

# Package ‘adept’

February 1, 2021

**Type** Package

**Title** Adaptive Empirical Pattern Transformation

**Version** 1.2

**Description** Designed for optimal use in performing fast, accurate walking strides segmentation from high-density data collected from a wearable accelerometer worn during continuous walking activity.

**License** GPL-3

**Encoding** UTF-8

**LazyData** true

**RoxygenNote** 7.1.1

**URL** <https://github.com/martakarass/adept>

**BugReports** <https://github.com/martakarass/adept/issues>

**Depends** R (>= 2.10)

**Suggests** knitr, rmarkdown, testthat, ggplot2, lubridate, reshape2, gridExtra, spelling, cluster, adeptdata, covr

**VignetteBuilder** knitr

**Imports** dplyr, magrittr, dvmisc, parallel, pracma

**Language** en-US

**NeedsCompilation** no

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**Repository** CRAN

**Date/Publication** 2021-02-01 16:20:02 UTC

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scaleTemplate	<i>Templates Scaling</i>
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### Description

Compute a list of scaled templates via linear interpolation.

### Usage

```
scaleTemplate(template, template.vl)
```

### Arguments

template	A list of numeric vectors. Each vector represents a distinct template.
template.vl	A numeric vector. A grid of vector lengths that each element of template is to be linearly interpolated into.

### Value

A list of lists of numeric vectors. Each element of the returned list is a list of templates scaled according to a particular vector length. The number of elements in the returned list equals the length of template.vl.

### Examples

```
## Construct a list of two templates
template <- list(sin(seq(0, 2 * pi, length.out = 100)),
                cos(seq(0, 2 * pi, length.out = 100)))
## A grid of vector lengths to which each of templates is scaled into
template.vl <- c(50, 100, 200)
## Compute list of rescaled templates
out <- scaleTemplate(template, template.vl)

## Plot 1st template after rescaling to three values of vector length
par(mfrow = c(2, 1), cex = 0.7)
plot(out[[3]][[1]], type = "l",
      main = "Pattern: sin([0, 2 * pi]) rescaled according to different scales",
      ylab = "Pattern", xlab = "Index")
lines(out[[2]][[1]], col = "red")
lines(out[[1]][[1]], col = "blue")
```

```
## Plot 2nd template after rescaling to three values of vector length
plot(out[[3]][[2]], type = "l",
      main = "Pattern: cos([0, 2 * pi]) rescaled according to different scales",
      ylab = "Pattern", xlab = "Index")
lines(out[[2]][[2]], col = "red")
lines(out[[1]][[2]], col = "blue")
```

---

segmentPattern

*Pattern Segmentation From a Time-series via ADEPT*


---

## Description

Segment pattern from a time-series  $x$  via Adaptive Empirical Pattern Transformation (ADEPT).

## Usage

```
segmentPattern(
  x,
  x.fs,
  template,
  pattern.dur.seq,
  similarity.measure = "cov",
  similarity.measure.thresh = 0,
  x.adept.ma.W = NULL,
  finetune = NULL,
  finetune.maxima.ma.W = NULL,
  finetune.maxima.nbh.W = NULL,
  run.parallel = FALSE,
  run.parallel.cores = 1L,
  x.cut = TRUE,
  x.cut.v1 = 6000,
  compute.template.idx = FALSE
)
```

## Arguments

<code>x</code>	A numeric vector. A time-series to segment pattern from.
<code>x.fs</code>	A numeric scalar. Frequency at which a time-series $x$ is collected, expressed in a number of observations per second.
<code>template</code>	A list of numeric vectors, or a numeric vector. Each vector represents a distinct pattern template used in segmentation.
<code>pattern.dur.seq</code>	A numeric vector. A grid of potential pattern durations used in segmentation. Expressed in seconds. See: Details.

