

# Package ‘FeatureHashing’

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**Type** Package

**Title** Creates a Model Matrix via Feature Hashing with a Formula Interface

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**Description** Feature hashing, also called as the hashing trick, is a method to transform features of a instance to a vector. Thus, it is a method to transform a real dataset to a matrix. Without looking up the indices in an associative array, it applies a hash function to the features and uses their hash values as indices directly. The method of feature hashing in this package was proposed in Weinberger et al. (2009). The hashing algorithm is the murmurhash3 from the digest package. Please see the README in <https://github.com/wush978/FeatureHashing> for more information.

**License** GPL (>= 3) | file LICENSE

**Depends** R (>= 3.1), methods

**Imports** Rcpp (>= 0.11), Matrix, digest(>= 0.6.8), magrittr (>= 1.5)

**LinkingTo** Rcpp, digest(>= 0.6.8), BH

**Suggests** RUnit

**SystemRequirements** C++11

**BugReports** <https://github.com/wush978/FeatureHashing/issues>

**URL** <https://github.com/wush978/FeatureHashing>

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**NeedsCompilation** yes

**Repository** CRAN

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## R topics documented:

CSCMatrix-class	2
hash.mapping	3
hash.size	4
hashed.model.matrix	5
intToRaw	9
ipinyou	9
simulate.split	10
test.tag	10

<b>Index</b>	<b>11</b>
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CSCMatrix-class	<i>CSCMatrix</i>
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### Description

The structure of `CSCMatrix` is the same as the structure of `dgMatrix`. However, the `CSCMatrix` has weaker constraints compared to `dgMatrix`.

`CSCMatrix` only supports limited operators. The users can convert it to `dgMatrix` for compatibility of existed algorithms.

### Details

The `CSCMatrix` violates two constraints used in `dgMatrix`:

- The row indices should be sorted with columns.
- The row indices should be unique with columns.

The result of matrix-vector multiplication should be the same.

### Methods

- `dim` The dimension of the matrix object `CSCMatrix`.
- `dim<-` The assignment of dimension of the matrix object `CSCMatrix`.
- `[` The subsetting operator of the matrix object `CSCMatrix`.
- `%*%` The matrix-vector multiplication of the matrix object `CSCMatrix`. The returned object is a numeric vector.

### See Also

[dgMatrix-class](#)

### Examples

```
# construct a CSCMatrix
m <- hashed.model.matrix(~ ., CO2, 8)
# convert it to dgMatrix
m2 <- as(m, "dgMatrix")
```

---

hash.mapping	<i>Extract mapping between hash and original values</i>
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---

**Description**

Extract mapping between hash and original values

**Usage**

```
hash.mapping(matrix)
```

**Arguments**

matrix            Matrix returned by hashed.model.matrix function

**Details**

Generate a mapping between original values and hashes.

Option create.mapping = T needs to be used in function hashed.model.matrix.

Original values are stores in the names of the vector.

**Value**

a named numeric vector

**Author(s)**

Michael Benesty

**Examples**

```
data(ipinyou)
```

```
m <- hashed.model.matrix(~., ipinyou.train, 2^10, create.mapping = TRUE)
mapping <- hash.mapping(m)
```

---

`hash.size`*Compute minimum hash size to reduce collision rate*

---

**Description**

Compute minimum hash size to reduce collision rate

**Usage**

```
hash.size(df)
```

**Arguments**

`df` data.frame with data to hash

**Details**

To reduce collision rate, the hash size should be equal or superior to the nearest power of two to the number of unique values in the input `data.frame`.

The value computed is a theoretical minimum hash size. It just means that in the best situation it may be possible that all computed hash can be stored with this hash size.

Intuitively, if the distribution of hash generated by the algorithm was perfect, when the computed size is used, each permutation of bits of the hash vector would correspond to one unique original value of your `data.frame`.

Because a bit value is  $\{0, 1\}$ , the computed size is  $2^x$  with a  $x$  big enough to have a hash vector containing each original value.

In real life, there will be some collisions if the computed size is used because the distribution of hash is not perfect. However, the hashing algorithm Murmur3 is known to minimize the number of collisions and is also very performant.

The only known solution to have zero collision is to build a dictionary of values, and for each new value to hash, check in the dictionary if the hash value already exists. It is not performant at all.

