

Package ‘autothresholdr’

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Type Package

Title An R Port of the 'ImageJ' Plugin 'Auto Threshold'

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Description Algorithms for automatically finding appropriate thresholds for numerical data, with special functions for thresholding images. Provides the 'ImageJ' 'Auto Threshold' plugin functionality to R users. See <<https://imagej.net/plugins/auto-threshold>> and Landini et al. (2017) <[DOI:10.1111/jmi.12474](https://doi.org/10.1111/jmi.12474)>.

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URL <https://rorynolan.github.io/autothresholdr/>,
<https://github.com/rorynolan/autothresholdr#readme>

BugReports <https://github.com/rorynolan/autothresholdr/issues>

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auto_thresh	<i>Automatically threshold an array of non-negative integers.</i>
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Description

These functions apply the ImageJ "Auto Threshold" plugin's image thresholding methods. The available methods are "IJDefault", "Huang", "Huang2", "Intermodes", "IsoData", "Li", "MaxEntropy", "Mean", "MinErrorI", "Minimum", "Moments", "Otsu", "Percentile", "RenyiEntropy", "Shanbhag", "Triangle" and "Yen". Read about them at <https://imagej.net/plugins/auto-threshold>.

Usage

```
auto_thresh(
  int_arr,
  method,
  ignore_black = FALSE,
  ignore_white = FALSE,
  ignore_na = FALSE
)
```

```
auto_thresh_mask(
  int_arr,
  method,
  ignore_black = FALSE,
  ignore_white = FALSE,
  ignore_na = FALSE
)
```

```

)

auto_thresh_apply_mask(
  int_arr,
  method,
  fail = NA,
  ignore_black = FALSE,
  ignore_white = FALSE,
  ignore_na = FALSE
)

mask(
  int_arr,
  method,
  ignore_black = FALSE,
  ignore_white = FALSE,
  ignore_na = FALSE
)

apply_mask(
  int_arr,
  method,
  fail = NA,
  ignore_black = FALSE,
  ignore_white = FALSE,
  ignore_na = FALSE
)

```

Arguments

int_arr	An array (or vector) of non-negative <i>integers</i> .
method	The name of the thresholding method you wish to use. The available methods are "IJDefault", "Huang", "Huang2", "Intermodes", "IsoData", "Li", "MaxEntropy", "Mean", "MinErrorI", "Minimum", "Moments", "Otsu", "Percentile", "RenyiEntropy", "Shanbhag", "Triangle" and "Yen". Partial matching is performed i.e. method = "h" is enough to get you "Huang" and method = "in" is enough to get you "Intermodes". To perform <i>manual</i> thresholding (where you set the threshold yourself), supply the threshold here as a number e.g. method = 3; so note that this would <i>not</i> select the third method in the above list of methods.
ignore_black	Ignore black pixels/elements (zeros) when performing the thresholding?
ignore_white	Ignore white pixels when performing the thresholding? If set to TRUE, the function makes a good guess as to what the white (saturated) value would be (see 'Details'). If this is set to a number, all pixels with value greater than or equal to that number are ignored.
ignore_na	This should be TRUE if NAs in int_arr should be ignored or FALSE if you want the presence of NAs in int_arr to throw an error.

`fail` When using `auto_thresh_apply_mask()`, to what value do you wish to set the pixels which fail to exceed the threshold? `fail = 'saturate'` sets them to saturated value (see "Details"). `fail = 'zero'` sets them to zero. You can also specify directly here a natural number (must be between 0 and $2^{16}-1$) to use.

Details

- Values greater than or equal to the found threshold *pass* the thresholding and values less than the threshold *fail* the thresholding.
- For `ignore_white = TRUE`, if the maximum value in the array is one of 2^8-1 , $2^{12}-1$, $2^{16}-1$ or $2^{32}-1$, then those max values are ignored. That's because they're the white values in 8, 12, 16 and 32-bit images respectively (and these are the common image bit sizes to work with). This guesswork has to be done because R does not know how many bits the image was on disk. This guess is very unlikely to be wrong, and if it is, the consequences are negligible anyway. If you're very concerned, then just specify the white value as an integer in this `ignore_white` argument.
- If you have set `ignore_black = TRUE` and/or `ignore_white = TRUE` but you are still getting error/warning messages telling you to try them, then your chosen method is not working for the given array, so you should try a different method.
- For a given array, if all values are less than 2^8 , saturated value is $2^8 - 1$, otherwise, if all values are less than 2^{16} , the saturated value is $2^{16} - 1$, otherwise the saturated value is $2^{32}-1$.
- For the `auto_thresh()` function, if you pass `int_arr` as a data frame with column names `value` and `n`, that's the same as passing an integer array having `n` entries of each `value`. For this form of `int_arr`, `ignore_white` and `ignore_black` are irrelevant.

