

# Package ‘ttgsea’

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**Type** Package

**Title** Tokenizing Text of Gene Set Enrichment Analysis

**Description** Functional enrichment analysis methods such as gene set enrichment analysis (GSEA) have been widely used for analyzing gene expression data. GSEA is a powerful method to infer results of gene expression data at a level of gene sets by calculating enrichment scores for predefined sets of genes. GSEA depends on the availability and accuracy of gene sets. There are overlaps between terms of gene sets or categories because multiple terms may exist for a single biological process, and it can thus lead to redundancy within enriched terms. In other words, the sets of related terms are overlapping. Using deep learning, this package is aimed to predict enrichment scores for unique tokens or words from text in names of gene sets to resolve this overlapping set issue. Furthermore, we can coin a new term by combining tokens and find its enrichment score by predicting such a combined tokens.

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**Depends** keras

**Imports** tm, text2vec, tokenizers, textstem, stopwords, data.table,  
purrr, DiagrammeR, stats

**Suggests** fgsea, knitr, testthat, reticulate, rmarkdown

**SystemRequirement** tensorflow

**License** Artistic-2.0

**biocViews** Software, GeneExpression, GeneSetEnrichment

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**Author** Dongmin Jung [cre, aut] (ORCID:  
<<https://orcid.org/0000-0001-7499-8422>>)

**Maintainer** Dongmin Jung <dmdmjung@gmail.com>

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bi_gru	<i>Bidirectional GRU with embedding layer</i>
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### Description

A predefined function that is used as a model in "ttgsea". This is a simple model, but you can define your own model. The loss function is "mean\_squared\_error" and the optimizer is "adam". Pearson correlation is used as a metric.

### Usage

```
bi_gru(num_tokens, embedding_dim, length_seq, num_units)
```

### Arguments

num_tokens	maximum number of tokens
embedding_dim	a non-negative integer for dimension of the dense embedding
length_seq	length of input sequences, input length of "layer_embedding"
num_units	dimensionality of the output space in the GRU layer

### Value

model

### Author(s)

Dongmin Jung

### See Also

keras::keras\_model, keras::layer\_input, keras::layer\_embedding, keras::layer\_gru, keras::bidirectional, keras::layer\_dense, keras::compile

**Examples**

```

library(reticulate)
if (keras::is_keras_available() & reticulate::py_available()) {
  num_tokens <- 1000
  length_seq <- 30
  embedding_dim <- 50
  num_units <- 32
  model <- bi_gru(num_tokens, embedding_dim, length_seq, num_units)

  # stacked gru
  num_units_1 <- 32
  num_units_2 <- 16
  stacked_gru <- function(num_tokens, embedding_dim, length_seq,
                          num_units_1, num_units_2)
  {
    model <- keras::keras_model_sequential() %>%
      keras::layer_embedding(input_dim = num_tokens,
                            output_dim = embedding_dim,
                            input_length = length_seq,
                            mask_zero = TRUE) %>%
      keras::layer_gru(units = num_units_1,
                      activation = "relu",
                      return_sequences = TRUE) %>%
      keras::layer_gru(units = num_units_2,
                      activation = "relu") %>%
      keras::layer_dense(1)

    model %>%
      keras::compile(loss = "mean_squared_error",
                    optimizer = "adam",
                    metrics = custom_metric("pearson_correlation",
                                           metric_pearson_correlation))
  }
}

```

---

**bi\_lstm***Bidirectional LSTM with embedding layer*

---

**Description**

A predefined function that is used as a model in "ttgsea". This is a simple model, but you can define your own model. The loss function is "mean\_squared\_error" and the optimizer is "adam". Pearson correlation is used as a metric.