If you increase the computed size (by multiplying it by  $2^x$ , it is up to you to choose a  $x$ ), you will reduce the collision rate. If you use a value under the computed size, there is a 100

There is a trade-off between collision rate and memory used to store hash. Machine learning algorithms usually deal well with collisions when the rate is reasonable.

**Value**

The hash size of feature hashing as a positive integer.

**Author(s)**

Michael Benesty

**Examples**

```

data(ipinyou)

#First try with a size of 2^10
mat1 <- hashed.model.matrix(~., ipinyou.train, 2^10, create.mapping = TRUE)

#Extract mapping
mapping1 <- hash.mapping(mat1)
#Rate of collision
mean(duplicated(mapping1))

#Second try, the size is computed
size <- hash.size(ipinyou.train)
mat2 <- hashed.model.matrix(~., ipinyou.train, size, create.mapping = TRUE)

#Extract mapping
mapping2 <- hash.mapping(mat2)
#Rate of collision
mean(duplicated(mapping2))

```

---

hashed.model.matrix    *Create a model matrix with feature hashing*

---

**Description**

Create a model matrix with feature hashing

**Usage**

```

hashed.model.matrix(formula, data, hash.size = 2^18, transpose = FALSE,
  create.mapping = FALSE, is.dgCMatrix = TRUE, signed.hash = TRUE)

```

**Arguments**

formula	formula or a character vector of column names (will be expanded to a formula)
data	data.frame. The original data.
hash.size	positive integer. The hash size of feature hashing.
transpose	logical value. Indicating if the transpose should be returned. It affects the space of the returned object when the dimension is imbalanced. Please see the details.
create.mapping	logical value. The indicator of whether storing the hash mapping or not. The mapping might miss some interaction terms which involves splitted features. Please see the details.
is.dgCMatrix	logical value. Indicating if the result is dgCMatrix or CSCMatrix
signed.hash	logical value. Indicating if the hashed value is multiplied by random sign. This will reduce the impact of collision. Disable it will enhance the speed.

## Details

The `hashed.model.matrix` hashes the feature during the construction of the model matrix. It uses the 32-bit variant of MurmurHash3 <https://code.google.com/p/smhasher/wiki/MurmurHash3>. Weinberger et. al. (2009) used two separate hashing function  $h(\text{hashed.value})$  and  $\xi(\text{hash.sign})$  to determine the indices and the sign of the values respectively. Different seeds are used to implement the hashing function  $h$  and  $\xi$  with MurmurHash3.

The formula is parsed via `terms.formula` with "split" as special keyword. The interaction term is hashed in different ways. Please see example for the detailed implementation. The "split" is used to expand the concatenated feature such as "10129,10024,13866,10111,10146,10120,10115,10063" which represents the occurrence of multiple categorical variable: "10129", "10024", "13866", "10111", "10146", "10120", "10115", and "10063". The `hashed.model.matrix` will expand the concatenated feature and produce the related model matrix.

The "split" accepts two parameters:

- `delim`, character value to use as delimiter for splitting.
- `type`, one of existence or count.

The user could explore the behavior via function `simulate.split`.

The argument `transpose` affects the size of the returned object in the following way. For a  $m \times n$  matrix with  $k$  non-zero elements, the returned `dgCMatrix` requires  $O(n) + O(k)$  space. For details, please check the documentation of the `dgCMatrix-class`. Note that the `rownames` of the returned `dgCMatrix` is `character(0)` so the space complexity does not contain the term  $O(m)$ .

The mapping created by enabling `create.mapping` might miss the interaction term which involves splitted features. For example, suppose there are two columns `a` and `b` while the value are 1 and 1,2,3 respectively. The user marks the column `b` with `split`. If the hashed value of `b1` and `b2` are collided, then the interaction `a1:b1` will not appear in the returned mapping table. Because this package is originally designed for predictive analysis and the mapping should not play an important role of predictive analysis. If you have a test case and want to ask us to fix this, please provide us a test case in <https://github.com/wush978/FeatureHashing/issues/67>.

## References

H. B. McMahan, G. Holt, D. Sculley, et al. "Ad click prediction: a view from the trenches". In: *The 19th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, KDD 2013, Chicago, IL, USA, August 11-14, 2013*. Ed. by I. S. Dhillon, Y. Koren, R. Ghani, T. E. Senator, P. Bradley, R. Parekh, J. He, R. L. Grossman and R. Uthurusamy. ACM, 2013, pp. 1222-1230. DOI: 10.1145/2487575.2488200. <URL: <http://doi.acm.org/10.1145/2487575.2488200>>.

