

6 Access to Elements from TDRcalibrate Objects

Extractor methods are also available to access the information stored in *TDRcalibrate* objects. These include: *getTDR*, *getGAct*, *getDAct*, *getDPhaseLab*, and *getSpeedCoefs*.

These are all generic functions[2] that access the (depth) calibrated *TDR* object, details from wet/dry periods, dives, dive phases, and speed calibration coefficients (see Section 7), respectively. Below is a short explanation of these methods.

getTDR This method simply takes the *TDRcalibrate* object as its single argument and extracts the *TDR* object[3]:

```
> getTDR(dcalib)

Time-Depth Recorder data -- Class TDRspeed object
  Source File              : sealMK8.csv
  Sampling Interval (s)    : 5
  Number of Samples        : 34199
  Sampling Begins          : 2002-01-05 11:32:00
  Sampling Ends            : 2002-01-07 11:01:50
  Total Duration (d)       : 1.979
```

getGAct There are two methods for this generic, allowing access to a list with details about all wet/dry periods found. One of these extracts the entire *list* (output omitted for brevity):

```
> getGAct(dcalib)
```

The other provides access to particular elements of the *list*, by their name. For example, if we are interested in extracting only the vector that tells us to which period number every row in the record belongs to, we would issue the command:

```
> getGAct(dcalib, "phase.id")
```

Other elements that can be extracted are named "trip.act", "trip.beg", and "trip.end", and can be extracted in a similar fashion. These elements correspond to the activity performed for each reading (see `?detPhase` for a description of the labels for each activity), the beginning and ending time for each period, respectively.

getDAct This generic also has two methods; one to extract an entire data frame with details about all dive and postdive periods found (output omitted):

```
> getDAct(dcalib)
```

The other method provides access to the columns of this data frame, which are named "dive.id", "dive.activity", and "postdive.id". Thus, providing any one of these strings to getDAct, as a second argument will extract the corresponding column.

[2] A few of them with more than one method
[3] In fact, a *TDRspeed* object in this example

getDPhaseLab This generic function extracts a factor identifying each row of the record to a particular dive phase (see `?detDive` for a description of the labels of the factor identifying each dive phase). Two methods are available; one to extract the entire factor, and the other to select particular dive(s), by its (their) number, respectively (output omitted):

```
> getDPhaseLab(dcalib)
> getDPhaseLab(dcalib, 20)

> dphases <- getDPhaseLab(dcalib, c(100:300))
```

The latter method is useful for visually inspecting the assignment of points to particular dive phases. Before doing that though, this is a good time to introduce another generic function that allows the subsetting of the original *TDR* object to a single a dive or group of dives' data:

```
> subSealX <- extractDive(dcalib, diveNo = c(100:300))
> subSealX

Time-Depth Recorder data -- Class TDRspeed object
  Source File             : sealMK8.csv
  Sampling Interval (s)   : 5
  Number of Samples       : 2410
  Sampling Begins         : 2002-01-06 00:45:15
  Sampling Ends           : 2002-01-07 03:27:10
  Total Duration (d)      : 1.112
```

As can be seen, the function takes a *TDRcalibrate* object and a vector indicating the dive numbers to extract, and returns a *TDR* object containing the subsetted data. Once a subset of data has been selected, it is possible to plot them and pass the factor labelling dive phases as the argument *phaseCol* to the *plot* method[4]:

```
> plot(subSealX, phaseCol = dphases)
```

7 Speed Calibration

Calibration of speed readings is done using the principles described in Blackwell (1999) and Hindell et al. (1999). The function `calibrateSpeed` performs this operation[5], and allows the selection of the particular subset of the data that should be used for the calibration:

[4] The function that the method uses is actually `plotDive`, so all the possible arguments can be studied by reading the help page for `plotDive`

[5] CAUTION: This implementation is experimental, and may give unexpected results.

```
> vcalib <- calibrateSpeed(dcalib, calType = "pooled")

> vcalib

Depth calibration -- Class TDRcalibrate object
  Source file                      : sealMK8.csv
  Number of dry phases             : 4
  Number of aquatic phases         : 3
  Number of dives detected         : 317
  Dry threshold used (s)           : 70
  Aquatic theshold used (s)        : 3610
  Dive threshold used (s)          : 4
  Speed calibration coefficients   : a = 0.4 ; b = 0.64
```

A side effect of such a call is the production of a plot displaying the quantile regression fit for the three phases (Figure 1). This can be displayed on the current device, or sent to a postscript file, using `postscript`=TRUE in the call, for a higher quality representation.

The default (calType="pooled") is to use data from the descent and ascent phases of all dives, but possible values also include "descent", "ascent", and "none". Because the function produces three plots of speed vs. rate of depth change, the latter is useful in cases where speed does not need calibration, but inspection of the plots is desired. Finer control is possible by the use of arguments *type*, which controls whether descent or ascent readings that are shared with the bottom phase of the dive should be included or not, and *bad*, which controls minimum speeds and rates of depth change through which the calibration line should be drawn. Finally, a maximum depth threshold can be supplied as the argument z, so that only data from dives where maximum depth was greater than this value are included in the construction of the calibration line.

If the calibration coefficients from the implicit quantile regression are known a priori, then these can be supplied to the function via its *coefs* argument. In this case, no plots are created.