Value

`auto_thresh()` returns an object of class `th` containing the threshold value. Pixels exceeding this threshold pass the thresholding, pixels at or below this level fail.

`auto_thresh_mask()` returns an object of class `masked_arr` which is a binarized version of the input, with a value of `TRUE` at points which exceed the threshold and `FALSE` at those which do not.

`auto_thresh_apply_mask()` returns an object of class `threshed_arr` which is the original input masked by the threshold, i.e. all points not exceeding the threshold are set to a user-defined value (default `NA`).

`mask()` is the same as `auto_thresh_mask()` and `apply_mask()` is the same as `auto_thresh_apply_mask()`.

Acknowledgements

Gabriel Landini coded all of these functions in Java. These java functions were then translated to C++.

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Examples

```
img_location <- system.file("extdata", "eg.tif", package = "autothresholdr")
img <- ijttiff::read_tif(img_location)
auto_thresh(img, "huang")
```

```

img_value_count <- magrittr::set_names(as.data.frame(table(img)),
                                     c("value", "n"))

print(head(img_value_count))
auto_thresh(img_value_count, "Huang")
auto_thresh(img, "tri")
auto_thresh(img, "Otsu")
auto_thresh(img, 9)
mask <- auto_thresh_mask(img, "huang")
ijttiff::display(mask[, , 1, 1])
masked <- auto_thresh_apply_mask(img, "huang")
ijttiff::display(masked[, , 1, 1])
masked <- auto_thresh_apply_mask(img, 25)
ijttiff::display(masked[, , 1, 1])

```

masked_arr	<i>Masked array class.</i>
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Description

A *mask* of an array with respect to a given threshold is found by taking the original array and setting all elements falling below the threshold to FALSE and the others to TRUE. An object of class [masked_arr](#) has the attribute `thresh` detailing the threshold value that was applied.

Usage

```
masked_arr(arr, thresh)
```

Arguments

<code>arr</code>	An array of logicals (the mask).
<code>thresh</code>	The threshold. Either a scalar or an object of class th .

Value

An object of class `masked_arr`.

mean_stack_thresh	<i>Threshold every image frame in an image stack based on their mean.</i>
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Description

An [ijttiff_img](#) is a 4-dimensional array indexed by `img[y, x, channel, frame]`. For each channel (which consists of a stack of frames), this function finds a threshold based on the sum all of the frames, uses this to create a mask and then applies this mask to every frame in the stack (so for a given pillar in the image stack, either all the pixels therein are thresholded away or all are untouched, where pillar `x,y` of channel `ch` is `img[y, x, ch,]`).

Usage

```
mean_stack_thresh(
    img,
    method,
    fail = NA,
    ignore_black = FALSE,
    ignore_white = FALSE,
    ignore_na = FALSE
)
```

Arguments

img	A 4-dimensional array in the style of an <code>ijtiff_img</code> (indexed by <code>img[y, x, channel, frame]</code>) or a 3-dimensional array which is a single channel of an <code>ijtiff_img</code> (indexed by <code>img[y, x, frame]</code>).
method	The name of the thresholding method you wish to use. The available methods are "IJDefault", "Huang", "Huang2", "Intermodes", "IsoData", "Li", "MaxEntropy", "Mean", "MinErrorI", "Minimum", "Moments", "Otsu", "Percentile", "RenyiEntropy", "Shanbhag", "Triangle" and "Yen". Partial matching is performed i.e. <code>method = "h"</code> is enough to get you "Huang" and <code>method = "in"</code> is enough to get you "Intermodes". To perform <i>manual</i> thresholding (where you set the threshold yourself), supply the threshold here as a number e.g. <code>method = 3.8</code> (so note that this would <i>not</i> select the third method in the above list of methods). This manual threshold will then be used to threshold the sum stack to create a 2D mask and then this mask will be applied to all frames in the stack. If you want a different method for each channel, specify this parameter as a vector or list, one element per channel.
fail	When using <code>auto_thresh_apply_mask()</code> , to what value do you wish to set the pixels which fail to exceed the threshold? <code>fail = 'saturate'</code> sets them to saturated value (see 'Details'). <code>fail = 'zero'</code> sets them to zero. You can also specify directly here a natural number (must be between 0 and $2^{16} - 1$) to use.
ignore_black	Ignore black pixels/elements (zeros) when performing the thresholding?
ignore_white	Ignore white pixels when performing the thresholding? If set to TRUE, the function makes a good guess as to what the white (saturated) value would be (see 'Details'). If this is set to a number, all pixels with value greater than or equal to that number are ignored.
ignore_na	This should be TRUE if NAs in <code>int_arr</code> should be ignored or FALSE if you want the presence of NAs in <code>int_arr</code> to throw an error.