**Usage**

```
bi_lstm(num_tokens, embedding_dim, length_seq, num_units)
```

**Arguments**

num_tokens	maximum number of tokens
embedding_dim	a non-negative integer for dimension of the dense embedding
length_seq	length of input sequences, input length of "layer_embedding"
num_units	dimensionality of the output space in the LSTM layer

**Value**

model

**Author(s)**

Dongmin Jung

**See Also**

keras::keras\_model, keras::layer\_input, keras::layer\_embedding, keras::layer\_lstm, keras::bidirectional, keras::layer\_dense, keras::compile

**Examples**

```
library(reticulate)
if (keras::is_keras_available() & reticulate::py_available()) {
  num_tokens <- 1000
  length_seq <- 30
  embedding_dim <- 50
  num_units <- 32
  model <- bi_lstm(num_tokens, embedding_dim, length_seq, num_units)

  # stacked lstm
  num_units_1 <- 32
  num_units_2 <- 16
  stacked_lstm <- function(num_tokens, embedding_dim, length_seq,
                           num_units_1, num_units_2)
  {
    model <- keras::keras_model_sequential() %>%
      keras::layer_embedding(input_dim = num_tokens,
                             output_dim = embedding_dim,
                             input_length = length_seq,
                             mask_zero = TRUE) %>%
      keras::layer_lstm(units = num_units_1,
                        activation = "relu",
                        return_sequences = TRUE) %>%
      keras::layer_lstm(units = num_units_2,
                        activation = "relu") %>%
      keras::layer_dense(1)

    model %>%
      keras::compile(loss = "mean_squared_error",
                     optimizer = "adam",
                     metrics = custom_metric("pearson_correlation",
                                             metric_pearson_correlation))
  }
}
```

**Description**

From the result of GSEA, we can predict enrichment scores for unique tokens or words from text in names of gene sets by using deep learning. The function "text\_token" is used for tokenizing text and the function "token\_vector" is used for encoding. Then the encoded sequence is fed to the embedding layer of the model.

**Usage**

```
fit_model(gseaRes, text, score, model, ngram_min = 1, ngram_max = 2,
          num_tokens, length_seq, epochs, batch_size,
          use_generator = TRUE, ...)
```

**Arguments**

gseaRes	a table with GSEA result having rows for gene sets and columns for text and scores
text	column name for text data
score	column name for enrichment score
model	deep learning model, input dimension and length for the embedding layer must be same to the "num_token" and "length_seq", respectively
ngram_min	minimum size of an n-gram (default: 1)
ngram_max	maximum size of an n-gram (default: 2)
num_tokens	maximum number of tokens, it must be equal to the input dimension of "layer_embedding" in the "model"
length_seq	length of input sequences, it must be equal to the input length of "layer_embedding" in the "model"
epochs	number of epochs
batch_size	batch size
use_generator	if "use_generator" is TRUE, the function "sampling_generator" is used for "fit_generator". Otherwise, the "fit" is used without a generator.
...	additional parameters for the "fit" or "fit_generator"

**Value**

model	trained model
tokens	information for tokens
token_pred	prediction for every token, each row has a token and its predicted score
token_gsea	list of the GSEA result only for the corresponding token
num_tokens	maximum number of tokens
length_seq	length of input sequences

**Author(s)**

Dongmin Jung

**See Also**

keras::fit\_generator, keras::layer\_embedding, keras::pad\_sequences, textstem::lemmatize\_strings, text2vec::create\_vocabulary, text2vec::prune\_vocabulary

## Examples

```
library(reticulate)
if (keras::is_keras_available() & reticulate::py_available()) {
  library(fgsea)
  data(examplePathways)
  data(exampleRanks)
  names(examplePathways) <- gsub("_", " ",
                                substr(names(examplePathways), 9, 1000))

  set.seed(1)
  fgseaRes <- fgsea(examplePathways, exampleRanks)

  num_tokens <- 1000
  length_seq <- 30
  batch_size <- 32
  embedding_dims <- 50
  num_units <- 32
  epochs <- 1

  ttgseaRes <- fit_model(fgseaRes, "pathway", "NES",
                        model = bi_gru(num_tokens,
                                       embedding_dims,
                                       length_seq,
                                       num_units),
                        num_tokens = num_tokens,
                        length_seq = length_seq,
                        epochs = epochs,
                        batch_size = batch_size,
                        use_generator = FALSE)
}
```

