Package ‘atSNP’

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Description

atSNP implements the affinity test for large sets of SNP-motif interactions using the importance sampling algorithm. Users may identify SNPs that potentially may affect binding affinity of transcription factors. Given a set of SNPs and a library of motif position weight matrices (PWMs), atSNP provides two main functions for analyzing SNP effects: (i) the binding affinity score for each allele and each PWM and the p-values for allele-specific binding affinity scores (ii) the p-values for affinity score changes between the two alleles for each SNP. Compared to other bioinformatics tools that provide similar functionalities, atSNP is highly scalable.

The atSNP main functions are:

1. **LoadMotifLibrary** - Load position weight matrices
2. **LoadSNPData** - Load the SNP information and code the genome sequences around the SNP locations
3. **LoadFastaData** - Load the SNP data from fasta files
4. **ComputeMotifScore** - Compute the scores for SNP effects on motifs
5. **ComputePValues** - Compute p-values for affinity scores
Some helper functions are:

1. **MatchSubsequence** - Compute the matching subsequence
2. **GetIUPACSequence** - Get the IUPAC sequence of a motif
3. **dtMotifMatch** - Compute the augmented matching subsequence on SNP and reference alleles

The composite logo plotting function is:

1. **plotMotifMatch** - Plot sequence logos of the position weight matrix of the motif and sequences of its corresponding best matching augmented subsequence on the reference and SNP allele

**Author(s)**

Chandler Zuo Sunyoung Shin <sunyoung.shin@utdallas.edu>

**References**


**See Also**

atSNP vignette for more information

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**ComputeMotifScore**

Compute the scores for SNP effects on motifs.

**Description**

Compute the log-likelihood scores for motifs.

**Usage**

```r
ComputeMotifScore(motif.lib, snp.info, ncores = 1)
```

**Arguments**

- `motif.lib` A list object with the output format of function `LoadMotifLibrary`.
- `snp.info` A list object with the output format of function `LoadSNPData`.
- `ncores` An integer for the number of parallel process. Default: 1.

**Details**

This function computes the binding affinity scores for both alleles at each SNP window. For each pair of SNP and motif, it finds the subsequence from both strand that maximizes the affinity binding score. It returns both the matching positions and the maximized affinity scores.
Value

A list of two data.frame's. Field `snp.tbl` contains:

- `snpid` SNP id.
- `ref_seq` Reference allele nucleotide sequence.
- `snp_seq` SNP allele nucleotide sequence.
- `ref_seq_rev` Reference allele nucleotide sequence on the reverse strand.
- `snp_seq_rev` SNP allele nucleotide sequence on the reverse strand.

Field `motif.score` contains:

- `motif` Name of the motif.
- `motif_len` Length of the motif.
- `ref_start`, `ref_end`, `ref_strand` Location of the best matching subsequence on the reference allele.
- `snp_start`, `snp_end`, `snp_strand` Location of the best matching subsequence on the SNP allele.
- `log_lik_ref` Log-likelihood score for the reference allele.
- `log_lik_snp` Log-likelihood score for the SNP allele.
- `log_lik_ratio` The log-likelihood ratio.
- `log_enhance_odds` Difference in log-likelihood ratio between SNP allele and reference allele based on the best matching subsequence on the reference allele.
- `log_reduce_odds` Difference in log-likelihood ratio between reference allele and SNP allele based on the best matching subsequence on the SNP allele.

Author(s)

Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>

Examples

```r
data(example)
ComputeMotifScore(motif_library, snpInfo, ncores = 2)
```

Description

This function computes the p-values for allele-specific affinity scores and between-allele affinity score changes using the importance sampling technique.

Usage

```r
ComputePValues(motif.lib, snp.info, motif.scores, ncores = 1,
    testing.mc = FALSE, figdir = NULL)
```
dtMotifMatch

Arguments

- **motif.lib** A list object with the output format of function `LoadMotifLibrary`.
- **snp.info** A list object with the output format of function `LoadSNPData`.
- **motif.scores** A data.frame object containing at least the following columns:
  - **motif** The name of the motif.
  - **log_lik_ref** The log-likelihood score for the reference allele.
  - **log_lik_snp** The log-likelihood score for the SNP allele.
- **ncores** An integer for the number of parallel process. Default: 1.
- **testing.mc** Monte Carlo sample size of 200 is considered. Do not change the default unless conducting a quick test. Default: FALSE
- **figdir** A string for the path to print p-value plots for monitoring results. Default: NULL (no figure).

