Package ‘keyperm’

August 30, 2023

Type Package

Title Keyword Analysis Using Permutation Tests

Version 0.1.1

Description Efficient implementation of permutation tests for keyword analysis in corpus linguistics as described in Mildenberger (2023) <arXiv:2308.13383>.

License GPL (>= 2)

Imports slam, tm

LinkingTo Rcpp

RoxygenNote 7.1.0

NeedsCompilation yes

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Repository CRAN

Date/Publication 2023-08-30 15:40:01 UTC

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combine_results

Combine results of permutation test for keyness

Description

Combine results of two runs of keyperm() with output = "counts", possibly with different subsets of terms.

Usage

combine_results(results_1, results_2)

Arguments

results_1 Results from permutation test. Must be of class keyperm_results_counts (obtained by setting output = "counts" in keyperm())
results_2 Results from permutation test. Must be of class keyperm_results_counts and have the same scoretype as results_1.

Details

Results of two runs of keyperm() with output = "counts", i.e. objects of type keyperm_results_counts using can be combined using combine_results(). For this to make sense, scoretype needs to be the same in both results, but terms in both objects need not be the same.

There are at least two important uses of the function:

Parallelization: keyperm() is run several times with the same parameters on different cores, using parallel::mclapply() or a similar function.

Screening runs: keyperm() is first run using a small to medium number of permutations, but considering all terms. Terms with p-values clearly exceeding some reasonable significance threshold are then excluded, and keyperm() is run a second time with a (preferably) large number of permutations but using only the remaining terms. The results of both runs can then be combined into one object. The rationale behind this approach is that in many cases small p-values need to be determined with much greater accuracy than larger ones far away from significance, especially if a correction for multiple testing is to be applied or the p-values are used for ranking (although they should not...).

Value

An object of class keyperm_results_counts
create_ifl

Create an Indexed Frequency List

Description

The keyperm package stores frequency lists in a special data structure called indexed frequency list. This can currently be created from a tdm object as implemented in the tm package.

Indexed frequency lists are essentially frequency lists stored in a three-column format, similar to the simple triplet matrix internally used by tm to store term-document-matrices. The first column stores number of document \( i \), second number of term \( j \) and the third the frequencies with which the term \( j \) occurs in document \( i \). Zero occurrences are omitted. All columns contain integers, and the frequency list is sorted by document.

The object returned is of class `indexed_frequency_list`. In addition to the actual frequency list it contains an index for fast access as well as pre-computed total number of tokens per document and total occurrences per term.

Usage

```r
create_ifl(
  tdm,
  subset_terms = 1:dim(tdm)[1],
  subset_docs = 1:dim(tdm)[2],
  corpus
)
```

Arguments

- `tdm` a tdm-matrix from the tm package. Currently, this is the only supported input, but others may be added in later versions.
- `subset_terms` vector of terms to be considered. Can be integer (indices) or boolean. Terms not included still are counted for total number of token per document.
- `subset_docs` vector of documents to be considered. Can be integer (indices) or boolean. Documents excluded do not contribute to total number of occurrences of a term.
- `corpus` vector indicating which documents belong to corpus A (first corpus). Can be integer (indices) or boolean. Currently, only comparisons of two corpora are supported.

Value

A list with class `indexed_frequency_list` containing the following components:
keyness_scores  

*Calculate observed keyness scores*

**Description**

Calculates a vector of observed keyness scores for a given pair of corpora.

**Usage**

```r
keyness_scores(ifl, type = "llr", laplace = 1)
```

**Arguments**

- `ifl`  
  Indexed frequency list as generated by `create_ifl()`.
- `type`  
  The type of keyness measure. One of `llr`, `chisq`, `diff`, `logratio` or `ratio`. See details.
- `laplace`  
  Parameter of laplace correction. Only relevant for `type = "ratio"` and `type = "logratio"`. See details.

**Details**

Keyness scores are calculated for an Indexed frequency list from a given pair of corpora as generated by `create_ifl()`.

Currently, the following types of scores are supported:

- `llr` The log-likelihood ratio
- `chisq` The Chi-Square-Statistic
- `diff` Difference of relative frequencies
- `logratio` Binary logarithm of the ratio of the relative frequencies, possibly using a laplace correction to avoid infinite values.
- `ratio` ratio of the relative frequencies, possibly using a laplace correction to avoid infinite values.

`llr` and `chisq` are the test-statistics for a two-by-two contingency table.

