

# Package ‘stcpR6’

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**Title** Sequential Test and Change-Point Detection Algorithms Based on E-Values / E-Detectors

**Version** 0.9.8

**Description** Algorithms of nonparametric sequential test and online change-point detection for streams of univariate (sub-)Gaussian, binary, and bounded random variables, introduced in following publications -  
Shin et al. (2024) <[doi:10.48550/arXiv.2203.03532](https://doi.org/10.48550/arXiv.2203.03532)>,  
Shin et al. (2021) <[doi:10.48550/arXiv.2010.08082](https://doi.org/10.48550/arXiv.2010.08082)>.

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**BugReports** <https://github.com/shinjaehyeok/stcpR6/issues>

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**Author** Jaehyeok Shin [aut, cre] (ORCID:  
<<https://orcid.org/0000-0003-0464-915X>>)

**Maintainer** Jaehyeok Shin <[shinjaehyeok@gmail.com](mailto:shinjaehyeok@gmail.com)>

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stcpR6-package	<i>stcpR6: Sequential Test and Change-Point Detection Algorithms Based on E-Values / E-Detectors</i>
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### Description

Algorithms of nonparametric sequential test and online change-point detection for streams of univariate (sub-)Gaussian, binary, and bounded random variables, introduced in following publications - Shin et al. (2024) [doi:10.48550/arXiv.2203.03532](https://doi.org/10.48550/arXiv.2203.03532), Shin et al. (2021) [doi:10.48550/arXiv.2010.08082](https://doi.org/10.48550/arXiv.2010.08082).

### Author(s)

**Maintainer:** Jaehyeok Shin <[shinjaehyeok@gmail.com](mailto:shinjaehyeok@gmail.com)> ([ORCID](#))

### See Also

Useful links:

- <https://github.com/shinjaehyeok/stcpR6>
- Report bugs at <https://github.com/shinjaehyeok/stcpR6/issues>

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checkDeltaRange	<i>Check whether the input delta parameters are acceptable</i>
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---

### Description

For each method and family, check whether delta parameters are within expected range with respect to the pre-change parameter.

### Usage

```
checkDeltaRange(method, family, alternative, m_pre, delta_lower, delta_upper)
```

**Arguments**

method	Method of the sequential procedure. <ul style="list-style-type: none"> <li>• ST: Sequential test based on a mixture of E-values.</li> <li>• SR: Sequential change detection based on e-SR procedure.</li> <li>• CU: Sequential change detection based on e-CUSUM procedure.</li> <li>• GLRCU: Sequential change detection based on GLR-CUSUM procedure.</li> </ul>
family	Distribution of underlying univariate observations. <ul style="list-style-type: none"> <li>• Normal: (sub-)Gaussian with sigma = 1.</li> <li>• Ber: Bernoulli distribution on {0,1}.</li> <li>• Bounded: General bounded distribution on [0,1]</li> </ul>
alternative	Alternative / post-change mean space <ul style="list-style-type: none"> <li>• two.sided: Two-sided test / change detection</li> <li>• greater: Alternative /post-change mean is greater than null / pre-change one</li> <li>• less: Alternative /post-change mean is less than null / pre-change one</li> </ul>
m_pre	The boundary of mean parameter in null / pre-change space
delta_lower	Minimum gap between null / pre-change space and alternative / post-change one. It must be strictly positive for ST, SR and CU. Currently, GLRCU does not support the minimum gap, and this param will be ignored.
delta_upper	Maximum gap between null / pre-change space and alternative / post-change one. It must be strictly positive for ST, SR and CU. Currently, GLRCU does not support the maximum gap, and this param will be ignored.

**Value**

A list of

1. Boolean indicating whether it is acceptable or not.
2. Character describing why it is not acceptable.
3. Updated delta\_upper for the case where the original input was NULL

---

compute_baseline	<i>Compute baseline processes.</i>
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---

**Description**

Compute parameters to build baseline processes.