similarity.measure	<p>A character scalar. Statistic used to compute similarity between a time-series <math>x</math> and pattern templates. Currently supported values:</p> <ul style="list-style-type: none"> <li>• "cov" - covariance,</li> <li>• "cor" - correlation,</li> </ul> <p>Default is "cov".</p>
similarity.measure.thresh	<p>A numeric scalar. Threshold of minimal similarity value between a time-series <math>x</math> and a template below which the algorithm does not identify a pattern occurrence from <math>x</math>. Default is 0.</p>
x.adept.ma.W	<p>A numeric scalar. A length of a window used in moving average smoothing of a time-series <math>x</math> for similarity matrix computation. Expressed in seconds. Default is NULL (no smoothing applied).</p>
finetune	<p>A character scalar. A type of fine-tuning procedure employed in segmentation. Defaults to NULL (no fine-tuning procedure employed). Currently supported values:</p> <ul style="list-style-type: none"> <li>• "maxima" - tunes preliminarily identified beginning and end of a pattern so as they correspond to local maxima of time-series <math>x</math> (or smoothed version of <math>x</math>) found within neighbourhoods of preliminary locations.</li> </ul>
finetune.maxima.ma.W	<p>A numeric scalar. A length of a window used in moving average smoothing of a time-series <math>x</math> in "maxima" fine-tuning procedure. Expressed in seconds. Default is NULL (no smoothing applied).</p>
finetune.maxima.nbh.W	<p>A numeric scalar. A length of the two neighborhoods centered at preliminarily identified beginning and end of a pattern within which we search for local maxima of <math>x</math> (or smoothed version of <math>x</math>) in "maxima" fine-tuning procedure. Expressed in seconds. Default is NULL. Note: if the length provided corresponds to an even number of <math>x</math> vector indices, it will be rounded down so as the corresponding number of vector indices is its closest odd number.</p>
run.parallel	<p>A logical scalar. Whether or not to use parallel execution in the algorithm with parallel package. Default is FALSE. DOES NOT WORK ON WINDOWS.</p>
run.parallel.cores	<p>An integer scalar. The number of cores to use for parallel execution. Defaults to 1L (no parallel). DOES NOT WORK ON WINDOWS.</p>
x.cut	<p>A logical scalar. Whether or not to use time optimization procedure in which a time-series <math>x</math> is cut into parts and segmentation is performed for each part of <math>x</math> separately. Recommended for a time-series <math>x</math> of vector length above 30,000. Default is TRUE.</p>
x.cut.vl	<p>An integer scalar. Defines a vector length of parts that <math>x</math> vector is cut into during the execution time optimization procedure. Default is 6000 (recommended).</p>
compute.template.idx	<p>A logical scalar. Whether or not to compute and return information about which of the provided pattern templates yielded a similarity matrix value that corresponds to an identified pattern occurrence. Setting to TRUE may increase computation time. Default is FALSE.</p>

## Details

Function implements Adaptive Empirical Pattern Transformation (ADEPT) method for pattern segmentation from a time-series  $x$ . ADEPT is optimized to perform fast, accurate walking strides segmentation from high-density data collected with a wearable accelerometer during walking.

ADEPT identifies patterns in a time-series  $x$  via maximization of chosen similarity statistic (correlation, covariance, etc.) between a time-series  $x$  and a pattern template(s). It accounts for variability in both (1) pattern duration and (2) pattern shape.

## Value

A data.frame with segmentation results. Each row describes one identified pattern occurrence:

- `tau_i` - index of  $x$  where pattern starts,
- `T_i` - pattern duration, expressed in  $x$  vector length,
- `sim_i` - similarity between a pattern and  $x$ ; note: if "maxima" fine-tune and/or  $x$  smoothing is employed, the similarity value between the final segmented pattern and a template may differ from the value in this table,
- `template_i` - if `compute.template.idx` equals TRUE: index of a template best matched to  $x$ ; if `compute.template.idx` equals FALSE: NA.

## References

Karas, M., Strackiewicz, M., Fadel, W., Harezlak, J., Crainiceanu, C.M., Urbanek, J.K. (2019). Adaptive empirical pattern transformation (ADEPT) with application to walking stride segmentation. *Biostatistics*. <https://doi.org/10.1093/biostatistics/kxz033>

