Package 'ActCR'

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Type Package

Title Extract Circadian Rhythms Metrics from Actigraphy Data

Version 0.3.0

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Description Circadian rhythms are rhythms that oscillate about every 24 h, which has been observed in multiple physiological processes including core body temperature, hormone secretion, heart rate, blood pressure, and many others. Measuring circadian rhythm with wearables is based on a principle that there is increased movement during wake periods and reduced movement during sleep periods, and has been shown to be reliable and valid. This package can be used to extract nonparametric circadian metrics like intradaily variability (IV), interdaily stability (IS), and relative amplitude (RA); and parametric cosinor model and extended cosinor model coefficient. Details can be found in Junrui Di et al (2019) <doi:10.1007/s12561-019-09236-4>.

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Imports zoo, cosinor, cosinor2, dplyr, minpack.lm

Depends R (>= 3.5.0),

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LazyData true

URL https://github.com/junruidi/ActCR

BugReports https://github.com/junruidi/ActCR/issues

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R topics documented:

`ActCosinor` *Cosinor Model for Circadian Rhythmicity*

Description

A parametric approach to study circadian rhythmicity assuming cosinor shape.

Usage

```
ActCosinor(x, window = 1, export_ts = FALSE)
```

Arguments

`x`	`vector` vector of dimension n*1440 which reprsents n days of 1440 minute activity data
`window`	The calculation needs the window size of the data. E.g window = 1 means each epoch is in one-minute window.
`export_ts`	A Boolean to indicate whether time series should be exported

Value

A list with elements

`mes`	MESOR which is short for midline statistics of rhythm, which is a rhythm adjusted mean. This represents mean activity level.
`amp`	amplitude, a measure of half the extend of predictable variation within a cycle. This represents the highest activity one can achieve.
`acro`	acrophase, a meaure of the time of the overall high values recurring in each cycle. Here it has a unit of radian. This represents time to reach the peak.
`acrotime`	acrophase in the unit of the time (hours)

ndays	Number of days modeled
cosinor_ts	Exported data frame with time, time over days, original time series, fitted time series using cosinor model

References

Cornelissen, G. Cosinor-based rhythmometry. Theor Biol Med Model 11, 16 (2014). https://doi.org/10.1186/1742-4682-11-16

Examples

```
count1 = c(t(example_activity_data$count[c(1:2),-c(1,2)]))
cos_coeff = ActCosinor(x = count1, window = 1, export_ts = TRUE)
```

ActCosinor_long *Cosinor Model for Circadian Rhythmicity for the Whole Dataset*

Description

A parametric approach to study circadian rhythmicity assuming cosinor shape.This function is a whole dataset wrapper for `ActCosinor`.

Usage

```
ActCosinor_long(count.data, window = 1, export_ts = FALSE)
```

Arguments

count.data	`data.frame` of dimension n * (p+2) containing the p dimensional activity data for all n subject days. The first two columns have to be ID and Day. ID can be either `character` or `numeric`. Day has to be `numeric` indicating the sequence of days within each subject.
window	The calculation needs the window size of the data. E.g window = 1 means each epoch is in one-minute window.
export_ts	A Boolean to indicate whether time series should be exported (notice: it takes time and storage space to export time series data for all subject-days. Use this with caution. Suggest to only export time series for selected subjects)

Value

A `data.frame` with the following 5 columns

ID	ID
ndays	number of days
mes	MESRO, which is short for midline statistics of rhythm, which is a rhythm adjusted mean. This represents mean activity level.

amp	amplitude, a measure of half the extend of predictable variation within a cycle. This represents the highest activity one can achieve.
acro	acrophase, a meaure of the time of the overall high values recurring in each cycle. Here it has a unit of radian. This represents time to reach the peak.
acrotime	acrophase in the unit of the time (hours)
ndays	Number of days modeled
and	
cosinor_ts	Exported data frame with time, time over days, original time series, fitted time series using cosinor model

Examples

```
counts_1 = example_activity_data$count[c(1:12),]
cos_all_1 = ActCosinor_long(count.data = counts_1, window = 1,export_ts = TRUE)
counts_10 = cbind(counts_1[,1:2],
as.data.frame(t(apply(counts_1[,-c(1:2)], 1,
FUN = bin_data, window = 10, method = "average"))))
cos_all_10 = ActCosinor_long(count.data = counts_10, window = 10)
```