**Usage**

```
compute_baseline(
  alpha,
  delta_lower,
  delta_upper,
  psi_fn_list = generate_sub_G_fn(),
  v_min = 1,
  k_max = 200,
  tol = 1e-10
)
```

**Arguments**

alpha	ARL parameter in (0,1)
delta_lower	Lower bound of target Delta. It must be positive and smaller than or equal to delta_upper.
delta_upper	Upper bound of target Delta. It must be positive and larger than or equal to delta_lower.
psi_fn_list	A list of R functions that computes psi and psi_star functions. Can be generated by generate_sub_G_fn() or counterparts for sub_B and sub_E.
v_min	A lower bound of v function in the baseline process. Default is 1.
k_max	Positive integer to determine the maximum number of baselines. Default is 200.
tol	Tolerance of root-finding, positive numeric. Default is 1e-10.

**Value**

A list of 1. Parameters of baseline processes, 2. Mixing weights, 3. Auxiliary values for computation.

---

```
compute_baseline_for_sample_size
```

*Compute baseline parameters given target variance process bounds.*

---

**Description**

Given target variance process bounds for confidence sequences, compute baseline parameters.

**Usage**

```
compute_baseline_for_sample_size(
  alpha,
  v_upper,
  v_lower,
  psi_fn_list = generate_sub_G_fn(),
  skip_g_alpha = TRUE,
```

```

    v_min = 1,
    k_max = 200,
    tol = 1e-10
  )

```

### Arguments

alpha	ARL parameter in (0,1)
v_upper	Upper bound of the target variance process bound
v_lower	Lower bound of the target variance process bound.
psi_fn_list	A list of R functions that computes psi and psi_star functions. Can be generated by generate_sub_G_fn() or counterparts for sub_B and sub_E.
skip_g_alpha	If true, we do not compute g_alpha and use log(1/alpha) instead.
v_min	A lower bound of v function in the baseline process. Default is 1.
k_max	Positive integer to determine the maximum number of baselines. Default is 200.
tol	Tolerance of root-finding, positive numeric. Default is 1e-10.

### Value

A list of 1. Parameters of baseline processes, 2. Mixing weights, 3. Auxiliary values for computation.

---

```
convertDeltaToExpParams
```

*converted input deltas to parameters for exponential baselines*

---

### Description

For each exponential baseline family, convert delta range into corresponding lambdas and weights.

### Usage

```

convertDeltaToExpParams(
  family,
  alternative,
  threshold,
  m_pre,
  delta_lower,
  delta_upper,
  k_max
)

```

**Arguments**

family	Distribution of underlying univariate observations. <ul style="list-style-type: none"> <li>• Normal: (sub-)Gaussian with <math>\sigma = 1</math>.</li> <li>• Ber: Bernoulli distribution on <math>\{0,1\}</math>.</li> <li>• Bounded: General bounded distribution on <math>[0,1]</math></li> </ul>
alternative	Alternative / post-change mean space <ul style="list-style-type: none"> <li>• two.sided: Two-sided test / change detection</li> <li>• greater: Alternative /post-change mean is greater than null / pre-change one</li> <li>• less: Alternative /post-change mean is less than null / pre-change one</li> </ul>
threshold	Stopping threshold. We recommend to use $\log(1/\alpha)$ for "ST" and "SR" methods where $\alpha$ is a testing level or $1/\text{ARL}$ . for "CU" and "GLRCU", we recommend to tune the threshold by using domain-specific sampler to hit the target ARL.
m_pre	The boundary of mean parameter in null / pre-change space
delta_lower	Minimum gap between null / pre-change space and alternative / post-change one. It must be strictly positive for ST, SR and CU. Currently, GLRCU does not support the minimum gap, and this param will be ignored.
delta_upper	Maximum gap between null / pre-change space and alternative / post-change one. It must be strictly positive for ST, SR and CU. Currently, GLRCU does not support the maximum gap, and this param will be ignored.
k_max	Positive integer to determine the maximum number of baselines. For GLRCU method, it is used as the lookup window size for GLRCU statistics.

**Value**

A list of weights and lambdas

---

generate\_sub\_B\_fn      *Pre-defined psi\_star functions for sub-Bernoulli family.*

---

**Description**

Pre-defined psi\_star functions for sub-Bernoulli family.

**Usage**

```
generate_sub_B_fn(p = 0.5)
```

**Arguments**

p                      The boundary of mean space of the pre-change distributions (default = 0.5).