## Examples

```
## Example 1: Simulate a time-series `x`. Assume that
## - `x` is collected at a frequency of 100 Hz,
## - there is one shape of pattern present within `x`,
## - each pattern lasts 1 second,
## - there is no noise in the collected data.
true.pattern <- cos(seq(0, 2 * pi, length.out = 100))
x <- c(true.pattern[1], replicate(10, true.pattern[-1]))
## Segment pattern from x.
out <- segmentPattern(
  x = x,
  x.fs = 100,
  template = true.pattern,
  pattern.dur.seq = c(0.9, 0.95, 1.03, 1.1),
  similarity.measure = "cor",
  compute.template.idx = TRUE)
out
## Segment pattern from x. Now assume a grid of potential pattern duratios
## contains true pattern duration
out <- segmentPattern(
  x = x,
  x.fs = 100,
  template = true.pattern,
```

```

pattern.dur.seq = c(0.9, 0.95, 1, 1.03, 1.1),
similarity.measure = "cor",
compute.template.idx = TRUE)
out

## Example 2: Simulate a time-series `x`. Assume that
## - `x` is collected at a frequency of 100 Hz,
## - there are two shapes of pattern present within `x`,
## - patterns have various duration,
## - there is no noise in the collected data.
true.pattern.1 <- cos(seq(0, 2 * pi, length.out = 200))
true.pattern.2 <- true.pattern.1
true.pattern.2[70:130] <- 2 * true.pattern.2[min(70:130)] + abs(true.pattern.2[70:130])
x <- numeric()
for (v1 in seq(70, 130, by = 10)){
  true.pattern.1.s <- approx(
    seq(0, 1, length.out = 200),
    true.pattern.1, xout = seq(0, 1, length.out = v1))$y
  true.pattern.2.s <- approx(
    seq(0, 1, length.out = 200),
    true.pattern.2, xout = seq(0, 1, length.out = v1))$y
  x <- c(x, true.pattern.1.s[-1], true.pattern.2.s[-1])
  if (v1 == 70) x <- c(true.pattern.1.s[1], x)
}
## Segment pattern from x. Use a `template` object consisting of both
## true patterns used in `x` simulation.
out <- segmentPattern(
  x = x,
  x.fs = 100,
  template = list(true.pattern.1, true.pattern.2),
  pattern.dur.seq = 60:130 * 0.01,
  similarity.measure = "cor",
  compute.template.idx = TRUE)
out

## Example 3: Simulate a time-series `x`. Assume that
## - `x` is collected at a frequency of 100 Hz,
## - there are two shapes of a pattern present within `x`,
## - patterns have various duration,
## - there is noise in the collected data.
set.seed(1)
x <- x + rnorm(length(x), sd = 0.5)
## Segment pattern from x.
out <- segmentPattern(
  x = x,
  x.fs = 100,
  template = list(true.pattern.1, true.pattern.2),
  pattern.dur.seq = 60:130 * 0.01,
  similarity.measure = "cor",
  compute.template.idx = TRUE)
out
## Segment pattern from x. Use `x.adept.ma.W` to define a length of a smoothing
## window to smooth `x` for similarity matrix computation.

```

```

out <- segmentPattern(
  x = x,
  x.fs = 100,
  template = list(true.pattern.1, true.pattern.2),
  pattern.dur.seq = 60:130 * 0.01,
  similarity.measure = "cor",
  x.adept.ma.W = 0.1,
  compute.template.idx = TRUE)
out
## Segment pattern from x. Use `x.adept.ma.W` to define a length of a smoothing
## window to smooth `x` for similarity matrix computation. Employ a fine-tuning
## procedure for stride identification.
out <- segmentPattern(
  x = x,
  x.fs = 100,
  template = list(true.pattern.1, true.pattern.2),
  pattern.dur.seq = 60:130 * 0.01,
  similarity.measure = "cor",
  x.adept.ma.W = 0.1,
  finetune = "maxima",
  finetune.maxima.nbh.W = 0.3,
  compute.template.idx = TRUE)
out
## Segment pattern from x. Employ a fine-tuning procedure for stride
## identification. Smooth `x` for both similarity matrix computation
## (set `x.adept.ma.W = 0.1`) and for fine-tune peak detection procedure
## (set `finetune.maxima.nbh.W = 0.3`).
out <- segmentPattern(
  x = x,
  x.fs = 100,
  template = list(true.pattern.1, true.pattern.2),
  pattern.dur.seq = 60:130 * 0.01,
  similarity.measure = "cor",
  x.adept.ma.W = 0.1,
  finetune = "maxima",
  finetune.maxima.nbh.W = 0.3,
  compute.template.idx = TRUE)
out

```

## Description

Segment walking stride pattern from a raw accelerometry data time-series (x,y,z) via Adaptive Empirical Pattern Transformation (ADEPT). Default algorithm parameters are optimized for a wrist-worn sensor and were evaluated with data collected in the free-living environment.