ActExtendCosinor *Extended Cosinor Model for Circadian Rhythmicity*

Description

Extended cosinor model based on sigmoidally transformed cosine curve using anti-logistic transformation

Usage

```
ActExtendCosinor(
  x,
  window = 1,
  lower = c(0, 0, -1, 0, -3),
  upper = c(Inf, Inf, 1, Inf, 27),
  export_ts = FALSE
)
```

Arguments

x	vector vector of dimension n*1440 which represents n days of 1440 minute activity data
window	The calculation needs the window size of the data. E.g window = 1 means each epoch is in one-minute window.
lower	A numeric vector of lower bounds on each of the five parameters (in the order of minimum, amplitude, alpha, beta, acrophase) for the NLS. If not given, the default lower bound for each parameter is set to -Inf.

upper	A numeric vector of upper bounds on each of the five parameters (in the order of minimum, amplitude, alpha, beta, acrophase) for the NLS. If not given, the default lower bound for each parameter is set to Inf
export_ts	A Boolean to indicate whether time series should be exported

Value

A list with elements

minimum	Minimum value of the of the function.
amp	amplitude, a measure of half the extend of predictable variation within a cycle. This represents the highest activity one can achieve.
alpha	It determines whether the peaks of the curve are wider than the troughs: when alpha is small, the troughs are narrow and the peaks are wide; when alpha is large, the troughs are wide and the peaks are narrow.
beta	It dertermines whether the transformed function rises and falls more steeply than the cosine curve: large values of beta produce curves that are nearly square waves.
acrotime	acrophase is the time of day of the peak in the unit of the time (hours)
F_pseudo	Measure the improvement of the fit obtained by the non-linear estimation of the transformed cosine model
UpMesor	Time of day of switch from low to high activity. Represents the timing of the rest- activity rhythm. Lower (earlier) values indicate increase in activity earlier in the day and suggest a more advanced circadian phase.
DownMesor	Time of day of switch from high to low activity. Represents the timing of the rest-activity rhythm. Lower (earlier) values indicate decline in activity earlier in the day, suggesting a more advanced circadian phase.
MESOR	A measure analogous to the MESOR of the cosine model (or half the deflection of the curve) can be obtained from mes=min+amp/2. However, it goes through the middle of the peak, and is therefore not equal to the MESOR of the cosine model, which is the mean of the data.
ndays	Number of days modeled.
cosinor_ts	Exported data frame with time, time over days, original time series, fitted time series using cosinor model from step 1, and fitted extended cosinor model from step 2

References

Marler MR, Gehrman P, Martin JL, Ancoli-Israel S. The sigmoidally transformed cosine curve: a mathematical model for circadian rhythms with symmetric non-sinusoidal shapes. Stat Med.

Examples

```
count1 = c(t(example_activity_data$count[c(1:2),-c(1,2)]))
cos_coeff = ActExtendCosinor(x = count1, window = 1,export_ts = TRUE)
```

ActExtendCosinor_long *Cosinor Model for Circadian Rhythmicity for the Whole Dataset*

Description

Extended cosinor model based on sigmoidally transformed cosine curve using anti-logistic transformation.This function is a whole dataset wrapper for `ActExtendCosinor`.

Usage

```
ActExtendCosinor_long(
  count.data,
  window = 1,
  lower = c(0, 0, -1, 0, -3),
  upper = c(Inf, Inf, 1, Inf, 27),
  export_ts = FALSE
)
```

Arguments

`count.data`	`data.frame` of dimension n * (p+2) containing the p dimensional activity data for all n subject days. The first two columns have to be ID and Day. ID can be either `character` or `numeric`. Day has to be `numeric` indicating the sequence of days within each subject.
`window`	The calculation needs the window size of the data. E.g window = 1 means each epoch is in one-minute window. window size as an argument.
`lower`	A numeric vector of lower bounds on each of the five parameters (in the order of minimum, amplitude, alpha, beta, acrophase) for the NLS. If not given, the default lower bound for each parameter is set to `-Inf`.
`upper`	A numeric vector of upper bounds on each of the five parameters (in the order of minimum, amplitude, alpha, beta, acrophase) for the NLS. If not given, the default lower bound for each parameter is set to `Inf`
`export_ts`	A Boolean to indicate whether time series should be exported (notice: it takes time and storage space to export time series data for all subject-days. Use this with caution. Suggest to only export time series for selected subjects)