**Value**

A list of pre-defined psi\_star functions for sub-Bernoulli family.

---

`generate_sub_E_fn`      *Pre-defined psi\_star functions for sub-exponential family.*

---

**Description**

Pre-defined psi\_star functions for sub-exponential family.

**Usage**

`generate_sub_E_fn()`

**Value**

A list of pre-defined psi\_star functions for sub-exponential family.

---

`generate_sub_G_fn`      *Pre-defined psi\_star functions for sub-Gaussian family.*

---

**Description**

Pre-defined psi\_star functions for sub-Gaussian family.

**Usage**

`generate_sub_G_fn(sig = 1)`

**Arguments**

`sig`                      The sigma parameter of the sub-Gaussian family (default = 1).

**Value**

A list of pre-defined psi\_star functions for sub-Gaussian family.

---

logSumExpTrick	<i>log-sum-exp trick</i>
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---

**Description**

Apply log-sum-exp trick to a numeric vector.

**Usage**

```
logSumExpTrick(xs)
```

**Arguments**

`xs`                    A numeric vector.

**Value**

log of sum of exp of `xs`, which is equal to  $\log(\text{sum}(\text{exp}(xs)))$ .

---

NormalCS	<i>NormalCS Class</i>
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---

**Description**

NormalCS class is used to compute always-valid confidence sequence for the standard normal process based on the STCP method.

**Methods****Public methods:**

- [NormalCS\\$new\(\)](#)
- [NormalCS\\$print\(\)](#)
- [NormalCS\\$getAlpha\(\)](#)
- [NormalCS\\$getWeights\(\)](#)
- [NormalCS\\$getLambdas\(\)](#)
- [NormalCS\\$computeWidth\(\)](#)
- [NormalCS\\$computeInterval\(\)](#)

**Method** `new()`: Create a new NormalCS object.

*Usage:*

```
NormalCS$new(
  alternative = c("two.sided", "greater", "less"),
  alpha = 0.05,
  n_upper = 1000,
  n_lower = 1,
  weights = NULL,
  lambdas = NULL,
  skip_g_alpha = TRUE,
  k_max = 1000
)
```

*Arguments:*

*alternative* Alternative / post-change mean space

- *two.sided*: Two-sided test / change detection
- *greater*: Alternative /post-change mean is greater than null / pre-change one
- *less*: Alternative /post-change mean is less than null / pre-change one

*alpha* Upper bound on the type 1 error of the confidence sequence.

*n\_upper* Upper bound of the target sample interval

*n\_lower* Lower bound of the target sample interval

*weights* If not null, the input weights will be used to initialize the object instead of *n\_upper* and *n\_lower*.

*lambdas* If not null, the input lambdas will be used to initialize the object. instead of *n\_upper* and *n\_lower*.

*skip\_g\_alpha* If true, we do not compute *g\_alpha* and use  $\log(1/\alpha)$  instead.

*k\_max* Positive integer to determine the maximum number of baselines.

*Returns:* A new NormalCS object.

**Method** `print()`: Print summary of Step object.

*Usage:*

```
NormalCS$print()
```

**Method** `getAlpha()`: Return the upper bound on the type 1 error

*Usage:*

```
NormalCS$getAlpha()
```

**Method** `getWeights()`: Return weights of mixture of e-values / e-detectors.

*Usage:*

```
NormalCS$getWeights()
```

**Method** `getLambdas()`: Return lambda parameters of mixture of e-values / e-detectors.

*Usage:*

```
NormalCS$getLambdas()
```

**Method** `computeWidth()`: Compute the width of confidence interval at time *n*.

*Usage:*

```
NormalCS$computeWidth(n)
```

*Arguments:*

n Positive time.

**Method** `computeInterval()`: Compute a vector of two end points of confidence interval at time n

*Usage:*

```
NormalCS$computeInterval(n, x_bar = 0)
```

*Arguments:*

n Positive time.

x\_bar The center of the confidence interval.

