Package 'Rvelslant'

February 14, 2012

Description R scripts for interactively analyzing downhole seismic data and interpreting layered velocity models of constant velocity layers accounting for refractions across layer boundaries.

Title Downhole Seismic Analysis in R

Version 0.2-3

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Depends MASS

Author Original method by Dave Boore <boore@usgs.gov>, R port and some additions by Eric M. Thompson.

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R topics documented:

`plotmod, plotresid` *Plot Travel Times And Residuals*

Description

`plotmod` plots the predicted versus observed travel time curves.
`plotresid` plots the residuals.

Usage

```
plotmod(mod, nticks = NULL, grid = FALSE, depth = "v", axes = TRUE)
plotresid(mod, nticks = NULL, grid = FALSE, depth = "v", axes = TRUE)
```

Arguments

`mod`	list of velocity model parameters returned by `regress`.
`nticks`	approximate number of tick marks desired for travel time plots.
`grid`	logical value for plotting grid lines.
`depth`	layout of plots. Value can be "v" for vertical or "h" for horizontal orientation of depth on the travel time plots.
`axes`	see `plot.default`.

Value

none

Author(s)

Eric M. Thompson <eric.thompson@tufts.edu>

See Also

`Rvelslant`

Examples

```
# Used internally by Rvelslant() to create the interactive
# plots for adding and removing boundaries by clicking
# with mouse.

# User can also call: see ?Rvelslant for example
```

`Rvelslant` *Downhole Seismic Analysis In R*

Description

The function `Rvelslant` is the main function for analyzing downhole seismic data and interpreting layered velocity models.

The travel time at depth z is given by the equation:

$$\sum_{i=1}^{N}(n_i h_i s_i) = tt_z$$

for $i = 1, 2, \ldots, N$ where h_i is layer thickness, s_i is the layer slowness ($v = 1/s$), and n_i is the number of transits of each layer (1 for all layers above the measurement depth z, 0 for all layers below). When refracted waves are considered, h_i is adjusted to be the length of the raypath in each layer according to Snell's law, then:

The slowness, s_i for $i = 1, 2, \ldots, N$, of each layer, is calculated by

$$A = \sum_{i=1}^{N}(n_i h_i s_i)$$

and

$$s_i = (A^T A)^{-1} A^T tt_z$$

Two-point ray-tracing is calculated with the function `path4sl` which is based on the FORTRAN subroutine `path4sl` by:

David Boore <boore@usgs.gov>
U.S. Geological Survey
Mail Stop 977
345 Middlefield Road
Menlo Park, CA 94025 USA

Usage

```
Rvelslant(data, snell = TRUE, bot = NULL, auto = FALSE, cex = 1,
          nticks = NULL, grid = FALSE, depth = "v", profile = "slow")
```

Arguments

data	a list containing the following elements: **z:** array of the depths of travel-time measurements, in meters (length = k). **tt.slant:** array of observed travel-time measurements in seconds (length = k). **hoffset:** the horizontal offset at the surface from the borehole. **sig:** array of the standard deviation of the travel-time measurements normalized to the standard deviation of the best pick. Defaults to 1 if none is given. Used for weighting the travel-time measurements in the regression.
snell	logical value for calculating the raypath according to Snell's Law, defaults is TRUE. If `snell == FALSE`, then the raypath is approximated by a slanted line and the inversion is much faster.
bot	an optional array (length = n) of depth to layer interfaces for the starting model. If not provided, then the initial model is a single layer extending from the surface to the depth of the last measurement.
auto	logical value for if the depths to boundaries should be autopicked for initial model. Default is TRUE
cex	see `par` function in R package 'graphics'.
nticks	approximate number of tick marks desired for depth-axis on travel-time plots. See `pretty` function in R package 'base'.
grid	logical value for plotting grid lines on travel-time plots.
depth	layout of plots. Value can be 'v' for vertical or 'h' for horizontal orientation of the depth-axis on travel-time plots.
profile	defaults to 'slow' for plotting the slowness profile with the travel-times and residuals. Any other value, i.e. 'vel' will plot the velocity profile instead.