Kilian Q. Weinberger, Anirban Dasgupta, John Langford, Alexander J. Smola, and Josh Attenberg. ICML, volume 382 of ACM International Conference Proceeding Series, page 140. ACM, (2009)

W. Zhang, S. Yuan, J. Wang, et al. "Real-Time Bidding Benchmarking with iPinYou Dataset". In: *\_arXiv preprint arXiv:1407.7073\_* (2014).

## Examples

```
# The following scripts show how to fit a logistic regression
# after feature hashing
```

```

## Not run:
data(ipinyou)
f <- ~ IP + Region + City + AdExchange + Domain +
  URL + AdSlotId + AdSlotWidth + AdSlotHeight +
  AdSlotVisibility + AdSlotFormat + CreativeID +
  Adid + split(UserTag, delim = ",")
# if the version of FeatureHashing is 0.8, please use the following command:
# m.train <- as(hashed.model.matrix(f, ipinyou.train, 2^16, transpose = FALSE), "dgCMatrix")
m.train <- hashed.model.matrix(f, ipinyou.train, 2^16)
m.test <- hashed.model.matrix(f, ipinyou.test, 2^16)

# logistic regression with glmnet

library(glmnet)

cv.g.lr <- cv.glmnet(m.train, ipinyou.train$IsClick,
  family = "binomial")#, type.measure = "auc")
p.lr <- predict(cv.g.lr, m.test, s="lambda.min")
auc(ipinyou.test$IsClick, p.lr)

## Per-Coordinate FTRL-Proximal with $L_1$ and $L_2$ Regularization for Logistic Regression

# The following scripts use an implementation of the FTRL-Proximal for Logistic Regression,
# which is published in McMahan, Holt and Sculley et al. (2013), to predict the probability
# (1-step prediction) and update the model simultaneously.

source(system.file("ftprl.R", package = "FeatureHashing"))
m.train <- hashed.model.matrix(f, ipinyou.train, 2^16, transpose = TRUE)
ftprl <- initialize.ftprl(0.1, 1, 0.1, 0.1, 2^16)
ftprl <- update.ftprl(ftprl, m.train, ipinyou.train$IsClick, predict = TRUE)
auc(ipinyou.train$IsClick, attr(ftprl, "predict"))

# If we use the same algorithm to predict the click through rate of the 3rd season of iPinYou,
# the overall AUC will be 0.77 which is comparable to the overall AUC of the
# 3rd season 0.76 reported in Zhang, Yuan, Wang, et al. (2014).

## End(Not run)

# The following scripts show the implementation of the FeatureHashing.

# Below the original values will be project in a space of 2^6 dimensions
m <- hashed.model.matrix(~ ., CO2, 2^6, create.mapping = TRUE,
  transpose = TRUE, is.dgCMatrix = FALSE)

# Print the matrix via dgCMatrix
as(m, "dgCMatrix")

# Extraction of the dictionary: values with their hash
mapping <- hash.mapping(m)

# To check the rate of collisions, we will extract the indices of the hash
# values through the modulo-division method, count how many duplicates