**Examples**

```
# Initialize two-sided standard normal confidence sequence
# optimized for the interval [10, 100]
normal_cs <- NormalCS$new(
  alternative = "two.sided",
  alpha = 0.05,
  n_upper = 100,
  n_lower = 10
)

# Compute confidence interval at n = 20 when observed sample mean = 0.5
normal_cs$computeInterval(20, x_bar = 0.5)

# (Advanced) NormalCS supports general variance process.
# Both n_upper and n_lower can be general positive numbers.
normal_cs2 <- NormalCS$new(
  alternative = "two.sided",
  alpha = 0.05,
  n_upper = 100.5,
  n_lower = 10.5
)
# Confidence interval at n = 20.5
normal_cs$computeInterval(20.5, x_bar = 0.5)
```

---

 Stcp

*Stcp Class*


---

**Description**

Stcp class supports a unified framework for sequential tests and change detection algorithms for streams of univariate (sub-)Gaussian, binary, and bounded random variables.

**Methods****Public methods:**

- `Stcp$new()`
- `Stcp$print()`
- `Stcp$getWeights()`
- `Stcp$getLambdas()`
- `Stcp$getLogValue()`
- `Stcp$getThreshold()`
- `Stcp$isStopped()`
- `Stcp$getTime()`
- `Stcp$getStoppedTime()`
- `Stcp$reset()`
- `Stcp$updateLogValues()`
- `Stcp$updateLogValuesUntilStop()`
- `Stcp$updateAndReturnHistories()`
- `Stcp$updateLogValuesByAvg()`
- `Stcp$updateLogValuesUntilStopByAvg()`
- `Stcp$updateAndReturnHistoriesByAvg()`

**Method** `new()`: Create a new `Stcp` object.

*Usage:*

```
Stcp$new(
  method = c("ST", "SR", "CU", "GLRCU"),
  family = c("Normal", "Ber", "Bounded"),
  alternative = c("two.sided", "greater", "less"),
  threshold = log(1/0.05),
  m_pre = 0,
  delta_lower = 0.1,
  delta_upper = NULL,
  weights = NULL,
  lambdas = NULL,
  k_max = 1000
)
```

*Arguments:*

`method` Method of the sequential procedure.

- ST: Sequential test based on a mixture of E-values.
- SR: Sequential change detection based on e-SR procedure.
- CU: Sequential change detection based on e-CUSUM procedure.
- GLRCU: Sequential change detection based on GLR-CUSUM procedure.

`family` Distribution of underlying univariate observations.

- Normal: (sub-)Gaussian with  $\sigma = 1$ .
- Ber: Bernoulli distribution on  $\{0,1\}$ .
- Bounded: General bounded distribution on  $[0,1]$

**alternative** Alternative / post-change mean space

- **two.sided**: Two-sided test / change detection
- **greater**: Alternative /post-change mean is greater than null / pre-change one
- **less**: Alternative /post-change mean is less than null / pre-change one

**threshold** Stopping threshold. We recommend to use  $\log(1/\alpha)$  for "ST" and "SR" methods where alpha is a testing level or 1/ARL. for "CU" and "GRLCU", we recommend to tune the threshold by using domain-specific sampler to hit the target ARL.

**m\_pre** The boundary of mean parameter in null / pre-change space

**delta\_lower** Minimum gap between null / pre-change space and alternative / post-change one. It must be strictly positive for ST, SR and CU. Currently, GLRCU does not support the minimum gap, and this param will be ignored.

**delta\_upper** Maximum gap between null / pre-change space and alternative / post-change one. It must be strictly positive for ST, SR and CU. Currently, GLRCU does not support the maximum gap, and this param will be ignored.

**weights** If not null, the input weights will be used to initialize Stcp object.

**lambdas** If not null, the input lambdas will be used to initialize Stcp object.

**k\_max** Positive integer to determine the maximum number of baselines. For GLRCU method, it is used as the lookup window size for GLRCU statistics.

*Returns:* A new Stcp object.

