Package 'TwoRegression'

May 7, 2026

Type Package

Title Develop and Apply Two-Regression Algorithms

Version 1.1.1

Depends R (>= 3.5.0)

Description Facilitates development and application of two-regression algorithms for research-grade wearable devices. It provides an easy way for users to access previously-developed algorithms, and also to develop their own. Initial motivation came from Hibbing PR, LaMunion SR, Kaplan AS, & Crouter SE (2018) <doi:10.1249/MSS.0000000000001532>. However, other algorithms are now supported. Please see the associated references in the package documentation for full details of the algorithms that are supported.

License GPL-3

Encoding UTF-8

LazyData true

Imports dplyr (>= 0.5.0), ggplot2 (>= 3.4.0), gridExtra (>= 2.3), lubridate, magrittr (>= 1.5), PAutilities (>= 1.1.0), pROC (>= 1.16.0), RcppRoll, rlang, stats, tidyr

RoxygenNote 7.1.2

Suggests knitr, rmarkdown, testthat (>= 3.0.0)

VignetteBuilder knitr

URL https://github.com/paulhibbing/TwoRegression

BugReports https://github.com/paulhibbing/TwoRegression/issues

Config/testthat/edition 3

NeedsCompilation no

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Contents

`all_data` *Two-regression-ready data frame*

Description

A dataset with pre-processed primary accelerometer and IMU data that is ready for applying a two-regression algorithm.

Usage

```
all_data
```

Format

A data frame with 299 rows and 17 variables:

PID Participant ID

file_source_PrimaryAccel The filename of the primary accelerometer file

date_processed_PrimaryAccel The date the primary accelerometer file was processed

file_source_IMU The filename of the IMU file

date_processed_IMU The date the IMU file was processed

Timestamp The corresponding time for each row of data

day_of_year The numeric day of the year, i.e., the Julian date

minute_of_day The numeric minute of the day

ENMO Euclidian Norm Minus One, in milli-g

Gyroscope_VM_DegPerS Gyroscope vector magnitude, in degrees per second

mean_abs_Gyroscope_x_DegPerS Rotation in x axis, degrees per second

mean_abs_Gyroscope_y_DegPerS Rotation in y axis, degrees per second

mean_abs_Gyroscope_z_DegPerS Rotation in z axis, degrees per second

mean_magnetometer_direction Cardinal direction of magnetometer signal, averaged over one second

ENMO_CV10s Coefficient of variation per 10-s, applied to Euclidian Norm Minus One

GVM_CV10s Coefficient of variation per 10-s, applied to gyroscope vector magnitude

Direction Direction changes per 5-s

`count_data` *Activity count data for demonstrating prior two-regression models*

Description

A small amount of 10-s epoch activity counts for code examples

Usage

```
count_data
```

Format

A data frame with 30 rows and 5 variables:

time POSIX. The timestamp

Axis1 numeric. The vertical axis activity counts

Axis2 numeric. The horizontal axis

Axis3 numeric. The lateral axis

Vector.Magnitude numeric. The vector magnitude of all three axes

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`fit_2rm` *Develop a two-regression algorithm*

Description

Develop a two-regression algorithm

Check if an object has class TwoRegression

Usage

```
fit_2rm(
  data,
  activity_var,
  sed_cp_activities,
  sed_activities,
  sed_cp_var,
  sed_METs,
  walkrun_activities,
  walkrun_cp_var,
  met_var,
  walkrun_formula,
  intermittent_formula,
  method = "user_unspecified"
)

is.TwoRegression(x)
```

Arguments

data	The data with which to develop the algorithm
activity_var	Character scalar. Name of the variable defining which activity is being performed
sed_cp_activities	Character vector. Activities to be included in the process of forming the sedentary classifier
sed_activities	Character vector. Actual sedentary activities
sed_cp_var	Character scalar. Name of the variable on which the sedentary cut-point is defined
sed_METs	Numeric scalar. Metabolic equivalent value to apply to sedentary activities
walkrun_activities	Character vector. Actual ambulatory activities
walkrun_cp_var	Character scalar. Name of the variable on which the walk/run cut-point is defined
met_var	Character scalar. Name of the variable giving actual energy expenditure (in metabolic equivalents)
walkrun_formula	Character scalar. Formula to use for developing the walk/run regression model
intermittent_formula	Character scalar. Formula to use for developing the intermittent activity regression model
method	character scalar. Optional name for the model, potentially useful for printing.
x	object to be tested

Value

An object of class 'TwoRegression'