8 TDR dive and postdive statistics

Once data have been calibrated and the record broken up at "trip" and "dive" scales, obtaining dive statistics is a trivial call to function `diveStats`:

```
> dives <- diveStats(vcalib)
> head(dives, 3)
```

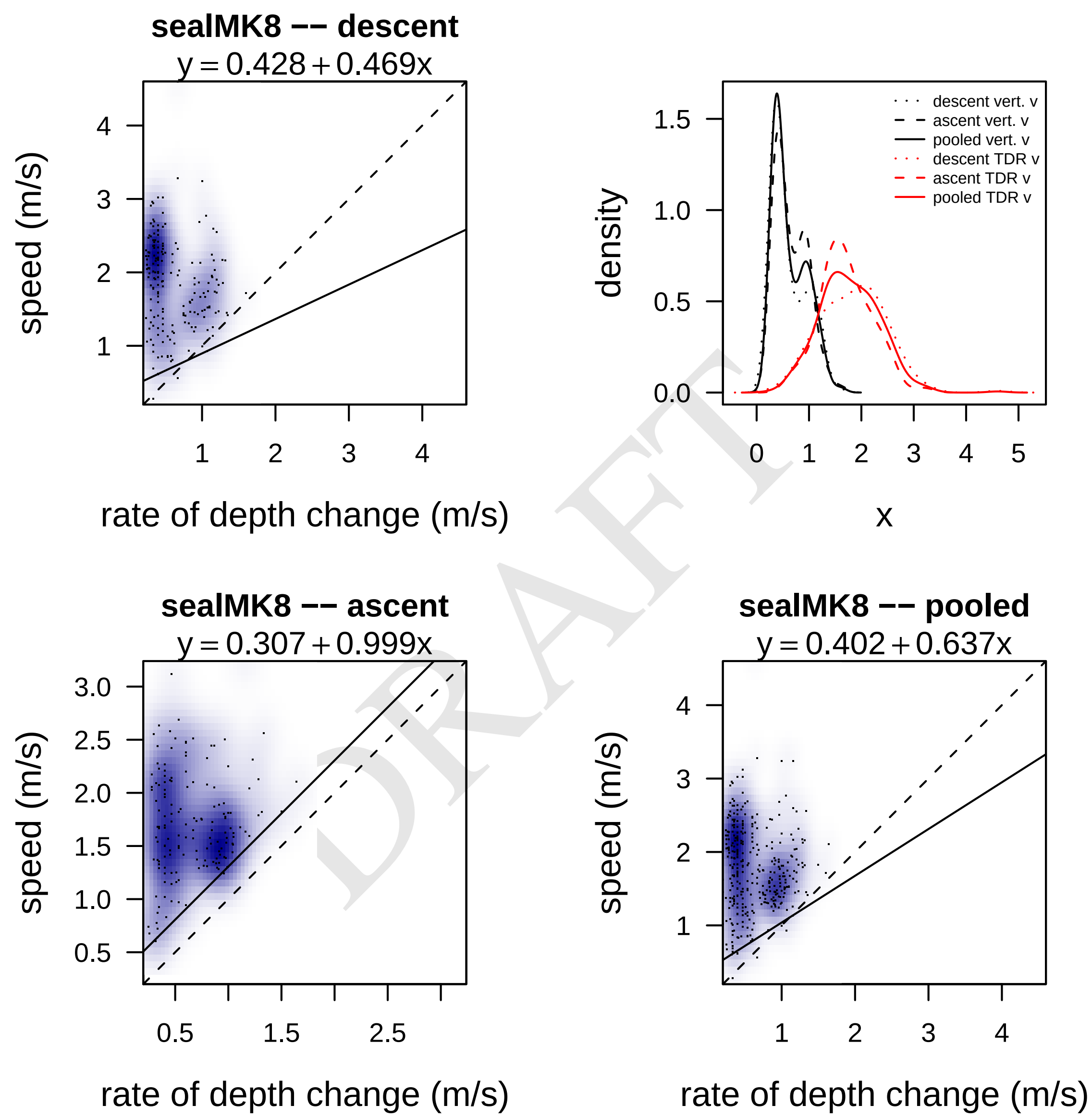

Figure 1. Example speed calibration lines, dividing dives into descent, ascent, or pooling both phases from a TDR record.

```
              begdesc             enddesc
1 2002-01-05 12:20:10 2002-01-05 12:20:15
2 2002-01-05 21:19:40 2002-01-05 21:20:20
3 2002-01-05 21:22:10 2002-01-05 21:23:15
               begasc desctim botttim asctim descdist
1 2002-01-05 12:20:20     7.5       5    7.5        6
2 2002-01-05 21:20:40    42.5      20   47.5       26
3 2002-01-05 21:23:50    67.5      35   72.5       63
  bottdist ascdist desc.tdist desc.mean.speed desc.angle
1        0       6      22.44           4.488      15.51
2        3      29     100.07           2.502      15.06
3        8      67     107.84           1.659      35.75
  bott.tdist bott.mean.speed asc.tdist asc.mean.speed
1      15.22           3.043     18.04          3.609
2      53.96           2.698     71.78          1.595
3      56.11           1.603     98.09          1.401
  asc.angle divetim maxdep postdive.dur postdive.tdist
1     19.42      20      6        32345       50445.70
2     23.83     110     29           35          16.85
3     43.08     175     67           75          58.18
  postdive.mean.speed
1              1.5652
2              0.4815
3              0.7758
```

The function takes a single argument: an object of class *TDRcalibrate*, and returns a data frame with one row per dive in the record, with a suite of basic dive statistics in each column. Please consult `?diveStats` for an explanation of each of the variables estimated, although the names of the output data frame should be self explanatory. These variables are thus available for calculating any other derived values, by extracting them using the standard R subscripting facilities.

9 Miscellaneous functions

Other functions are included for handling location data, and these are `readLocs`, `austFilter`, and `distSpeed`. These are useful for reading, filtering, and summarizing travel information. For extensive animal movement analyses, refer to package `timeTrack` available at http://staff.acecrc.org.au/~mdsumner/Rutas/.

10 Acknowledgements

Invaluable input and help during development of this package has been offered by John P.Y. Arnould, and regular contributors to R-help.