**Method print():** Print summary of Stcp object.

*Usage:*

Stcp\$print()

**Method getWeights():** Return weights of mixture of e-values / e-detectors.

*Usage:*

Stcp\$getWeights()

**Method getLambdas():** Return lambda parameters of mixture of e-values / e-detectors.

*Usage:*

Stcp\$getLambdas()

**Method getLogValue():** Return the log value of mixture of e-values / e-detectors.

*Usage:*

Stcp\$getLogValue()

**Method getThreshold():** Return the threshold of the sequential test / change detection

*Usage:*

Stcp\$getThreshold()

**Method isStopped():** Return TRUE if the sequential test / change detection was stopped by crossing the threshold.

*Usage:*

Stcp\$isStopped()

**Method** `getTime()`: Return the number of observations having been passed.

*Usage:*

`Stcp$getTime()`

**Method** `getStoppedTime()`: Return the stopped time. If it has been never stopped, return zero.

*Usage:*

`Stcp$getStoppedTime()`

**Method** `reset()`: Reset the stcp object to the initial setup.

*Usage:*

`Stcp$reset()`

**Method** `updateLogValues()`: Update the log value and related fields by passing a vector of observations.

*Usage:*

`Stcp$updateLogValues(xs)`

*Arguments:*

`xs` A numeric vector of observations.

**Method** `updateLogValuesUntilStop()`: Update the log value and related fields until the log value is crossing the boundary.

*Usage:*

`Stcp$updateLogValuesUntilStop(xs)`

*Arguments:*

`xs` A numeric vector of observations.

**Method** `updateAndReturnHistories()`: Update the log value and related fields then return updated log values by passing a vector of observations.

*Usage:*

`Stcp$updateAndReturnHistories(xs)`

*Arguments:*

`xs` A numeric vector of observations.

**Method** `updateLogValuesByAvg()`: Update the log value and related fields by passing a vector of averages and number of corresponding samples.

*Usage:*

`Stcp$updateLogValuesByAvg(x_bars, ns)`

*Arguments:*

`x_bars` A numeric vector of averages.

`ns` A numeric vector of sample sizes.

**Method** `updateLogValuesUntilStopByAvg()`: Update the log value and related fields by passing a vector of averages and number of corresponding samples until the log value is crossing the boundary.

*Usage:*

```
Stcp$updateLogValuesUntilStopByAvg(x_bars, ns)
```

*Arguments:*

`x_bars` A numeric vector of averages.

`ns` A numeric vector of sample sizes.

**Method** `updateAndReturnHistoriesByAvg()`: Update the log value and related fields then return updated log values a vector of averages and number of corresponding samples.

*Usage:*

```
Stcp$updateAndReturnHistoriesByAvg(x_bars, ns)
```

*Arguments:*

`x_bars` A numeric vector of averages.

`ns` A numeric vector of sample sizes.

**Examples**

```
# Sequential Normal mean test H0: mu <= 0
# Initialize stcp object for this test.
stcp <- Stcp$new(method = "ST",
                 family = "Normal",
                 alternative = "greater",
                 threshold = log(1 / 0.05),
                 m_pre = 0)

# Update the observations
obs <- c(1.0, 3.0, 2.0)
stcp$updateLogValuesUntilStop(obs)

# Check whether the sequential test is stopped
stcp$isStopped() # TRUE

# Check when the test was stopped
stcp$getStoppedTime() # 3

# Although the number of observations was 4, the test was stopped at 3.
stcp$getTime() # 3

# Get the log value of the mixture of e-values at the current time (3)
stcp$getLogValue() # 4.425555

# ...which is higher than the threshold log(1 / 0.05) ~ 2.996
stcp$getThreshold() # 2.995732

# Reset the test object
stcp$reset()

# Rerun the test but, at this time, we track updated log values
log_values <- stcp$updateAndReturnHistories(obs)
print(log_values) # 0.1159777 2.7002207 4.4255551 1.9746508
```

```
# Again, the test was stopped at 3rd observation
stcp$getStoppedTime() # 3

# But, at this time, log values were evaluated until the 4th observation.
stcp$getTime() # 4

# Print overall summary
stcp # or stcp$print() or print(stcp)
# stcp Model:
# - Method: ST
# - Family: Normal
# - Alternative: greater
# - Alpha: 0.05
# - m_pre: 0
# - Num. of mixing components: 55
# - Obs. have been passed: 4
# - Current log value: 1.974651
# - Is stopped before: TRUE
# - Stopped time: 3
```

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