Details

It's called `mean_stack_thresh()` and not `sum_stack_thresh()` because its easier for people to visualize the mean of an image series than to visualize the sum, but for the sake of this procedure, both are equivalent, except for the fact that the thresholding routine invoked inside this function prefers integers, which we get by using a sum but not by using a mean.

- Values greater than or equal to the found threshold *pass* the thresholding and values less than the threshold *fail* the thresholding.

- For `ignore_white = TRUE`, if the maximum value in the array is one of 2^8-1 , $2^{16}-1$ or $2^{32}-1$, then those max values are ignored. That's because they're the white values in 8, 16 and 32-bit images respectively (and these are the common image bit sizes to work with). This guesswork has to be done because R does not know how many bits the image was on disk. This guess is very unlikely to be wrong, and if it is, the consequences are negligible anyway. If you're very concerned, then just specify the white value as an integer in this `ignore_white` argument.
- If you have set `ignore_black = TRUE` and/or `ignore_white = TRUE` but you are still getting error/warning messages telling you to try them, then your chosen method is not working for the given array, so you should try a different method.
- For a given array, if all values are less than 2^8 , saturated value is $2^8 - 1$, otherwise, saturated value is $2^{16} - 1$.

Value

An object of class `stack_threshed_img` which is the thresholded image (an array in the style of an `ijtiff_img`). Pillars not exceeding the threshold are set to the `fail` value (default NA).

Examples

```
img <- ijtiff::read_tif(system.file("extdata", "50.tif",
  package = "autothresholdr"
))
ijtiff::display(img[, , 1, 1])
img_thresh_mask <- mean_stack_thresh(img, "Otsu")
ijtiff::display(img_thresh_mask[, , 1, 1])
ijtiff::display(img[, , 1, 1])
img_thresh_mask <- mean_stack_thresh(img, "Huang")
ijtiff::display(img_thresh_mask[, , 1, 1])
```

med_stack_thresh	<i>Threshold every image frame in a stack based on their median.</i>
------------------	--

Description

An `ijtiff_img` is a 4-dimensional array indexed by `img[y, x, channel, frame]`. For each channel (which consists of a stack of frames), this function finds a threshold based on all of the frames, then takes the median of all the frames in the stack image, uses this to create a mask with the found threshold and then applies this mask to every frame in the stack (so for a given pillar in the image stack, either all the pixels therein are thresholded away or all are untouched, where pillar `x,y` of channel `ch` is `img[y, x, ch,]`).

Usage

```
med_stack_thresh(
  img,
  method,
  fail = NA,
  ignore_black = FALSE,
  ignore_white = FALSE,
  ignore_na = FALSE
)
```

Arguments

<code>img</code>	A 3-dimensional array (the image stack, possibly a time-series of images) where the <i>n</i> th slice is the <i>n</i> th image in the stack.
<code>method</code>	The name of the thresholding method you wish to use. The available methods are "IJDefault", "Huang", "Huang2", "Intermodes", "IsoData", "Li", "MaxEntropy", "Mean", "MinErrorI", "Minimum", "Moments", "Otsu", "Percentile", "RenyiEntropy", "Shanbhag", "Triangle" and "Yen". Partial matching is performed i.e. <code>method = "h"</code> is enough to get you "Huang" and <code>method = "in"</code> is enough to get you "Intermodes". To perform <i>manual</i> thresholding (where you set the threshold yourself), supply the threshold here as a number e.g. <code>method = 3</code> (so note that this would <i>not</i> select the third method in the above list of methods). This manual threshold will then be used to threshold the median stack to create a 2D mask and then this mask will be applied to all frames in the stack. If you want a different method for each channel, specify this parameter as a vector or list, one element per channel.
<code>fail</code>	When using <code>auto_thresh_apply_mask()</code> , to what value do you wish to set the pixels which fail to exceed the threshold? <code>fail = 'saturate'</code> sets them to saturated value (see 'Details'). <code>fail = 'zero'</code> sets them to zero. You can also specify directly here a natural number (must be between 0 and $2^{32}-1$) to use.
<code>ignore_black</code>	Ignore black pixels/elements (zeros) when performing the thresholding?
<code>ignore_white</code>	Ignore white pixels when performing the thresholding? If set to TRUE, the function makes a good guess as to what the white (saturated) value would be (see 'Details').
<code>ignore_na</code>	This should be TRUE if NAs in <code>int_arr</code> should be ignored or FALSE if you want the presence of NAs in <code>int_arr</code> to throw an error.