References

Blackwell, S. (1999). A method for calibrating swim-speed recorders. *Marine Mammal Science*, 15(3):894–905.

Hindell, M., McConnell, B., Fedak, M., Slip, D., Burton, H., Reijnders, P., and McMahon, C. (1999). Environmental and physiological determinants of successful foraging by naive southern elephant seal pups during their first trip to sea. *Canadian Journal of Zoology*, 77:1807–1821.

diveMove

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R topics documented:

`austFilter` *Filter satellite locations*

Description

Apply a three stage algorithm to eliminate erroneous locations, based on the procedure outlined in Austin et al. (2003).

Usage

```
austFilter(time, lon, lat, id=gl(1, 1, length(time)),
           speedthres, distthres, window=5)
grpSpeedFilter(x, speedthres, window=5)
rmsDistFilter(x, speedthres, window=5, distthres)
```

Arguments

`time`	`POSIXct` object with dates and times for each point.
`lon`	numeric vectors of longitudes, in decimal degrees.
`lat`	numeric vector of latitudes, in decimal degrees.
`id`	a factor grouping points in different categories (e.g. individuals).
`speedthres`	speed threshold (m/s) above which filter tests should fail any given point.
`distthres`	distance threshold above which the last filter test should fail any given point.
`window`	integer indicating the size of the moving window over which tests should be carried out.
`x`	3-column matrix with column 1: `POSIXct` vector; column 2: numeric longitude vector; column 3: numeric latitude vector.

Details

These functions implement the location filtering procedure outlined in Austin et al. (2003). `grpSpeedFilter` and `rmsDistFilter` can be used to perform only the first stage or the second and third stages of the algorithm on their own, respectively. Alternatively, the three filters can be run sequentially using `austFilter`.

The first stage of the filter is an iterative process which tests every point, except the first and last two, for travel velocity relative to the preceeding/following two points. If all these four speeds are greater than the specified threshold, the point is marked as failing the first stage. In this case, the next point is tested, removing the failing point from the set of test points.

The second stage runs McConnell et al. (1992) algorithm, which tests all the points that passed the first stage, in the same manner as above. The root mean square of all four speeds is calculated, and if it is greater than the specified threshold, the point is marked as failing the second stage.

The third stage is run simultaneously with the second stage, but if the mean distance of all four pairs of points is greater than the specified threshold, then the point is marked as failing the third stage.

Value

A matrix with three columns of logical vectors with values TRUE for points that failed each stage. Results from each filter are presented independently of the others; i.e. points marked as failing one filter are not necessarily marked as failing the next one.

Warning

This function applies McConnell et al.'s filter as described in Austin et al. (2003), but other authors may have used the filter differently. Austin et al. (2003) have apparently applied the filter in a vectorized manner. It is not clear from the original paper whether the filter is applied iteratively or in a vectorized fashion, so authors may be using it inconsistently.

Author(s)

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References

McConnell BJ, Chambers C, Fedak MA. 1992. Foraging ecology of southern elephant seals in relation to bathymetry and productivity of the Southern Ocean. *Antarctic Science* 4:393-398.

Austin D, McMillan JI, Bowen D. 2003. A three-stage algorithm for filtering erroneous Argos satellite locations. *Marine Mammal Science* 19: 371-383.

See Also

`distSpeed`

`calibrateDepth` *Calibrate and build a "TDRcalibrate" object*

Description

These functions create a "TDRcalibrate" object which is necessary to obtain dive summary statistics.

Usage

```
calibrateDepth(x, landerr=70, seaerr=3610, divethres=4, offset)
calibrateSpeed(x, type="all", calType="pooled", bad=c(0, 0),
               z=0, filename=slot(getTDR(x), "file"), coefs, ...)
```

Arguments

`x` an object of class `TDR` for `calibrateDepth`, and an object of class `TDRcalibrate-class` for `calibrateSpeed`.

`landerr, seaerr` arguments to `detPhase`.

`divethres` argument to `detDive`.

`offset` argument to `zoc`.

`type, calType, bad, z, filename` further arguments for `.getSpeedCalib` and `doSpeedCalib`.

`coefs` known speed calibration coefficients from quantile regression as a vector of length 2 (intercept, slope). If provided, these coefficients are used for calibrating speed, ignoring all other arguments, except `x`.

`...` argument passed to `doSpeedCalib`.

Details

These functions are really wrappers around functions that are usually called in sequence, so they provided an abbreviated method for running them together during analyses. See the functions in the 'See Also' section for more details.

`calibrateDepth` performs zero-offset correction of depth, wet/dry phase detection, and detection of dives, as well as proper labelling of the latter.

`calibrateSpeed` calibrates speed readings.

Value

An object of class `TDRcalibrate-class`

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See Also

`detPhase`, `detDive`, `doSpeedCalib`, `zoc`, for the underlying functions.

`detDive` *Detect dives from depth readings*

Description

Identify dives in TDR records based on a dive threshold.

Usage

```
detDive(zdepth, act, divethres=4, ...)
labDive(act, string, interval)
labDivePhase(x, diveID)
```

Arguments

`zdepth`	vector of zero-offset corrected depths.
`act`	factor as long as `depth` coding activity, with levels specified as in `detPhase`.
`divethres`	threshold depth below which an underwater phase should be considered a dive.
`string`	a character belonging to a level of `act` to search for and label sequentially.
`interval, ...`	the sampling interval in seconds.
`x`	a class 'TDR' object
`diveID`	numeric vector indexing each dive (non-dives should be 0)

Details

`emph{detDive}` detects a dive whenever the zero-offset corrected depth in an underwater phase is below the supplied dive threshold. The adjustment is done only for phases of at-sea activity, completely ignoring phases with other activity.

`emph{labDive}` assigns a unique number to each dive along a vector of depths, and equally numbering the subsequent postdive interval.