---

metric\_pearson\_correlation

*Pearson correlation coefficient*

---

## Description

Pearson correlation coefficient can be seen as one of the model performance metrics. This is a measure of how close the predicted value is to the true value. If it is close to 1, the model is considered a good fit. If it is close to 0, the model is not good. A value of 0 corresponds to a random prediction.

## Author(s)

Dongmin Jung

## See Also

keras::k\_mean, keras::sum, keras::k\_square, keras::k\_sqrt

## Examples

```
library(reticulate)
if (keras::is_keras_available() & reticulate::py_available()) {
  num_tokens <- 1000
  length_seq <- 30
  embedding_dims <- 50
  num_units_1 <- 32
  num_units_2 <- 16

  stacked_gru <- function(num_tokens, embedding_dims, length_seq,
                          num_units_1, num_units_2)
  {
    model <- keras::keras_model_sequential() %>%
      keras::layer_embedding(input_dim = num_tokens,
                             output_dim = embedding_dims,
                             input_length = length_seq) %>%
      keras::layer_gru(units = num_units_1,
                       activation = "relu",
                       return_sequences = TRUE) %>%
      keras::layer_gru(units = num_units_2,
                       activation = "relu") %>%
      keras::layer_dense(1)

    model %>%
      keras::compile(loss = "mean_squared_error",
                    optimizer = "adam",
                    metrics = custom_metric("pearson_correlation",
                                             metric_pearson_correlation))
  }
}
```

---

plot\_model

*visualization of the model architecture*

---

## Description

You are allowed to create a visualization of your model architecture. This architecture displays the information about the name, input shape, and output shape of layers in a flowchart.

## Usage

```
plot_model(x)
```

## Arguments

x                    deep learning model

## Value

plot for the model architecture

## Author(s)

Dongmin Jung

**See Also**

purrr::map, purrr::map\_chr, purrr::pluck, purrr::imap\_dfr, DiagrammeR::grViz

**Examples**

```
library(reticulate)
if (keras::is_keras_available() & reticulate::py_available()) {
  inputs1 <- layer_input(shape = c(1000))
  inputs2 <- layer_input(shape = c(1000))

  predictions1 <- inputs1 %>%
    layer_dense(units = 128, activation = 'relu') %>%
    layer_dense(units = 64, activation = 'relu') %>%
    layer_dense(units = 32, activation = 'softmax')

  predictions2 <- inputs2 %>%
    layer_dense(units = 128, activation = 'relu') %>%
    layer_dense(units = 64, activation = 'relu') %>%
    layer_dense(units = 32, activation = 'softmax')

  combined <- layer_concatenate(c(predictions1, predictions2)) %>%
    layer_dense(units = 16, activation = 'softmax')

  model <- keras_model(inputs = c(inputs1, inputs2),
                       outputs = combined)
  plot_model(model)
}
```

---

predict\_model

*Model prediction*

---

**Description**

From the result of the function "ttgsea", we can predict enrichment scores. For each new term, lemmatized text, predicted enrichment score, Monte Carlo p-value and adjusted p-value are provided. The function "token\_vector" is used for encoding as we did for training. Of course, mapping from tokens to integers should be the same.