**Usage**

```

segmentWalking(
  xyz,
  xyz.fs,
  template,
  sim_MIN = 0.85,
  dur_MIN = 0.8,
  dur_MAX = 1.4,
  ptp_r_MIN = 0.2,
  ptp_r_MAX = 2,
  vmc_r_MIN = 0.05,
  vmc_r_MAX = 0.5,
  mean_abs_diff_med_p_MAX = 0.5,
  mean_abs_diff_med_t_MAX = 0.2,
  mean_abs_diff_dur_MAX = 0.2,
  compute.template.idx = FALSE,
  run.parallel = FALSE,
  run.parallel.cores = 1
)

```

**Arguments**

xyz	A numeric matrix (or data frame) of $n \times 3$ dimension. Three-dimensional raw accelerometry data time-series; acceleration measurements (x,y,z) collected along three orthogonal axes by the sensor's accelerometer.
xyz.fs	A numeric scalar. Frequency at which a time-series (x,y,z) is collected, expressed in a number of observations per second.
template	A list of numeric vectors, or a numeric vector. Distinct pattern template(s) of walking stride.
sim_MIN	numeric scalar. Minimum value of correlation between pattern template(s) and (r_t)_t vector magnitude of accelerometry data. Default used is 0.85.
dur_MIN	A numeric scalar. Minimum value of a stride duration allowed to be identified. Expressed in seconds. Default used is 0.8.
dur_MAX	A numeric scalar. Maximum value of a stride duration allowed to be identified. Expressed in seconds. Default used is 1.4.
ptp_r_MIN	A numeric scalar. Minimum value of "peak to peak" difference in (r_t)_t vector magnitude data of a stride. Default used is 0.2.
ptp_r_MAX	A numeric scalar. Maximum value of "peak to peak" difference in (r_t)_t vector magnitude data of a stride. Default used is 2.0
vmc_r_MIN	A numeric scalar. Minimum value of VMC in (r_t)_t vector magnitude data of a stride. Default used is 0.05.
vmc_r_MAX	A numeric scalar. Maximum value of VMC in (r_t)_t vector magnitude data of a stride. Default used is 0.5.
mean_abs_diff_med_p_MAX	A numeric scalar. Maximum value of MAD* of Azimuth (az_)_t median for 3 subsequent valid strides. Here, MAD* stands for mean of 2 absolute differences between 3 subsequent values. Default used is 0.5.



<code>mean_abs_diff_med_t_MAX</code>	A numeric scalar. Maximum value of MAD* of Elevation (el_)_t median for 3 subsequent valid strides. Here, MAD* stands for mean of 2 absolute differences between 3 subsequent values. Default used is 0.2.
<code>mean_abs_diff_dur_MAX</code>	A numeric scalar. Maximum value of MAD* of duration time for 3 subsequent valid strides. Here, MAD* stands for mean of 2 absolute differences between 3 subsequent values. Default used is 0.2.
<code>compute.template.idx</code>	A logical scalar. Whether or not to compute and return information about which of the provided pattern templates yielded a similarity matrix value that corresponds to an identified pattern occurrence. Setting to TRUE may increase computation time. Default is FALSE.
<code>run.parallel</code>	A logical scalar. Whether or not to use parallel execution in the algorithm with parallel package. Default is FALSE. DOES NOT WORK ON WINDOWS.
<code>run.parallel.cores</code>	An integer scalar. The number of cores to use for parallel execution. Defaults to 1L (no parallel). DOES NOT WORK ON WINDOWS.

**Value**

A data.frame with segmentation results. Each row describes one identified pattern occurrence:

- `tau_i` - row index of xyz where pattern starts,
- `T_i` - pattern duration, expressed in xyz vector length,
- `sim_i` - similarity between a pattern and best-fit template; see `segmentPattern` for details,
- `template_i` - if `compute.template.idx` equals TRUE: index of a template best matched to x; if `compute.template.idx` equals FALSE: NA,
- `is_walking_i` - 1 if a pattern is identified as walking stride; 0 otherwise.