`emph{labDivePhase}` labels each row identifying it with a portion of the dive.

Value

A data frame with the following elements for `detDive`

- `dive.id` numeric vector numbering each dive in the record.
- `dive.activity` factor with levels 'L', 'W', 'U', 'D', and 'Z', see `detPhase`. All levels may be represented.
- `postdive.id` numeric vector numbering each postdive interval with the same value as the preceding dive.

`labDive` returns a matrix with as many rows as its first two arguments with two columns: dive.id, and postdive.id, each one sequentially numbering each dive and postdive period.

`labDivePhase` returns a factor with levels "D", "DB", "B", "BA", "A", "DA", and "X", breaking the input into descent, descent/bottom, bottom, bottom/ascent, ascent, and non-dive, respectively.

Author(s)

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See Also

`detPhase`, `zoc`

`detPhase` *Detect phases of activity from depth readings*

Description

Functions to identify sections of a TDR record displaying one of three possible activities: on-land, at-sea, and at-sea leisure.

Usage

```
detPhase(time, depth, landerr, seaerr, ...)
getAct(time, act, interval)
```

Arguments

- `time` `POSIXct` object with date and time for all depths.
- `depth` numeric vector with depth readings.
- `landerr` land error threshold in seconds. On-land phases shorter than this threshold will be considered as at-sea.
- `seaerr` at-sea leisure threshold in seconds. At-sea phases shorter than this threshold will be considered as at-sea leisure.
- `act` A numeric vector indicating the activity for every element of `time`.
- `interval, ...` sampling interval in seconds.

Details

`detPhase` first creates a factor with value 'L' (on-land) for rows with NAs for `depth` and value 'W' (at-sea) otherwise. It subsequently calculates the duration of each of these phases of activity. If the duration of an on-land phase ('L') is less than `landerr`, then the values in the factor for that phase are changed to 'W' (at-sea). The duration of phases is then recalculated, and if the duration of a phase of at-sea activity is less than `seaerr`, then the corresponding value for the factor is changed to 'Z' (at-sea leisure). The durations of all phases are recalculated a third time to provide final phase durations.

`getAct` takes a factor indicating different activity phases, their associated time, and the sampling interval to return a factor uniquely identifying each phase of activity, i.e. labelling them. In addition, it returns the duration of each phase, and their beginning and end times.

Value

A list with components; the first 4 are returned by `detPhase` and the rest by `getAct`:

`phase.id` numeric vector identifying each activity phase, starting from 1 for every input record.

`trip.act` factor with levels 'L' indicating land, 'W' indicating at-sea, 'U' for underwater (above dive criterion), 'D' for diving, 'Z' for at-sea leisure animal activities. Only 'L', 'W', and 'Z' are actually represented.

`trip.beg` a `POSIXct` object as long as the number of unique activity phases identified, indicating the start times for each activity phase.

`trip.end` a `POSIXct` object as long as the number of unique activity phases identified, indicating the end times for each activity phase.

`time.br` a factor dividing the factor `act` in phases.

`time.peract` duration of each phase defined by `time.br`.

`beg.time` `POSIXct` object; beginning time for each phase.

`end.time` `POSIXct` object; ending time for each phase.

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See Also

`detDive`

`distSpeed` *Calculate distance and speed between locations*

Description

Calculate distance, time difference, and speed between pairs of points defined by latitude and longitude, given the time at which all points were measured.

Usage

```
distSpeed(pt1, pt2, speed=TRUE)
track(txy, id=gl(1, nrow(txy)), subset)
```

Arguments

`pt1`	a matrix or data frame with three columns; the first a `POSIXct` object with dates and times for all points, the second and third numeric vectors of longitude and latitude for all points, respectively, in decimal degrees.
`pt2`	a matrix with the same structure as `pt1`.
`speed`	logical; should speed between points be calculated?
`txy`	a data frame with a `POSIXct` object in its first column, lon and lat in second and third column, respectively.
`id`	a factor dividing the data in `txy` into distinct groups.
`subset`	a logical expression indicating the rows to be analyzed, in terms of elements of `txy`.

Details

`pt1` and `pt2` may contain any number of rows. `track` is essentially a wrapper for `distSpeed`, taking a data frame, assumed to be ordered chronologically, and calculations are done between all successive rows.

Value

For `distSpeed`, a matrix with three columns: distance (km), time difference (h), and speed (m/s). For `track`, a data frame with an id column and the same columns as in `distSpeed`.

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`diveMove-internal` *Internal diveMove Functions*

Description

Functions used for very particular tasks within larger functions in diveMove

Usage

```
.cutDive(x)
.descAsc(x, phase, type=c("all", "strict"), interval, z=0)
.diveIndices(diveID, diveNo)
.getInterval(time)
.getSpeedCalib(time, zdepth, speed, dives, phase, ...)
.getSpeedStats(x, vdist)
```

Arguments

`x`	a single dive's data; for *`.cutDive`*: a 2-col matrix with subscript in original TDR object and non NA depths. For *.descAsc*: a 4-col matrix with dive id, time, depth, and speed. For *.getSpeedStats*: a 3-col matrix with time, depth, and speed.
`time`	`POSIXct` object representing time.
`dtformat`	A string to interpret date and time (see `strptime`.
`phase`	factor labelling each row for its phase in dive.
`type`	string indicating whether all points belonging to descent/ascent should be included ("all"), or points shared with bottom phase should be excluded ("srict").
`interval`	sampling interval in seconds.
`z`	minimum depth differences to use.
`zdepth`	zero-offset corrected depth m.
`speed`	speed in m/s. For doSpeedCalib: uncalibrated speeds; ignored if `calType` is "none".
`dives`	3-col `data.frame` with dive id (numeric), activity (factor), and postdive id (numeric).
`...`	arguments to pass to .descAsc (`type`, `interval`, and `z`).
`vdist`	vertical distance travelled during ascent or descent.
`diveID`	Numeric vector of all dive and non dive IDs.
`diveNo`	Numeric vector of unique dive IDs to index in `diveID`.