**Usage**

```
predict_model(object, new_text, num_simulations = 1000,
              adj_p_method = "fdr")
```

**Arguments**

object	result of "ttgsea"
new_text	new text data
num_simulations	number of simulations for Monte Carlo p-value (default: 1000)
adj_p_method	correction method (default: "fdr")

**Value**

table for lemmatized text, predicted enrichment score, MC p-value and adjusted p-value

**Author(s)**

Dongmin Jung

**See Also**

stats::p.adjust

**Examples**

```
library(reticulate)
if (keras::is_keras_available() & reticulate::py_available()) {
  library(fgsea)
  data(examplePathways)
  data(exampleRanks)
  names(examplePathways) <- gsub("_", " ",
                                substr(names(examplePathways), 9, 1000))

  set.seed(1)
  fgseaRes <- fgsea(examplePathways, exampleRanks)

  num_tokens <- 1000
  length_seq <- 30
  batch_size <- 32
  embedding_dims <- 50
  num_units <- 32
  epochs <- 1

  ttgseaRes <- fit_model(fgseaRes, "pathway", "NES",
                        model = bi_gru(num_tokens,
                                       embedding_dims,
                                       length_seq,
                                       num_units),
                        num_tokens = num_tokens,
                        length_seq = length_seq,
                        epochs = epochs,
                        batch_size = batch_size,
                        use_generator = FALSE)

  set.seed(1)
  predict_model(ttgseaRes, "Cell Cycle")
}
```

---

sampling\_generator

*Generator function*

---

**Description**

This is a generator function that yields batches of training data then pass the function to the "fit\_generator" function.

**Usage**

```
sampling_generator(X_data, Y_data, batch_size)
```

**Arguments**

X_data	inputs
Y_data	targets
batch_size	batch size

**Value**

generator for "fit\_generator"

**Author(s)**

Dongmin Jung

**Examples**

```
X_data <- matrix(rnorm(200), ncol = 2)
Y_data <- matrix(rnorm(100), ncol = 1)
sampling_generator(X_data, Y_data, 32)
```

---

text\_token

*Tokenizing text*

---

**Description**

An n-gram is used for tokenization. This function can also be used to limit the total number of tokens.

**Usage**

```
text_token(text, ngram_min = 1, ngram_max = 1, num_tokens)
```

**Arguments**

text	text data
ngram_min	minimum size of an n-gram (default: 1)
ngram_max	maximum size of an n-gram (default: 1)
num_tokens	maximum number of tokens

**Value**

token	result of tokenizing text
ngram_min	minimum size of an n-gram
ngram_max	maximum size of an n-gram

**Author(s)**

Dongmin Jung

**See Also**

tm::removeWords, stopwords::stopwords, textstem::lemmatize\_strings, text2vec::create\_vocabulary, text2vec::prune\_vocabulary

**Examples**

```
library(fgsea)
data(examplePathways)
data(exampleRanks)
names(examplePathways) <- gsub("_", " ",
                               substr(names(examplePathways), 9, 1000))
set.seed(1)
fgseaRes <- fgsea(examplePathways, exampleRanks)
tokens <- text_token(data.frame(fgseaRes)[,"pathway"],
                      num_tokens = 1000)
```

---

token_vector	<i>Vectorization of tokens</i>
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---

**Description**

A vectorization of words or tokens of text is necessary for machine learning. Vectorized sequences are padded or truncated.

**Usage**

```
token_vector(text, token, length_seq)
```

**Arguments**

text	text data
token	result of tokenization (output of "text_token")
length_seq	length of input sequences

**Value**

sequences of integers

**Author(s)**

Dongmin Jung

**See Also**

tm::removeWords, stopwords::stopwords, textstem::lemmatize\_strings, tokenizers::tokenize\_ngrams, keras::pad\_sequences

**Examples**

```
library(reticulate)
if (keras::is_keras_available() & reticulate::py_available()) {
  library(fgsea)
  data(examplePathways)
  data(exampleRanks)
  names(examplePathways) <- gsub("_", " ",
                                substr(names(examplePathways), 9, 1000))
  set.seed(1)
  fgseaRes <- fgsea(examplePathways, exampleRanks)
  tokens <- text_token(data.frame(fgseaRes)[,"pathway"],
                       num_tokens = 1000)
  sequences <- token_vector("Cell Cycle", tokens, 10)
}
```

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