See Also

predict.TwoRegression summary.TwoRegression plot.TwoRegression

Examples

```
set.seed(307)

data(all_data, package = "TwoRegression")
fake_sed <- c("Lying", "Sitting")
fake_lpa <- c("Sweeping", "Dusting")
fake_cwr <- c("Walking", "Running")
fake_ila <- c("Tennis", "Basketball")

fake_activities <- c(fake_sed, fake_lpa, fake_cwr, fake_ila)

all_data$Activity <- sample(fake_activities, nrow(all_data), TRUE)

all_data$fake_METs <- ifelse(
  all_data$Activity %in% c(fake_sed, fake_lpa),
  runif(nrow(all_data), 1, 2),
  runif(nrow(all_data), 2.5, 8)
)

fit_2rm(
  data = all_data,
  activity_var = "Activity",
  sed_cp_activities = c(fake_sed, fake_lpa),
  sed_activities = fake_sed,
  sed_cp_var = "ENMO",
  sed_METs = 1.25,
  walkrun_activities = fake_cwr,
  walkrun_cp_var = "ENMO_CV10s",
  met_var = "fake_METs",
  walkrun_formula = "fake_METs ~ ENMO",
  intermittent_formula = "fake_METs ~ ENMO + I(ENMO^2) + I(ENMO^3)"
)
```

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imu_to_check *IMU data to check*

Description

A dataset for demonstrating checks that are applied to IMU data.

Usage

```
imu_to_check
```

Format

A data frame with 300 rows and 8 variables:

file_source_IMU The filename of the IMU file

date_processed_IMU The date the IMU file was processed

Timestamp The corresponding time for each row of data

Gyroscope_VM_DegPerS Gyroscope vector magnitude, in degrees per second

mean_abs_Gyroscope_x_DegPerS Rotation in x axis, degrees per second

mean_abs_Gyroscope_y_DegPerS Rotation in y axis, degrees per second

mean_abs_Gyroscope_z_DegPerS Rotation in z axis, degrees per second

mean_magnetometer_direction Cardinal direction of magnetometer signal, averaged over one second

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imu_to_collapse *IMU data to collapse*

Description

A partially-processed IMU dataset ready to be collapsed from raw samples to one-second summaries.

Usage

```
imu_to_collapse
```

Format

A data frame with 1500 rows and 17 variables:

Timestamp The corresponding time for each row of data

Accelerometer.X Secondary accelerometer x-axis data, in G

Accelerometer.Y Secondary accelerometer y-axis data, in G

Accelerometer.Z Secondary accelerometer z-axis data, in G

Temperature Temperature of the IMU, in Celcius

Gyroscope.X Gyroscope x-axis data, in degrees per second

Gyroscope.Y Gyroscope y-axis data, in degrees per second

Gyroscope.Z Gyroscope z-axis data, in degrees per second

Magnetometer.X Magnetometer x-axis data, in micro-Teslas

Magnetometer.Y Magnetometer y-axis data, in micro-Teslas

Magnetometer.Z Magnetometer z-axis data, in micro-Teslas

file_source_IMU The filename of the IMU file

date_processed_IMU The date the IMU file was processed

ms The millisecond value of the timestamp

mean_Accel_VM Vector magnitude of the secondary accelerometer signal, in G

Gyroscope_VM_DegPerS Gyroscope vector magnitude, in degrees per second

Magnetometer_VM_MicroT Vector magnitude of the magnetometer signal, in micro-Teslas

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`plot.TwoRegression` *Create summary plots for TwoRegression objects*

Description

Four plots are generated: a threshold plot for both cut-points, and a model plot for both regression models

Usage

```
## S3 method for class 'TwoRegression'
plot(
  x = NULL,
  object = NULL,
  sed_cp_activities,
  sed_activities,
  sed_cpVar = NULL,
  activity_var,
  met_var,
  walkrun_activities,
  walkrun_cpVar,
  x_sed = NULL,
  y_sed = NULL,
  x_walkrun = NULL,
  y_walkrun = NULL,
  print = TRUE,
  ...
)
```

Arguments

`x`	passed from generic function but not used in the method
`object`	the TwoRegression object
`sed_cp_activities`	Character vector. Activities to be included in the process of forming the sedentary classifier

sed_activities	Character vector. Actual sedentary activities
sed_cpVar	character scalar. The name of the variable on which the cut-point is based
activity_var	Character scalar. Name of the variable defining which activity is being performed
met_var	character scalar. The name of the variable containing energy expenditure values, in metabolic equivalents
walkrun_activities	Character vector. Actual ambulatory activities
walkrun_cpVar	character scalar giving the name of the variable on which the walk/run cut-point is based
x_sed	numeric scalar giving x coordinate for label placement in sedentary cut-point plot
y_sed	numeric scalar giving y coordinate for label placement in sedentary cut-point plot
x_walkrun	numeric scalar giving x coordinate for label placement in walk/run cut-point plot
y_walkrun	numeric scalar giving y coordinate for label placement in walk/run cut-point plot
print	logical. Should the plot be arranged in a grid? If false, the panels will be returned in a list of gg/ggplot objects.
...	further arguments passed to plotting calls