```

```

# we have (in best case it should be zero) and perform a mean.
mean(duplicated(mapping))

# The type of the result produced by the function `hashed.model.matrix`
# is a CSCMatrix. It supports simple subsetting
# and matrix-vector multiplication
rnorm(2^6) %*% m

# Detail of the hashing
# To hash one specific value, we can use the `hashed.value` function
# Below we will apply this function to the feature names
vectHash <- hashed.value(names(mapping))

# Now we will check that the result is the same than the one got with
# the more generation `hashed.model.matrix` function.
# We will use the Modulo-division method (that's the [% 2^6] below)
# to find the address in hash table easily.
stopifnot(all(vectHash % 2^6 + 1 == mapping))

# The sign is corrected by `hash.sign`
hash.sign(names(mapping))

## The interaction term is implemented as follow:
m2 <- hashed.model.matrix(~ .^2, CO2, 2^6, create.mapping = TRUE,
  transpose = TRUE, is.dgMatrix = FALSE)
# The ^ operator indicates crossing to the specified degree.
# For example (a+b+c)^2 is identical to (a+b+c)*(a+b+c)
# which in turn expands to a formula containing the main effects
# for a, b and c together with their second-order interactions.

# Extract the mapping
mapping2 <- hash.mapping(m2)

# Get the hash of combination of two items, PlantQn2 and uptake
mapping2["PlantQn2:uptake"]

# Extract hash of each item
h1 <- hashed.value("PlantQn2")
h2 <- hashed.value("uptake")

# Computation of hash of both items combined
h3 <- hashed.value(rawToChar(c(intToRaw(h1), intToRaw(h2))))
stopifnot(h3 % 2^6 + 1 == mapping2["PlantQn2:uptake"])

# The concatenated feature, i.e. the array<string> type in hive
data(test.tag)
df <- data.frame(a = test.tag, b = rnorm(length(test.tag)))
m <- hashed.model.matrix(~ split(a, delim = ",", type = "existence"):b, df, 2^6,
  create.mapping = TRUE)
# The column `a` is splitted by "," and have an interaction with "b":
mapping <- hash.mapping(m)
names(mapping)

```



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intToRaw	<i>Convert the integer to raw vector with endian correction</i>
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---

**Description**

Convert the integer to raw vector with endian correction

**Usage**

```
intToRaw(src)
```

**Arguments**

src            integer value.

**Value**

raw vector with length 4

---

ipinyou	<i>iPinYou Real-Time Bidding Dataset for Computational Advertising Research</i>
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**Description**

This is a sample from the iPinYou Real-Time Bidding dataset. The data.frame named `ipinyou.train` is a sample from the data of 2013-10-19 and the data.frame named `ipinyou.test` is a sample from the data of 2013-10-20.

**Usage**

```
data(ipinyou)
```

**Format**

The column name of the data is the description of the data in Zhang, Yuan, Wang, et al. (2014). Most of the columns should be clearly described by their column names. For the details of the dataset, please read the Zhang, Yuan, Wang, et al. (2014).

BidID, the id of the RTB which is the unique identifier of the events.

Adid, the advertiser id.

UserTag, the user tags (segments) in iPinYou's proprietary audience database. This is also a real example of the concatenated feature.

**Source**

<http://data.computational-advertising.org/>

**References**

W. Zhang, S. Yuan, J. Wang, et al. "Real-Time Bidding Benchmarking with iPinYou Dataset". In: arXiv preprint arXiv:1407.7073 (2014).

---

simulate.split	<i>Simulate how split work in hashed.model.matrix to split the string into tokens</i>
----------------	---

---

**Description**

Simulate how split work in hashed.model.matrix to split the string into tokens

**Usage**

```
simulate.split(x, delim = ",", type = c("existence", "count"))
```

**Arguments**

x	character vector or factor. The source of concatenated feature.
delim	character value. The string to use for splitting.
type	character value. Either "count" or "existence". "count" indicates the number of occurrence of the token. "existence" indicates the boolean that whether the token exist or not.

**Value**

integer vector for type = "count" and logical vector for type = "existence".

---

test.tag	<i>test.tag</i>
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---

**Description**

This is a vector to demo the concatenated feature.

**Format**

For each element, the string represents the occurrence of different tags. For example, the string "1,27,19,25,tp,tw" of the first instance represents that the feature '1' is TRUE, the feature '27' is TRUE, et. al. On the contrary, the missing feature such as '2' is FALSE.

# Index

[,CSCMatrix,missing,numeric,ANY-method  
(CSCMatrix-class), 2

[,CSCMatrix,numeric,missing,ANY-method  
(CSCMatrix-class), 2

[,CSCMatrix,numeric,numeric,ANY-method  
(CSCMatrix-class), 2

%%,CSCMatrix,numeric-method  
(CSCMatrix-class), 2

%%,numeric,CSCMatrix-method  
(CSCMatrix-class), 2

CSCMatrix-class, 2

dim,CSCMatrix-method (CSCMatrix-class),  
2

dim<- ,CSCMatrix-method  
(CSCMatrix-class), 2

hash.mapping, 3

hash.sign (hashed.model.matrix), 5

hash.size, 4

hashed.model.matrix, 5

hashed.value (hashed.model.matrix), 5

intToRaw, 9

ipinyou, 9

simulate.split, 6, 10

terms.formula, 6

test.tag, 10