Details

- Values greater than or equal to the found threshold *pass* the thresholding and values less than the threshold *fail* the thresholding.
- For `ignore_white = TRUE`, if the maximum value in the array is one of 2^8-1 , $2^{16}-1$ or $2^{32}-1$, then those max values are ignored. That's because they're the white values in 8, 16 and 32-bit images respectively (and these are the common image bit sizes to work with). This guesswork has to be done because R does not know how many bits the image was on disk. This guess is very unlikely to be wrong, and if it is, the consequences are negligible anyway.

If you're very concerned, then just specify the white value as an integer in this `ignore_white` argument.

- If you have set `ignore_black = TRUE` and/or `ignore_white = TRUE` but you are still getting error/warning messages telling you to try them, then your chosen method is not working for the given array, so you should try a different method.
- For a given array, if all values are less than 2^8 , saturated value is $2^8 - 1$, otherwise, saturated value is $2^{16} - 1$.

Value

An object of class `stack_threshed_img` which is the thresholded image (an array in the style of an `ijtiff_img`). Pillars not exceeding the threshold are set to the `fail` value (default NA).

Examples

```
img <- ijtiff::read_tif(system.file("extdata", "50.tif",
  package = "autothresholdr"
))
ijttiff::display(img[, , 1, 1])
img_thresh_mask <- med_stack_thresh(img, "Otsu")
ijttiff::display(img_thresh_mask[, , 1, 1])
ijttiff::display(img[, , 1, 1])
img_thresh_mask <- med_stack_thresh(img, "Triangle")
ijttiff::display(img_thresh_mask[, , 1, 1])
```

`stack_threshed_img` *Stack-thresholded image class.*

Description

A stack-thresholded array is an array which has had stack-thresholding applied to it. See `mean_stack_thresh()`. It has 3 necessary attributes:

- `thresh` is the threshold that was applied. This is either a number or an object of class `th`. Values in the original array which were less than this value are deemed to have failed the thresholding.
- `fail_value` is the value to which elements of the array which failed the thresholding were set. This could be something like `0` or `NA`.
- `stack_thresh_method` details which stacked-thresholding method was employed; this is either `"mean"` or `"median"`.

Usage

```
stack_threshed_img(img, thresh, fail_value, stack_thresh_method)
```

Arguments

img	A 4-dimensional array in the style of an ijtiff_img (indexed by <code>img[y, x, channel, frame]</code>) or a 3-dimensional array which is a single channel of an ijtiff_img (indexed by <code>img[y, x, frame]</code>).
thresh	The threshold that was used. Either a number or an object of class th .
fail_value	The value to which elements of the array which failed the thresholding were set.
stack_thresh_method	This must be set to either "mean" or "median" to tell which stacked-thresholding method was employed.

Value

An object of class `stack_threshed_img`.

See Also

[threshed_arr](#), [mean_stack_thresh\(\)](#), [med_stack_thresh\(\)](#).

th	<i>Automatically found threshold class.</i>
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Description

A threshold found automatically via [auto_thresh\(\)](#). It is a number (the value of the threshold) with 4 attributes:

- `ignore_black` is TRUE if black values were ignored during the thresholding and FALSE otherwise.
- `ignore_white` is TRUE if white values were ignored during the thresholding and FALSE otherwise.
- `ignore_na` is TRUE if NAs were ignored during the thresholding and FALSE otherwise.
- `autothresh_method` details which automatic thresholding method was used.

Usage

```
th(thresh, ignore_black, ignore_white, ignore_na, autothresh_method)
```

Arguments

thresh	A scalar. The threshold.
ignore_black	TRUE if black values were ignored during the thresholding and FALSE otherwise.
ignore_white	TRUE if white values were ignored during the thresholding and FALSE otherwise.
ignore_na	TRUE if NA values were ignored during the thresholding and FALSE otherwise.
autothresh_method	The name of the automatic thresholding method used.

Value

An object of class `th`.

<code>threshed_arr</code>	<i>Thresholded array class.</i>
---------------------------	---------------------------------

Description

A thresholded array is an array which has had a threshold applied to it. It has an attribute `thresh` which is the threshold that was applied which can be a number or an object of class `th`.

Usage

```
threshed_arr(arr, thresh)
```

Arguments

<code>arr</code>	The thresholded array (<i>not</i> the original array).
<code>thresh</code>	The threshold that was used. Either a number or an object of class <code>th</code> .

Details

The term 'array' is used loosely here in that vectors and matrices qualify as arrays.

Value

An object of class `threshed_arr`.

See Also

`stack_threshed_img`, `apply_mask()`.

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