Value

A two-by-two grid of summary plots

Examples

```
data(all_data, package = "TwoRegression")
all_data$PID <-
  rep(
    c("Test1", "Test2"),
    each = ceiling(nrow(all_data) / 2))[seq(nrow(all_data))]

fake_sed <- c("Lying", "Sitting")
fake_lpa <- c("Sweeping", "Dusting")
fake_cwr <- c("Walking", "Running")
fake_ila <- c("Tennis", "Basketball")

fake_activities <- c(fake_sed, fake_lpa, fake_cwr, fake_ila)

all_data$Activity <-
  sample(fake_activities, nrow(all_data), TRUE)

all_data$fake_METs <-
  ifelse(all_data$Activity %in% c(fake_sed, fake_lpa),
    runif(nrow(all_data), 1, 2),
    runif(nrow(all_data), 2.5, 8)
  )
```

```
ex_2rm <- fit_2rm(
  data = all_data,
  activity_var = "Activity",
  sed_cp_activities = c(fake_sed, fake_lpa),
  sed_activities = fake_sed,
  sed_cp_var = "ENMO",
  sed_METs = 1.25,
  walkrun_activities = fake_cwr,
  walkrun_cp_var = "ENMO_CV10s",
  met_var = "fake_METs",
  walkrun_formula = "fake_METs ~ ENMO",
  intermittent_formula = "fake_METs ~ ENMO + I(ENMO^2) + I(ENMO^3)"
)

model_plot_list <- plot(
  object = ex_2rm,
  sed_cp_activities = c(fake_sed, fake_lpa),
  sed_activities = fake_sed,
  sed_cpVar = "ENMO",
  activity_var = "Activity",
  met_var = "fake_METs",
  walkrun_activities = fake_cwr,
  walkrun_cpVar = "ENMO_CV10s",
  print = FALSE
)


  print(model_plot_list$sed_cut_point)
  print(model_plot_list$walkrun_cut_point)
  print(model_plot_list$walkrun_regression)
  print(model_plot_list$intermittent_regression)

  plot(
    object = ex_2rm,
    sed_cp_activities = c(fake_sed, fake_lpa),
    sed_activities = fake_sed,
    sed_cpVar = "ENMO",
    activity_var = "Activity",
    met_var = "fake_METs",
    walkrun_activities = fake_cwr,
    walkrun_cpVar = "ENMO_CV10s",
    print = TRUE
  )
```

`predict.TwoRegression` *Predict metabolic equivalents from a TwoRegression object*

Description

Predict metabolic equivalents from a TwoRegression object

Usage

```
## S3 method for class 'TwoRegression'
predict(
  object,
  newdata,
  min_mets = object$sed_METs,
  max_mets = 20,
  warn_high_low = TRUE,
  verbose = FALSE,
  ...
)
```

Arguments

object	the TwoRegression object
newdata	the data on which to predict metabolic equivalents (METs)
min_mets	the minimum allowable value for MET predictions. Defaults to the value stored in object$sed_METs
max_mets	the maximum allowable value for MET predictions. There is no value embedded in object. The default is 20
warn_high_low	logical. Issue warnings about values less than min_mets or greater than max_mets?
verbose	logical. Print processing updates?
...	further arguments passed to or from other methods

Value

A two-column data frame giving the activity classification (sedentary, walk/run, or intermittent activity) and the corresponding metabolic equivalent prediction

Examples

```
data(all_data, package = "TwoRegression")
all_data$PID <-
  rep(
    c("Test1", "Test2"),
    each = ceiling(nrow(all_data) / 2))[seq(nrow(all_data))]

train_data <- all_data[all_data$PID != "Test2", ]
test_data <- all_data[all_data$PID == "Test2", ]

fake_sed <- c("Lying", "Sitting")
fake_lpa <- c("Sweeping", "Dusting")
fake_cwr <- c("Walking", "Running")
fake_ila <- c("Tennis", "Basketball")

fake_activities <- c(fake_sed, fake_lpa, fake_cwr, fake_ila)

train_data$Activity <-
```

```
  sample(fake_activities, nrow(train_data), TRUE)

train_data$fake_METs <-
  ifelse(train_data$Activity %in% c(fake_sed, fake_lpa),
    runif(nrow(train_data), 1, 2),
    runif(nrow(train_data), 2.5, 8)
  )

ex_2rm <- fit_2rm(
  data = train_data,
  activity_var = "Activity",
  sed_cp_activities = c(fake_sed, fake_lpa),
  sed_activities = fake_sed,
  sed_cp_var = "ENMO",
  sed_METs = 1.25,
  walkrun_activities = fake_cwr,
  walkrun_cp_var = "ENMO_CV10s",
  met_var = "fake_METs",
  walkrun_formula = "fake_METs ~ ENMO",
  intermittent_formula = "fake_METs ~ ENMO + I(ENMO^2) + I(ENMO^3)"
)

predict(ex_2rm, test_data)
```