Value

a list containing model info and original data. The specific elements of the list are:

A	$A = \sum_{i=1}^{N}(n_i h_i s_i)$
s	array containing the slowness of each layer (length = n).
v	array containing the velocity of each layer (length = n).
n	integer number of layers in the velocity model.
k	number of travel-time measurements.
h	array of thicknesses of each layer (length = n).
bot	array of depth to bottoms of each layer (length = n).
tt	array of observed travel-time arrivals (length = k).
z	array of depths of each travel-time measurement, in meters (length = k).
hoffset	horizontal offset at the surface from the borehole.
N	k by n matrix of transits.
theta	k by n matrix of angles of incidence when `snell == TRUE`. Otherwise defaults to 0.

LM.tt	array of predicted travel-times (length = k).
wt	array of weights used in the regression (length = k). Defaults to 1 if sig is unspecified. Calculated as $1/sig^2$
sig	array of the standard deviation of the travel-time measurements normalized to the standard deviation of the best pick (length = k).
se	array of standard error of slowness for each layer (length = n). Used to calculate the upper and lower bounds in the velocity model.
sigma.hat	$\hat{\sigma} = \sqrt{\sum(res^2 wt)/(k-n)}$
v.upper	array of layer velocities corresponding to $s_i - se_i$ (length = n).
v.lower	array of layer velocities corresponding to $s_i + se_i$ (length = n).
tt.slant	array of observed travel-time measurements (length = k).
snell	logical value for if the Snell's Law raypaths should be used. If FALSE, then raypaths are assumed to be straight lines from source to receiver.

Author(s)

Eric M. Thompson <eric.thompson@tufts.edu>

References

Boore, D. M. (2003) *A compendium of p- and s-wave velocities from surface-to-borehole logging: Summary and reanalysis of previously published data and analysis of unpublished data* U.S. Geological Survey Open-File Report 03-191.

Faraway, J. J. (2005) *Linear Models with R* Chapman & Hall/CRC.

Examples

```
# Load table of Dave Boore's downhole seismic data:
data(tt.s) # S-wave arrivals

# Select hole code 293:
f <- tt.s$hole.code == 293
example <- tt.s[f, ]
data <- list(tt.slant = example$tt.slant,
             hoffset = example$hoffset[1],
             z = example$z,
             sig = example$sig,
             hole.code = 293)

# If Using the Windows GUI, it is best to uncheck the 'Buffered output'
# option in the Misc pull-down menu. This will allow you to see the
# outputs to the console as they occur rather than all at once at the
# end.

# The command to calculate the layered model is:
mod1 <- Rvelslant(data)

# The default is to use depth on the vertical axis. However, if you
```

```
# prefer depth to be displayed on the horizontal axis, use:

mod1 <- Rvelslant(data, depth = "h")

  ###################################################
  #    Notes:
  # You can select layer boundaries by clicking on the
  # travel-time or residual plots. You can remove a
  # boundary by left clicking on it in the velocity
  # profile plot.

  # Right-click anywhere once your have found a model
  # that you want to save.
  #  -> In WINDOWS must select 'stop' after right-click
  #  -> In MAC OS, can use ESC key instead if you don't
  #     have a second mouse button.

  # The layered model depth to bottom, thickness, and
  # velocity will be printed to the terminal.

  # The default is to calculate the refracted ray path
  # according to Snell's law and iteratively update
  # the velocity mode. To override this, and do the
  # inversion assuming the raypaths are straight lines
  # from source to receiver, use:

mod2 <- Rvelslant(data, snell = FALSE, ntick = 10, grid = TRUE)

# To use the auto picker:
mod3 <- Rvelslant(data, auto = TRUE)

# To manually enter layer interfaces:
mod4 <- Rvelslant(data, bot = c(6.2, 9.5, 14.5, 29.5,
                    47, 54.5, 74.5, 89.5))

# To view the profiles, type:

velprofile(mod1)
velprofile(mod2, col = "green")

# If you have more than one model and you want to compare the profiles:

velprofile(mod1, col = "black")
velprofile(mod2, add = TRUE, col = "red")
velprofile(mod3, add = TRUE, col = "blue")

# To view the fit of travel-times and the residuals:
par(mfrow = c(1, 2))
plotmod(mod1)
plotresid(mod1)

# To save the model to a file
writemod(mod1, prefix = "hc293")
```

`slowprofile, velprofile` *Display the slowness or velocity profile*

Description

This function plots the layered velocity or slowness model versus depth.