<table>
<thead>
<tr>
<th></th>
<th>corpus A</th>
<th>corpus B</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>term of interest</td>
<td>$o_{11}$</td>
<td>$o_{12}$</td>
<td>$r_1$</td>
</tr>
<tr>
<td>other tokens</td>
<td>$o_{21}$</td>
<td>$o_{22}$</td>
<td>$r_2$</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$c_1$</td>
<td>$c_2$</td>
<td>$N$</td>
</tr>
</tbody>
</table>

Both measure deviations from equal proportions but do not indicate the direction. For `llr`, the correct version using terms for all four fields of the table is used, not the version using only two terms that is sometimes used in corpus linguistics:

$$llr = -2 \star (o_{11} \star \log(o_{11}/e_{11}) + o_{12} \star \log(o_{12}/e_{12}) + o_{21} \star \log(o_{21}/e_{21}) + o_{22} \star \log(o_{22}/e_{22}))$$
where \( o_{ij} \ast \log(o_{ij}/e_{ij}) = 0 \) if \( o_{ij} = 0 \).

\( \text{chisq} \) is the usual Chi-Square statistic for a test of independence / homogeneity:

\[
\text{chisq} = \frac{(o_{11} - e_{11})^2}{e_{11}} + \frac{(o_{12} - e_{12})^2}{e_{12}} + \frac{(o_{21} - e_{21})^2}{e_{21}} + \frac{(o_{22} - e_{22})^2}{e_{22}}
\]

Here, \( o_{ij} \) are the observed counts as given above and \( e_{ij} \) are the corresponding expected values under an independence / homogeneity assumption.

diff and logratio are measures of the effect size, but using the permutation approach implemented here a p-value can be calculated as well. Both indicate the direction of the effect, and can be used for one- or two-sided tests.

\[
diff = \frac{o_{11}}{c_1} - \frac{o_{12}}{c_2}
\]

logratio is based on a ratio of ratios and would be infinite when a term does not occur in either of the two corpora, irrespective of number of occurrences in the other corpus. Hence, we use a laplace correction adding a (not necessarily integer) number \( k \) of fictitious occurrences to both corpora:

\[
\text{logratio} = \log2\left(\frac{(o_{11} + k)/(c_{1} + k))}{((o_{12} + k)/(c_{2} + k))}\right)
\]

where \( o_{11} \) and \( o_{12} \) are the number of occurrences of the term of interest in Corpora A and B and \( c_{1} \) and \( c_{2} \) are the total numbers of tokens in A and B. Setting \( k \) to zero corresponds to the usual logratio (which may be infinite). \( k \) is given by the laplace argument and defaults to one, meaning one fictitious occurrence is added to either corpus. Doing so prevents infinite values but has little effect when the number of occurrences is large.

ratio is the same as logratio but omits the logarithm:

\[
\text{ratio} = \frac{(o_{11} + k)/(c_{1} + k))}{((o_{12} + k)/(c_{2} + k))}
\]

This leads to the same p-values but is faster to compute.

Value

a numerical vector of the scores, one for each term. Terms are stored in the names attribute.

<table>
<thead>
<tr>
<th>keyperm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculate the permutation distribution for a keyness measure</td>
</tr>
</tbody>
</table>

Description

Calculate the permutation distributions of a given keyness measure for each term by shuffling the corpus labels. Number of documents per corpus is kept constant.

Usage

keyperm(ifl, observed, type = "llr", laplace = 1, output = "counts", nperm)
Arguments

- **ifl**: Indexed frequency list as generated by `create_ifl()`.
- **observed**: The vector of observed values of the keyness scores as generated by `keyness_scores()`.
- **type**: The type of keyness measure. One of `llr`, `chisq`, `diff`, `logratio` or `ratio`. See details.
- **laplace**: Parameter of laplace correction. Only relevant for `type = "ratio"` and `type = "logratio"`. See details.
- **output**: The type of output. For `output = "full"` a matrix with all generated scores is returned, for `output = "counts"` a matrix with three columns counting the number of permutations for which the score is strictly smaller than, equal to or strictly larger than the observed value.
- **nperm**: The number of permutations to generate.

Details

While usually keyness scores are judged by reference to a limiting null distribution under a token-by-token-sampling model, this implementation approximates the null distribution under a document-by-document sampling model. The permutation distributions of a given keyness measure for each term is calculated by repeatedly shuffling the corpus labels. Number of documents per corpus is kept constant.

Currently, the following types of scores are supported:

- **llr**: The log-likelihood ratio
- **chisq**: The Chi-Square-Statistic
- **diff**: Difference of relative frequencies
- **logratio**: Binary logarithm of the ratio of the relative frequencies, possibly using a laplace correction to avoid infinite values.
- **ratio**: ratio of the relative frequencies, possibly using a laplace correction to avoid infinite values.

`llr` and `chisq` are the test-statistics for a two-by-two contingency table.