`raw_for_cv` *Primary accelerometer data to calculate coefficient of variation per 10-s*

Description

A partially-processed primary accelerometer dataset ready to calculate the coefficient of variation per 10-s

Usage

```
raw_for_cv
```

Format

A data frame with 299 rows and 2 variables:

Block A vestigial variable synonymous with row number

ENMO Euclidian Norm Minus One, in milli-g

raw_to_collapse *Primary accelerometer data to collapse*

Description

A partially-processed primary accelerometer dataset ready to be collapsed from raw samples to one-second summaries.

Usage

```
raw_to_collapse
```

Format

A data frame with 24000 rows and 3 variables:

Accelerometer X Primary accelerometer x-axis data, in G

Accelerometer Y Primary accelerometer y-axis data, in G

Accelerometer Z Primary accelerometer z-axis data, in G

smooth_2rm *Smooth two-regression estimates over specified periods*

Description

Smooth two-regression estimates over specified periods

Usage

```
smooth_2rm(AG, time_var = "Timestamp", unit = "60 sec", verbose = FALSE, ...)
```

Arguments

AG	data frame of ActiGraph data
time_var	character scalar. Name of the timestamp variable (required to verify that input epoch length is 10 seconds)
unit	the interval to use for smoothing (see floor_date). Default is "60 sec"
verbose	logical. Print updates to console?
...	currently unused

Value

Smoothed data, collapsed in the specified intervals

Examples

```
data(all_data, package = "TwoRegression")

  result <- TwoRegression(
    all_data, "Hibbing 2018", gyro_var = "Gyroscope_VM_DegPerS",
    direction_var = "mean_magnetometer_direction",
    site = c("Left Ankle", "Right Ankle"), algorithm = 1:2
  )

  smooth_2rm(result)
```

`TwoRegression-Package` *Develop and Apply Two-Regression Algorithms*

Description

The TwoRegression package is designed to make working with two-regression algorithms quick, easy, and accurate.

Details

Originally, the package was designed to house the algorithms created by Hibbing et al. (2018). Since then, support has been added for other algorithms, including Crouter et al. (2006), Crouter et al. (2010), and Crouter et al. (2012). Functionality has also been added to develop and cross-validate new two-regression algorithms. The package `RcppRoll` has also been invoked to speed up rolling coefficient of variation calculations.

Associated References

Hibbing PR, LaMunion SR, Kaplan AS, & Crouter SE (2018). Estimating energy expenditure with ActiGraph GT9X Inertial Measurement Unit. *Medicine and Science in Sports and Exercise*. 50(5), 1093-1102. doi: 10.1249/MSS.0000000000001532

Crouter, S. E., Clowers, K. G., & Bassett Jr, D. R. (2006). A novel method for using accelerometer data to predict energy expenditure. *Journal of Applied Physiology*, 100(4), 1324-1331.

Crouter, S. E., Kuffel, E., Haas, J. D., Frongillo, E. A., & Bassett Jr, D. R. (2010). Refined Two-Regression Model for the ActiGraph Accelerometer. *Medicine and Science in Sports and Exercise*, 42(5), 1029.

Crouter, S. E., Horton, M., & Bassett Jr, D. R. (2012). Use of a Two-regression model for estimating energy expenditure in children. *Medicine and Science in Sports and Exercise*, 44(6), 1177.

Examples

```
## Datasets

  data(count_data, package = "TwoRegression")
```

```
  data(all_data, package = "TwoRegression")

## Crouter 2006-2012 models

  TwoRegression(
    count_data, "Crouter 2006",
    movement_var = "Axis1", time_var = "time"
  )

  TwoRegression(
    count_data, "Crouter 2010",
    movement_var = "Axis1", time_var = "time"
  )

  TwoRegression(
    count_data, "Crouter 2012", movement_var = "Axis1",
    time_var = "time", model = "VA", check = FALSE
  )

  TwoRegression(
    count_data, "Crouter 2012", movement_var = "Vector.Magnitude",
    time_var = "time", model = "VM", check = FALSE
  )

## Hibbing 2018 models (can be vectorized)

  all_data$ENMO_CV10s <- NULL
  all_data$GVM_CV10s  <- NULL
  all_data$Direction  <- NULL

  result <- TwoRegression(
    all_data, "Hibbing 2018", gyro_var = "Gyroscope_VM_DegPerS",
    direction_var = "mean_magnetometer_direction",
    site = c("Left Ankle", "Right Ankle"), algorithm = 1:2
  )

  utils::head(result)
```

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