Value

A `data.frame` with the following 11 columns

`ID`	ID
`ndays`	number of days
`minimum`	Minimum value of the of the function.
`amp`	amplitude, a measure of half the extend of predictable variation within a cycle. This represents the highest activity one can achieve.

alpha	It determines whether the peaks of the curve are wider than the troughs: when alpha is small, the troughs are narrow and the peaks are wide; when alpha is large, the troughs are wide and the peaks are narrow.
beta	It dertermines whether the transformed function rises and falls more steeply than the cosine curve: large values of beta produce curves that are nearly square waves.
acrotime	acrophase is the time of day of the peak in the unit of the time (hours)
F_pseudo	Measure the improvement of the fit obtained by the non-linear estimation of the transformed cosine model
UpMesor	Time of day of switch from low to high activity. Represents the timing of the rest- activity rhythm. Lower (earlier) values indicate increase in activity earlier in the day and suggest a more advanced circadian phase.
DownMesor	Time of day of switch from high to low activity. Represents the timing of the rest-activity rhythm. Lower (earlier) values indicate decline in activity earlier in the day, suggesting a more advanced circadian phase.
MESOR	A measure analogous to the MESOR of the cosine model (or half the deflection of the curve) can be obtained from mes=min+amp/2. However, it goes through the middle of the peak, and is therefore not equal to the MESOR of the cosine model, which is the mean of the data.
cosinor_ts	Exported data frame with time, time over days, original time series, fitted time series using cosinor model from step 1, and fitted extended cosinor model from step 2

Examples

```
counts_1 = example_activity_data$count[c(1:12),]
cos_all_1 = ActExtendCosinor_long(count.data = counts_1, window = 1, export_ts = TRUE)
counts_10 = cbind(counts_1[,1:2],
as.data.frame(t(apply(counts_1[,-c(1:2)], 1,
FUN = bin_data, window = 10, method = "average"))))
cos_all_10 = ActExtendCosinor_long(count.data = counts_10, window = 10, export_ts = FALSE)
```

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bin_data *Bin data into longer windows*

Description

Bin minute level data into different time resolutions

Usage

```
bin_data(x = x, window = 1, method = c("average", "sum"))
```

Arguments

x	vector of activity data.
window	window size used to bin the original 1440 dimensional data into. Window size should be an integer factor of 1440
method	character of "sum" or "average", function used to bin the data

Value

a vector of binned data

Examples

```
data(example_activity_data)
count1 = c(t(example_activity_data$count[1,-c(1,2)]))
xbin = bin_data(x = count1, window = 10, method = "average")
```

---

example_activity_data *Activity/Wear Data from 50 Subjects from NHANES 2003 - 2006*

Description

A list of two data.frames containing the counts and the weartime for 50 NHANES subjects

Usage

```
example_activity_data
```

Format

A list of two data.frames with 1442 columns, which are in the following order:

ID identifier of the person.

Day numeric sequence 1,2,.. indicating the order of days within a subject.

MIN1-MIN1440 counts of activity of that specific minute.

IS *Interdaily Statbility*

Description

This function calcualte interdaily stability, a nonparametric metric of circadian rhtymicity

Usage

```
IS(x)
```

Arguments

x	data.frame of dimension ndays by p, where p is the dimension of the data.

References

Junrui Di et al. Joint and individual representation of domains of physical activity, sleep, and circadian rhythmicity. Statistics in Biosciences.