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Both measure deviations from equal proportions but do not indicate the direction. For `llr`, the correct version using terms for all four fields of the table is used, not the version using only two terms that is sometimes used in corpus linguistics:

$$llr = -2 \times (o_{11} \times \log(o_{11}/e_{11}) + o_{12} \times \log(o_{12}/e_{12}) + o_{21} \times \log(o_{21}/e_{21}) + o_{22} \times \log(o_{22}/e_{22}))$$

where $o_{ij} \times \log(o_{ij}/e_{ij}) = 0$ if $o_{ij} = 0$.

`chisq` is the usual Chi-Square statistic for a test of independence / homogeneity:

$$chisq = (o_{11} - e_{11})^2/e_{11} + (o_{12} - e_{12})^2/e_{12} + (o_{21} - e_{21})^2/e_{21} + (o_{22} - e_{22})^2/e_{22}$$
Both llr and chisq asymptotically follow a Chi-Square-Distribution with 1 degree of freedom if the null hypothesis of equal frequencies in both populations is true and the corpora are drawn iid token-by-token. In contrast, the p-values calculated here are obtained based on a document-by-document sampling model, which is arguably more realistic in many cases.

Here, $o_{ij}$ are the observed counts as given above and $e_{ij}$ are the corresponding expected values under an independence / homogeneity assumption.

$diff$ and $logratio$ are measures of the effect size, but using the permutation approach implemented here a p-value can be calculated as well. Both indicate the direction of the effect, and can be used for one- or two-sided tests.

$$diff = o_{11}/c_1 - o_{12}/c_2$$

$logratio$ is based on a ratio of ratios and would be infinite when a term does not occur in either of the two corpora, irrespective of number of occurrences in the other corpus. Hence, we use a laplace correction adding a (not necessarily integer) number $k$ of ficticious occurrences to both corpora:

$$logratio = \log2(((o_{11} + k)/(c_1 + k))/((o_{12} + k)/(c_2 + k)))$$

where $o_{11}$ and $o_{12}$ are the number of occurrences of the term of interest in Corpora A and B, and $c_1$ and $c_2$ are the total numbers of tokens in A and B. Setting $k$ to zero corresponds to the usual logratio (which may be infinite). $k$ is given by the laplace argument and defaults to one, meaning one ficticious occurrence is added to either corpus. Doing so prevents infinite values but has little effect when the number of occurrences is large.

$ratio$ is the same as $logratio$ but omits the logarithm:

$$ratio = ((o_{11} + k)/(c_1 + k))/((o_{12} + k)/(c_2 + k))$$

This leads to the same p-values but is faster to compute.

**Value**

A numeric matrix with number of rows equal to the number of terms. The columns contain either all permutation values of the keyness score (output = "full") or the number of permutations for which the score is strictly smaller than, equal to or strictly larger than the observed value (output = "counts").

**Description**

Convert results of permutation test for keyness to p-values

**Usage**

p_value(results, alternative = NULL)
Arguments

results results from permutation test. Must be of class keyperm_results_counts (obtained by setting output = "counts" in keyperm())

alternative direction of p-value to calculate, one of "two.sided", "greater", "less". Defaults depend on the scores used. See details.

Details

Valid (slightly conservative) p-values are calculated from an object of class keyperm_results_counts that is obtained by running keyperm() with output = "counts". keyperm_results_counts is a matrix with three columns that contain the counts of generated permutations that resulted in a score strictly less than, equal to and strictly greater than the observed score.

For a one-sided p-value we use

\[ p_{value, greater} = \frac{no.greater + no.equal + 1}{no.ofperms + 1} \]

or

\[ p_{value, less} = \frac{no.less + no.equal + 1}{no.ofperms + 1} \]

Adding 1 in both the numerator and denominator amounts to including the observed values. This results in a slightly conservative p-value, but guarantees that the test is valid for any number of random permutations. It also means that never a p-value of zero is returned but the minimum possible p-value is \( \frac{1}{no.perms + 1} \).

The two-sided p-value is calculated by

\[ p_{value, twosided} = 2 \times \min(p_{value, less}, p_{value, greater}) \]

(values larger than 1 are set to 1).

If alternative is not specified by the user, different defaults are used depending on the score-type (which is included as an attribute in the keyperm_results_counts object). Since for llr and chisq, large values indicate a great deviation from equal frequencies without indicating the direction, alternative = "greater" is basically the only alternative of interest and is used as a default. For diff and logratio large absolute values indicate a great deviation from equal frequencies, and positive values correspond to higher frequencies in A, negative frequencies correspond to a higher frequency in B. For these scoretypes, the default is alternative = "two.sided". If only "positive" keywords for A with respect to B are desired, use alternative = "less".

Value

a numeric vector of p-values.
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