Details

These functions are not meant to be called directly by the user, as he/she could not care less (right?). This may change in the future.

.getSpeedCalib extracts the rates of descent and ascent with associated mean speed during descent and ascent phases, respectively and returns a list that is later manipulated by doSpeedCalib to calibrate speed. The speed used for each rate of depth change corresponds to the speed read for the last point, assuming that each speed reading is the average speed for the last measurement interval.

Value

.getSpeedCalib: A list with two elements (named "descent" and "ascent"). Each element is a 2-column matrix with rate of depth change in the first column, and speed in the second, corresponding to the descent phase of each dive.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

`diveMove-package` *Time depth recorder analysis*

Description

This package is a collection of functions for visualizing, and analyzing depth and speed data from time-depth recorders *TDR*s. These can be used to zero-offset correct depth, calibrate speed, and divide the record into different phases, or time budget. Functions are provided for calculating summary dive statistics for the whole record, or at smaller scales within dives.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

See Also

A vignette with a guide to this package is available by doing 'vignette("diveMove")'. `TDR-class`, `calibrateDepth`, `calibrateSpeed`, `attendance`, `stampDive`.

Examples

```
## read in data and create a TDR object
(sealX <- readTDR(system.file(file.path("data", "sealMK8.csv"),
                              package="diveMove")))
## Not run:
plot(sealX)  # pan and zoom through the record
## End(Not run)

## detect periods of activity, and calibrate depth, creating
## a 'TDRcalibrate' object
```

```
## Not run: dcalib <- calibrateDepth(sealX) # interactively
(dcalib <- calibrateDepth(sealX, offset=3)) # zero-offset correct at 3 m

## Not run:
## plot all readings and label them with the phase of the record
## they belong to, excluding surface readings
plot(dcalib, labels="phase.id", surface=FALSE)
## plot the first 300 dives, showing dive phases and surface readings
plot(dcalib, diveNo=seq(300), labels="dive.phase", surface=TRUE)
## End(Not run)

## calibrate speed (using default remaining arguments)
(vcalib <- calibrateSpeed(dcalib))

## Obtain dive statistics for all dives detected
dives <- diveStats(vcalib)
head(dives)

## Attendance table
att <- attendance(vcalib, FALSE) # taking trivial aquatic activities into account
att <- attendance(vcalib, TRUE)  # ignoring them
## Add trip stamps to each dive
stamps <- stampDive(vcalib)
sumtab <- data.frame(stamps, dives)
head(sumtab)
```

`diveStats` *Per-dive statistics*

Description

Calculate dive statistics in TDR records.

Usage

```
diveStats(x)
getDive(x, interval, speed=FALSE)
stampDive(x, ignoreZ=TRUE)
```

Arguments

`x`	a `TDRcalibrate-class` object for `diveStats` and `stampDive`. a data frame containing a single dive's data.
`interval`	sampling interval for interpreting `x`.
`speed`	logical; should speed statistics be calculated?
`ignoreZ`	logical indicating whether trips should be numbered considering all aquatic activities ("W" and "Z") or ignoring "Z" activities.

Details

`diveStats` calculates various dive statistics based on time and depth for an entire TDR record. `getDive` obtains these statistics from a single dive, and `stampDive` stamps each dive with associated trip information.

Value

A `data.frame` with one row per dive detected (durations are in s, and linear variables in m):

- `begdesc` A `POSIXct` object, specifying the start time of each dive.
- `enddesc` A `POSIXct` object, as `begdesc` indicating descent's end time.
- `begasc` A `POSIXct` object, as `begdesc` indicating the time ascent began.
- `desctim` descent duration of each dive.
- `botttim` bottom duration of each dive.
- `asctim` ascent duration of each dive.
- `descdist` numeric vector with descent depth.
- `bottdist` numeric vector with the sum of absolute depth differences while at the bottom of each dive; measure of amount of "wiggling" while at bottom.
- `ascdist` numeric vector with ascent depth.
- `desc.tdist` numeric vector with descent total distance, estimated from speed.
- `desc.mean.speed` numeric vector with descent mean speed.
- `desc.angle` numeric vector with descent angle.
- `bott.tdist` numeric vector with bottom total distance, estimated from speed.
- `bott.mean.speed` numeric vector with bottom mean speed.
- `asc.tdist` numeric vector with ascent total distance, estimated from speed.
- `asc.mean.speed` numeric vector with ascent mean speed.
- `asc.angle` numeric vector with ascent angle.
- `divetim` dive duration.
- `maxdep` numeric vector with maximum depth.
- `postdive.dur` postdive duration.
- `postdive.tdist` numeric vector with postdive total distance, estimated from speed.
- `postdive.mean.speed` numeric vector with postdive mean speed.

The number of columns depends on the value of speed.

`stampDive` returns a data.frame with trip number, trip type, and start and end times for each dive.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

See Also

`detPhase`, `zoc`, `TDRcalibrate-class`

`readLocs` *Read comma-delimited file with location data*

Description

Read a comma delimited (*.csv) file with (at least) time, latitude, longitude readings.