Examples

```
data(example_activity_data)
count1 = example_activity_data$count[c(1,2,3),-c(1,2)]
is = IS(x = count1)
```

IS_long *Interdaily Statbility for the Whole Dataset*

Description

This function calcualte interdaily stability, a nonparametric metric of circadian rhtymicity. This function is a whole dataset wrapper for IS

Usage

```
IS_long(count.data, window = 1, method = c("average", "sum"))
```

Arguments

count.data	data.frame of dimension n * (1440+2) containing the 1440 dimensional activity data for all n subject days. The first two columns have to be ID and Day. ID can be either character or numeric. Day has to be numeric indicating the sequency of days within each subject.
window	an integer indicating what is the window to bin the data before the function can be apply to the dataset. For details, see bin_data.
method	character of "sum" or "average", function used to bin the data

Value

A `data.frame` with the following 2 columns

`ID`	ID
`IS`	IS

References

Junrui Di et al. Joint and individual representation of domains of physical activity, sleep, and circadian rhythmicity. Statistics in Biosciences.

Examples

```
data(example_activity_data)
count1 = example_activity_data$count
is_subj = IS_long(count.data = count1, window = 10, method = "average")
```

`IV` *Intradaily Variability*

Description

This function calcualte intradaily variability, a nonparametric metric reprsenting fragmentation of circadian rhtymicity

Usage

```
IV(x)
```

Arguments

`x`	`vector` of activity data

Value

IV

References

Junrui Di et al. Joint and individual representation of domains of physical activity, sleep, and circadian rhythmicity. Statistics in Biosciences.

Examples

```
data(example_activity_data)
count1 = c(t(example_activity_data$count[1,-c(1,2)]))
iv = IV(x = count1)
```

IV_long *Intradaily Variability for the Whole Dataset*

Description

This function calcualte intradaily variability, a nonparametric metric reprsenting fragmentation of circadian rhtymicity. This function is a whole dataset wrapper for IV.

Usage

```
IV_long(count.data, window = 1, method = c("average", "sum"))
```

Arguments

count.data	data.frame of dimension n * (1440+2) containing the 1440 dimensional activity data for all n subject days. The first two columns have to be ID and Day. ID can be either character or numeric. Day has to be numeric indicating the sequency of days within each subject.
window	an integer indicating what is the window to bin the data before the function can be apply to the dataset. For details, see bin_data.
method	character of "sum" or "average", function used to bin the data

Value

A data.frame with the following 5 columns

ID	ID
Day	Day
IV	IV

References

Junrui Di et al. Joint and individual representation of domains of physical activity, sleep, and circadian rhythmicity. Statistics in Biosciences.

Examples

```
data(example_activity_data)
count1 = example_activity_data$count
iv_subj = IV_long(count.data = count1, window = 10, method = "average")
```

RA *Relative Amplitude*

Description

This function calcualte relative amplitude, a nonparametric metric reprsenting fragmentation of circadian rhtymicity

Usage

```
RA(x, window = 1, method = c("average", "sum"))
```

Arguments

x	vector vector of activity data
window	since the caculation of M10 and L5 depends on the dimension of data, we need to include window size as an argument.
method	character of "sum" or "average", function used to bin the data

Value

A list with elements

M10	Maximum 10 hour activity
L5	Minimum 5 hour activity
RA	Relative amplitude

References

Junrui Di et al. Joint and individual representation of domains of physical activity, sleep, and circadian rhythmicity. Statistics in Biosciences.

Examples

```
data(example_activity_data)
count1 = c(t(example_activity_data$count[1,-c(1,2)]))
ra = RA(x = count1, window = 10, method = "average")
```

RA_long *Relative Amplitude for the Whole Datset*

Description

This function calcualte relative amplitude, a nonparametric metric of circadian rhtymicity. This function is a whole dataset wrapper for RA.

Usage

```
RA_long(count.data, window = 1, method = c("average", "sum"))
```

Arguments

count.data	data.frame of dimension n * (p+2) containing the p dimensional activity data for all n subject days. The first two columns have to be ID and Day. ID can be either character or numeric. Day has to be numeric indicating the sequency of days within each subject.
window	since the caculation of M10 and L5 depends on the dimension of data, we need to include window size as an argument. This function is a whole dataset wrapper for RA.
method	character of "sum" or "average", function used to bin the data

Value

A data.frame with the following 3 columns

ID	ID
Day	Day
RA	RA

Examples

```
data(example_activity_data)
count1 = example_activity_data$count[1:12,]
ra_all = RA_long(count.data = count1, window = 10, method = "average")
```

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