**Examples**

```
library(adeptdata)
library(dplyr)
library(adept)
xyz <-
  adeptdata::acc_walking_IU %>%
  filter(loc_id == "left_wrist", subj_id == "id86237981") %>%
  arrange(time_s) %>%
  select(v1 = x, v2 = y, v3 = z) %>%
  as.matrix()
# define raw accelerometry data sample frequency
xyz.fs <- 100

# define template list based on predefined templates
template_mat <- adeptdata::stride_template$left_wrist[[3]]
template <- list(
  template_mat[1, ],
  template_mat[2, ],
```

```

    template_mat[3, ]
  )

# run walking segmentation
# (parallel supported, except for Windows; see run.parallel, run.parallel.cores args)
segmentWalking(xyz, xyz.fs, template)

```

---

similarityMatrix      *ADEPT Similarity Matrix Computation*

---

### Description

Compute ADEPT similarity matrix between a time-series `x` and a collection of scaled templates.

### Usage

```
similarityMatrix(x, template.scaled, similarity.measure)
```

### Arguments

`x`                    A numeric vector. A time-series `x`.

`template.scaled`      A list of lists of numeric vectors, as returned by `scaleTemplate`. Each element of `template.scaled` is a list of templates interpolated to a particular vector length. Number of elements in the `template.scaled` corresponds to the number of unique template length values used in segmentation.

`similarity.measure`    A character scalar. Statistic used in similarity matrix computation; one of the following:

- "cov" - for covariance,
- "cor" - for correlation.

### Value

A numeric matrix. Contains values of similarity between a time-series `x` and scaled templates.

- Number of rows equals `template.scaled` length, number of columns equals `x` length.
- A particular matrix row consists of similarity statistic between `x` and a template rescaled to a particular vector length. Precisely, each row's element is a maximum out of similarity values computed for each distinct template used in segmentation.

### See Also

`scaleTemplate {adept}`

**Examples**

```
## Simulate data
par(mfrow = c(1,1))
x0 <- sin(seq(0, 2 * pi * 100, length.out = 10000))
x <- x0 + rnorm(1000, sd = 0.1)
template <- list(x0[1:500])
template.vl <- seq(300, 700, by = 50)

## Rescale pattern
template.scaled <- scaleTemplate(template, template.vl)

## Compute ADEPT similarity matrix
out <- similarityMatrix(x, template.scaled, "cov")

## Visualize
par(mfrow = c(1,1))
image(t(out),
      main = "ADEPT similarity matrix\nfor time-series x and scaled versions of pattern templates",
      xlab = "Time index",
      ylab = "Pattern vector length",
      xaxt = "n", yaxt = "n")
xaxis <- c(1, seq(1000, length(x0), by = 1000))
yaxis <- template.vl
axis(1, at = xaxis/max(xaxis), labels = xaxis)
axis(2, at = (yaxis - min(yaxis))/(max(yaxis) - min(yaxis)), labels = yaxis)
```

---

windowSmooth

*Fast Computation of Moving Window Average*


---

**Description**

Compute moving window average of a time-series  $x$ .

**Usage**

```
windowSmooth(x, W, x.fs = 1)
```

**Arguments**

$x$	A numeric vector. A time-series for which a moving window average is computed.
$W$	A numeric scalar. A length of a moving window, expressed in time (seconds).
$x.fs$	Frequency of a time-series $x$ , expressed in a number of observations per second. Defaults to 1.

### Details

Time-series frequency  $x.fs$  and a length of a moving window (expressed in time)  $W$  together determine  $W.v1 = \text{round}(W * x.fs)$ , a length of a moving window expressed in a length of  $x$  vector object. Note:  $W.v1$  must be equal or greater than 3.

- If  $W.v1 < 3$  then an error is thrown.
- If  $W.v1$  is an even number then  $(W.v1-1)$  value is silently used instead as a length of a moving window expressed in  $x$  vector length.

### Value

A numeric vector. Moving window average of a time-series  $x$ . Note: head and tail of the output vector where the moving window is undefined are filled with NA.

### Examples

```
## Time-series defined as a function  $f(x) = x$ 
N <- 100
W <- 20
x <- 1:N
x.smoothed <- windowSmooth(x, W)
plot(x, type = "l")
points(x.smoothed, col = "red")

## Time-series defined as a function  $f(x) = \sin(x) + \text{noise}$ 
N <- 1000
W <- 100
x <- sin(seq(0, 4 * pi, length.out = N)) + rnorm(N, sd = 0.1)
x.smoothed <- windowSmooth(x, W)
plot(x, type = "l")
points(x.smoothed, col = "red")
```

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