Usage

```
readLocs(file, loc.idCol, idCol, dateCol, timeCol=NULL,
         dtformat="%m/%d/%Y %H:%M:%S", tz="GMT",
         classCol, lonCol, latCol, alt.lonCol=NULL, alt.latCol=NULL)
```

Arguments

`file`	A string indicating the name of the file to read. Provide the entire path if the file is not on the current directory.
`loc.idCol`	Column number containing location ID.
`idCol`	Column number containing an identifier for locations belonging to different groups.
`dateCol`	Column number containing dates, and, optionally, times.
`timeCol`	Column number containing times.
`dtformat`	A string, specifying the format in which the date and time columns, when pasted together, should be interpreted (see `strptime`) in `file`.
`tz`	A string indicating the time zone for the date and time readings.
`lonCol`	Column number containing longitude readings.
`latCol`	Column number containing latitude readings.
`classCol`	Column number containing the ARGOS rating for each location.
`alt.lonCol`	Column number containing alternative longitude readings.
`alt.latCol`	Column number containing alternative latitude readings.

Details

The file must have a header row identifying each field, and all rows must be complete (i.e. have the same number of fields). Field names need not follow any convention.

Value

A data frame.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

---

readTDR *Read comma-delimited file with TDR data*

Description

Read a comma delimited (*.csv) file containing time-depth recorder (TDR) data from various TDR models. Models supported are MK5, MK7, and MK8 Wildlife Computers instruments. Return a `TDR` or `TDRspeed` object. `buildTDR` creates an object of one of these classes from other objects in the session.

Usage

```
readTDR(file, dateCol=1, timeCol=2, depthCol=3, speedCol=6,
        subsamp=5, dtformat="%d/%m/%Y %H:%M:%S", tz="GMT")
createTDR(time, depth, speed, dtime, file)
```

Arguments

`file`	A string indicating the path to the file to read.
`dateCol`	Column number containing dates, and optionally, times.
`timeCol`	Column number with times.
`depthCol`	Column number containing depth readings.
`speedCol`	Column number containing speed readings.
`subsamp`	Subsample rows in `file` with `subsamp` interval, in s.
`dtformat`	A string, specifying the format in which the date and time columns, when pasted together, should be interpreted (see `strptime`).
`tz`	A string indicating the time zone assumed for the date and time readings.
`time`	a `POSIXct` object with date and time readings for locations.
`depth`	numeric vector with depth readings.
`speed`	optional numeric vector with speed readings.
`dtime`	sampling interval used in seconds.

Details

The file name must contain the adjacent letter "mk" somewhere to be able to identify the TDR model. If the number following these letters is an 8, then a column for speed readings is expected, in addition to depth.

The file must have a header row identifying each field, and all rows must be complete (i.e. have the same number of fields). Field names need not follow any convention. However, depth and speed should preferably be given in m, and $m \cdot s^{-1}$ for further analyses.

Value

An object of class 'TDR' or 'TDRspeed'.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

Examples

```
readTDR(system.file(file.path("data", "sealMK8.csv"),
                    package="diveMove"))
```

`rqPlot` *Plot of quantile regression for speed calibrations*

Description

Plot of quantile regression for assessing quality of speed calibrations

Usage

```
rqPlot(rdepth, speed, rqFit, main="qtRegression",
       xlab="rate of depth change (m/s)", ylab="speed (m/s)",
       colramp=colorRampPalette(c("white", "darkblue")))
```

Arguments

`speed`	speed in m/s.
`rdepth`	numeric vector with rate of depth change.
`rqFit`	object of class "rq" representing a quantile regression fit of rate of depth change on mean speed.
`main`	string; title prefix to include in ouput plot.
`xlab, ylab`	axis labels.
`colramp`	function taking an integer n as an argument and returning n colors.

Details

The dashed line in the plot represents a reference indicating a one to one relationship between speed and rate of depth change. The other line represent the quantile regression fit.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

See Also

`doSpeedCalib`, `diveStats`

`sealMK8` *Sample TDR data from a fur seal*

Description

This data set is meant to show the organization a TDR *.csv file must have in order to be used as input for `readTDR`.

Format

A comma separated value (csv) file with 69560 TDR readings with the following columns:

date date

time time

depth depth in m

light light level

temperature temperature in C

speed speed in m/s

Details

The data is a subset of an entire TDR record, so it is not meant to make any inferences from this particular individual/deployment.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

Source

Sebastian P. Luque, Christophe Guinet, John P.Y. Arnould

See Also

`readTDR`

doSpeedCalib	*Calibration of TDR speed*

Description

Calibrate speed readings from a TDR, based on the principles outlined in Blackwell et al. (1999).

Usage

```
doSpeedCalib(rates, speed, calType="pooled", bad=c(0, 0), filename,
             postscript=FALSE, ...)
```

Arguments

`rates`	two-element list corresponding to descent and ascent phases of dives, respectively. Each element should be a 3-column `matrix` with dive id, rate of depth change, and mean speed.
`speed`	numeric vector with uncalibrated speeds.
`calType`	string specifying the type of calibration to perform. It should be one of "descent", "ascent", or "pooled".
`bad`	vector of length 2 indicating values for rate of depth change and mean speed, respectively, below which data should be excluded to build the calibration curve.
`filename`	string indicating name of file to use as base name for the output postscript file.
`postscript`	logical; whether output plot to eps.
`...`	arguments passed to rqPlot; currently, xlab, ylab, and colramp.

Details

Provide calibrated speeds in a TDR record, using the quantile regression of speed on rate of depth change, based on principles outlined in Blackwell et al. (1999). Choice of calibrating against pooled, or descentr ascent phases.

The function takes the rates of depth change and speed, for each phase of the dive separately or combined (based on the value of `calType`). It subsequently fits a quantile regression through the second percentile of the distribution of speed conditional on rate of depth change. The calibrated speed is $s_c = \frac{s_u - a}{b}$, where s_c is the calibrated speed, s_u is the uncalibrated speed, and a and b are the intercept and slope of the quantile regression, respectively.