Usage

```
velprofile(mod, add = FALSE, col = "blue", lty = 1, lwd = 1, new = TRUE,
           nticks = NULL, grid = FALSE, axes = TRUE, depth = "v",
           bounds = TRUE)
slowprofile(mod, add = FALSE, col = "blue", lty = 1, lwd = 1,
            new = TRUE, nticks = NULL, grid = FALSE, axes = TRUE,
            depth = "v", bounds = TRUE)
```

Arguments

`mod`	a velocity model returned from `Rvelslant`.
`add`	logical value for if the model will be added to a previous profile for comparison.
`col`	line color for the profile.
`lty`	line type for the profile.
`lwd`	line width for the profile.
`new`	logical value for if a new window will be created for the profile.
`nticks`	approximate number of tick marks desired for depth-axis on travel-time plots. See `pretty` function in R package 'base'.
`grid`	logical value for plotting grid lines.
`axes`	see `plot.default`.
`depth`	layout of plots. Value can be 'v' for vertical or 'h' for horizontal orientation of depth on the travel-time plots.
`bounds`	logical value for if the upper and lower bounds should be plotted.

Value

none

Author(s)

Eric M. Thompson <eric.thompson@tufts.edu>

See Also

Rvelslant

Examples

```
# See ?Rvelslant for example.
```

`tt.s, tt.p` *P- and S-Wave Travel Time Measurements*

Description

Dataframe of travel-time measurements for P- and S-waves.

Usage

```
data(tt.p)
data(tt.s)
```

Format

`tt.p` is a dataframe containing 5151 rows and `tt.s` is a dataframe containing 5364 rows. Each dataframe has the folowing columns:

[,1]	hole.code	An integer identifier for the site.
[,2]	hoffset	Horizontal offset of the seismic source from borehole in meters.
[,3]	z	Depth of each measurement in meters.
[,4]	tt.slant	Travel-time of each measurement in seconds.
[,5]	sig	Estimates of the standard deviation of each pick relative to the best pick.

Background

See reference for more information including descriptions and details of each hole code.

Author(s)

Eric M. Thompson <eric.thompson@tufts.edu>

Source

http://quake.wr.usgs.gov/~boore/data_online.htm

References

Boore, D. M. (2003) *A compendium of p- and s-wave velocities from surface-to-borehole logging: Summary and reanalysis of previously published data and analysis of unpublished data* U.S. Geo-

logical Survey Open-File Report 03-191.

Examples

```
data(tt.p)
data(tt.s)

dim(tt.p)
# [1] 5151    5
names(tt.p)
# [1] "hole.code" "hoffset"   "z"         "tt.slant"  "sig"

dim(tt.s)
# [1] 5364    5
names(tt.s)
# [1] "hole.code" "hoffset"   "z"         "tt.slant"  "sig"
```

`vs30` *Calculate Vs(30)*

Description

Simple function for quickly calculating the average shear wave velocity in the upper 30 meters from the output of Rvelslant().

Usage

```
vs30(mod)
```

Arguments

`mod`	a list, as returned by `Rvelslant`.

Value

the average shear-wave velocity in the upper 30 meters.

Author(s)

Eric M. Thompson <eric.thompson@tufts.edu>

`writemod` *Save Layered Velocity Model*

Description

Write two fixed-width text files. One is the layered velocity model that also contains the observed travel times, the predicted travel times and has the extension '.mod'. The other file is a stair-step function for the velocity model for making plotting the model easier and has the extension '.ss'.

Usage

```
writemod(mod, prefix)
```

Arguments

`mod`	a velocity model returned from `velslant`.
`prefix`	prefix to be used in the name of the of files. If path is not included then it is saved to the current directory.

Value

none

Author(s)

Eric M. Thompson <eric.thompson@tufts.edu>

See Also

`Rvelslant`

Examples

```
# See ?Rvelslant for example.
```

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