Value

If `calType` is not "none", a list of two elements:

`coefficients`	numeric vector of length two with the intercept and the slope of the quantile regression defining the calibration curve.
`corrSpeed`	numeric vector as long as `speed` with the calibrated speeds.

A plot (possibly via `postscript`, depending on the value of postscript argument) of the calibration lines for all possible cases: "descent", "ascent", and "pooled", is created as a side effect.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

References

Blackwell, S. (1999) A method for calibrating swim-speed recorders. Marine Mammal Science **15(3)**: 894-905.

See Also

TDRcalibrate-class, rqPlot

TDRcalibrate-class *Class "TDRcalibrate" for dive analysis*

Description

This class holds information produced at various stages of dive analysis. Methods are provided for extracting data from each slot.

Usage

```
## S4 method for signature 'TDRcalibrate, logical':
attendance(obj, ignoreZ)
## S4 method for signature 'TDRcalibrate, numeric,
##   missing':
extractDive(obj, diveNo)
## S4 method for signature 'TDRcalibrate, missing':
getDAct(x)
## S4 method for signature 'TDRcalibrate, character':
getDAct(x, y)
## S4 method for signature 'TDRcalibrate, missing':
getDPhaseLab(x)
## S4 method for signature 'TDRcalibrate, numeric':
getDPhaseLab(x, diveNo)
## S4 method for signature 'TDRcalibrate, missing':
getGAct(x)
## S4 method for signature 'TDRcalibrate, character':
getGAct(x, y)
## S4 method for signature 'TDRcalibrate, missing':
plot(x, diveNo=seq(unique(getDAct(x, "dive.id"))),
     labels="phase.id", surface=FALSE, ...)
```

Arguments

`x, obj`	`"TDRcalibrate"` object.
`ignoreZ`	logical indicating whether to ignore trivial aquatic periods.
`diveNo`	numeric vector with dive numbers to plot.
`labels`	one of "phase.id" or "dive.phase", specifying whether to label observations based on the gross phase ID of the `"TDR"` object, or based on each dive phase, respectively.
`surface`	logical indicating whether to plot surface readings.
`...`	further arguments to `plotDive`.
`y`	string; "dive.id", "dive.activity", or "postdive.id" in the case of `getDAct`, to extract the numeric dive ID, the factor identifying dive phases in each dive, or the numeric postdive ID, respectively. In the case of `getGAct` it should be one of "phase.id", "trip.act", "trip.beg", or "trip.end", to extract the numeric phase ID for each observation, a factor indicating what major activity the observation corresponds to, or the beginning and end times of each phase in the record, respectively.

Details

This is perhaps the most important class in diveMove, as it holds all the information necessary for calculating requested summaries for a TDR.

The `tdr` slot contains the time, zero-offset corrected depth, and possibly calibrated or uncalibrated speed. See `readTDR` and the accessor function `getTDR` for this slot. Convenient access to each vector in this slot is available through `getTime`, getDepth, and getSpeed.

The slot gross.activity holds, as a list, a vector (named `phase.id`) numbering each major activity phase found in the record, a factor (named `trip.act`) labelling each row as being on-land, at-sea, or leisure at-sea activity. These two elements are as long as there are rows in `tdr`. This slot also contains two more vectors: one with the beginning time of each phase, and another with the ending time; both represented as `POSIXct` objects. See `detPhase`.

The slot `dive.activity` contains a data.frame, again with as many rows as those in `tdr`, consisting of three vectors named: `dive.id`, which is an integer vector, sequentially numbering each dive (rows that are not part of a dive are labelled 0), dive.activity is a factor which completes that in `trip.act` above, further identifying rows in the record belonging to a dive. The third vector in `dive.activity` is an integer vector sequentially numbering each postdive interval (all rows that belong to a dive are labelled 0). See `detDive`, and `getDAct` to access all or any one of these vectors.

`dive.phases` is a slot corresponding to a factor that labels each row in the record as belonging to a particular phase of a dive. See `labDivePhase`, and `getDPhaseLab` to access this slot.

`land.threshold`, `sea.threshold`, `dive.threshold`, and `speed.calib.coefs` are each a single number representing parameters used for detecting phases, and calibrating the TDR. Except for the latter, these are mostly for internal use, and hence do not have an accessor function. See `getSpeedCoef` for accessing `speed.calib.coefs`.

The plot method for this class creates an interactive plot of the `"TDR"` object, labelling the identified observations with a chosen factor from the corresponding `"TDRcalibrate"` object. The argument `surface` allows for the inclusion/exclusion of identified surface readings.

Objects from the Class

Objects can be created by calls of the form `new("TDRcalibrate", ...)`. The objects of this class contain information necessary to divide the record into sections (e.g. land/water), dive/surface, and different sections within dives. They also contain the parameters used to calibrate speed and criteria to divide the record into phases.

Slots

`tdr`: Object of class `"TDR"`, with concurrent time, depth, and possibly speed (if `"TDRspeed"`). See `Details`.

`gross.activity`: Object of class `"list"`, must be the same as value returned by `detPhase`.

`dive.activity`: Object of class `"data.frame"`, must be the same as value returned by `detDive`.

`dive.phases`: Object of class `"factor"`, must be the same as value returned by `labDivePhase`.

`land.threshold`: Object of class `"numeric"` the temporal criteria used for detecting periods on land that should be considered as at-sea.

`sea.threshold`: Object of class `"numeric"` the temporal criteria used for detecting periods at-sea that should not be considered as foraging time.

`dive.threshold`: Object of class `"numeric"` the criteria used for defining a dive.

`speed.calib.coefs`: Object of class `"numeric"` the intercept and slope derived from the speed calibration procedure.

Methods

attendance `signature(obj = "TDRcalibrate", ignoreZ = "logical")`: generates an attendance table for the TDR record; the duration of each dry and wet phase.

getDAct `signature(x = "TDRcalibrate", y = "missing")`: extracts a data frame with vectors identifying all readings to a particular dive and postdive number, and a factor identifying all readings to a particular activity.

getDAct `signature(x = "TDRcalibrate", y = "character")`: as the method for missing `y`, but selects a particular vector to extract.

getDPhaseLab `signature(x = "TDRcalibrate", diveNo = "missing")`: extracts a factor identifying all readings to a particular dive phase.

getDPhaseLab `signature(x = "TDRcalibrate", diveNo = "numeric")`: as the method for missing `y`, but selects data from a particular dive number to extract.

extractDive `signature(obj = "TDRcalibrate", diveNo = "numeric", id = "missing")`: extract particular dives.

getGAct `signature(x = "TDRcalibrate", y = "missing")`: extracts elements that divide the data into major wet and dry activities.

getGAct `signature(x = "TDRcalibrate", y = "character")`: as the method for missing `y`, but extracts particular elements.

show `signature(object = "TDRcalibrate")`: prints informative summary of the data.

getTDR `signature(x = "TDRcalibrate")`: extracts the `TDR` object.

getSpeedCoef `signature(x = "TDRcalibrate")`: extracts the speed calibration coefficients.

plot `signature(x = "TDRcalibrate", y = "missing")`: plot the TDR object, labelling identified sections of it (see `Usage` and `Details`).

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

See Also

`TDR-class` for links to other classes in the package

`TDR-class` *Classes "TDR" and "TDRspeed" for representing TDR information*

Description

These classes store information gathered by time-depth recorders.

Usage

```
## S4 method for signature 'TDR, numeric, numeric':
extractDive(obj, diveNo, id)
```

Arguments

`obj`	`"TDR"` object.
`diveNo`	numeric vector or scalar with dive numbers to extract.
`id`	numeric vector of dive numbers from where `diveNo` should be chosen.

Details

Since the data to store in objects of these clases usually come from a file, the easiest way to construct such objects is with the function `readTDR` to retrieve all the necessary information. The methods listed above can thus be used to access all slots.

Objects from the Class

Objects can be created by calls of the form `new("TDR", ...)` and `new("TDRspeed", ...)`.

`TDR` objects contain concurrent time and depth readings, as well as a string indicating the file the data originates from, and a number indicating the sampling interval for these data. `TDRspeed` extends `TDR` objects containing additional concurrent speed readings.

Slots

In class *TDR*:

`file`: Object of class `"character"`, string indicating the file where the data comes from.

`dtime`: Object of class `"numeric"`, sampling interval in seconds.

`time`: Object of class `"POSIXct"`, time stamp for every reading.

`depth`: Object of class `"numeric"`, depth (m) readings.

Class *TDRspeed* adds:

`speed`: Object of class `"numeric"` speed (m/s) readings.

Methods

as.data.frame `signature(x="TDR")`: Coerce object to data.frame.

as.data.frame `signature(x="TDRspeed")`: Coerce object to data.frame.

coerce `signature(from="TDR", to="data.frame")`: Coerce object to data.frame.

coerce `signature(from="TDRspeed", to="data.frame")`: Coerce object to data.frame.

getDepth `signature(x = "TDR")`: depth slot accessor.

getDtime `signature(x = "TDR")`: sampling interval accessor.

extractDive `signature(obj = "TDR", diveNo = "numeric", id = "numeric")`: extract particular dives.

getFileName `signature(x="TDR")`: source file name accessor.

plot `signature(x = "TDR", y = "missing")`: interactive graphical display of the data, with zooming and panning capabilities.

plot `signature(x = "TDRspeed", y = "missing")`: As the TDR method, but also plots the speed slot.

show `signature(object = "TDR")`: print an informative summary of the data.

getTime `signature(x = "TDR")`: time slot accessor.

getSpeed `signature(x = "TDRspeed")`: speed accessor for `TDRspeed` objects.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩

See Also

`readTDR`, `TDRcalibrate-class`.

zoc *Interactive zero-offset correction of TDR data*

Description

Correct zero-offset in TDR records, with the aid of a graphical user interface (GUI), allowing for dynamic selection of offset and multiple time windows to perform the adjustment.

Usage

```
zoc(time, depth, offset)
plotDive(time, depth, speed=NULL, xlim=NULL, phaseCol=NULL)
```

Arguments

`time`	`POSIXct` object with date and time.
`depth`	numeric vector with depth in m.
`offset`	known amount of meters for zero-offset correcting depth throughout the entire TDR record.
`speed`	numeric vector with speed in m/s.
`xlim`	vector of length 2, with lower and upper limits of time to be plotted.
`phaseCol`	factor dividing rows into sections.

Details

These functions are used primarily to correct, visually, drifts in the pressure transducer of TDR records. `zoc` calls `plotDive`, which plots depth and, optionally, speed vs. time with the possibility zooming in and out on time, changing maximum depths displayed, and panning through time. The option to zero-offset correct sections of the record gathers x and y coordinates for two points, obtained by clicking on the plot region. The first point clicked indicates the offset and beginning time of section to correct, and the second one indicates the ending time of the section to correct. Multiple sections of the record can be corrected in this manner, by panning through the time and repeating the procedure. In case there's overlap between zero offset corrected windows, the last one prevails.

Once the whole record has been zero-offset corrected, remaining points with depth values lower than zero, are turned into zeroes, as these are assumed to be values at the surface.

Value

`zoc` returns a numeric vector, as long as `depth` of zero-offset corrected depths.

`plotDive` returns a list with as many components as sections of the record that were zero-offset corrected, each consisting of two further lists with the same components as those returned by `locator`.

Author(s)

Sebastian P. Luque ⟨spluque@gmail.com⟩, with many ideas from CRAN package sfsmisc.

See Also

`detDive`

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