Value

A data.frame extending `motif.scores` by the following additional columns:

- **pval_ref** P-values for scores on the reference allele.
- **pval_snp** P-values for scores on the SNP allele.
- **pval_cond_ref** Conditional p-values for scores on the reference allele.
- **pval_cond_snp** Conditional p-values for scores on the SNP allele.
- **pval_diff** P-values for the difference in scores between the reference and the SNP alleles.
- **pval_rank** P-values for the log rank ratio between the reference and the SNP alleles.

Author(s)

Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>

Examples

data(example)
ComputePVValues(motif_library, snpInfo, motif_scores$motif.scores, ncores = 2, testing.mc=TRUE)

Description

Calculate the best matching augmented subsequences on both SNP and reference alleles for motifs. Obtain extra unmatched position on the best matching augmented subsequence of the reference and SNP alleles.
Usage

dtMotifMatch(snp.tbl, motif.scores, snpids = NULL, motifs = NULL, 
motif.lib, ncores = 2)

Arguments

snp.tbl A data.frame with the following information:

- snpid SNP id.
- ref_seq Reference allele nucleobase sequence.
- snp_seq SNP allele nucleobase sequence.
- ref_seq_rev Reference allele nucleobase sequence on the reverse strand.
- snp_seq_rev SNP allele nucleobase sequence on the reverse strand.

motif.scores A data.frame with the following information:

- motif Name of the motif.
- motif_len Length of the motif.
- ref_start, ref_end, ref_strand Location of the best matching subsequence on the reference allele.
- snp_start, snp_end, snp_strand Location of the best matching subsequence on the SNP allele.
- log_lik_ref Log-likelihood score for the reference allele.
- log_lik_snp Log-likelihood score for the SNP allele.
- log_lik_ratio The log-likelihood ratio.
- log_enhance_odds Difference in log-likelihood ratio between SNP allele and reference allele based on the best matching subsequence on the reference allele.
- log_reduce_odds Difference in log-likelihood ratio between reference allele and SNP allele based on the best matching subsequence on the SNP allele.

snpids A subset of snpids to compute the subsequences. Default: NULL, when all snps are computed.

motifs A subset of motifs to compute the subsequences. Default: NULL, when all motifs are computed.

motif.lib A list of named position weight matrices.

ncores The number of cores used for parallel computing. Default: 10

Value

A data.frame containing all columns from the function, `MatchSubsequence`. In addition, the following columns are added:

- snp_ref_start, snp_ref_end, snp_ref_length Location and Length of the best matching augmented subsequence on both the reference and SNP alleles.
- ref_aug_match_seq_forward Best matching augmented subsequence or its corresponding sequence to the forward strand on the reference allele.
- snp_aug_match_seq_forward Best matching augmented subsequence or its corresponding sequence to the forward strand on the SNP allele.
- ref_aug_match_seq_reverse Best matching augmented subsequence or its corresponding sequence to the reverse strand on the reference allele.
- snp_aug_match_seq_reverse Best matching augmented subsequence or its corresponding sequence to the reverse strand on the SNP allele.
- ref_location SNP location of the best matching augmented subsequence on the reference allele. Starting from zero.
- snp_location SNP location of the best matching augmented subsequence on the SNP allele. Starting from zero.
encode_motif

ref_extra_pwm_left  Left extra unmatching position on the best matching augmented subsequence of the reference allele.
ref_extra_pwm_right Right extra unmatching position on the best matching augmented subsequence of the reference allele.
snp_extra_pwm_left  Left extra unmatching position on the best matching augmented subsequence of the SNP allele.
snp_extra_pwm_right Right extra unmatching position on the best matching augmented subsequence of the SNP allele.

Author(s)
Sunyoung Shin <sunyoung.shin@utdallas.edu>

Examples
data(example)
dtMotifMatch(motif_scores$snp.tbl, motif_scores$motif.scores, motif.lib = motif_library)

___

Description
This motif library can be loaded by 'data(encode_library)'.

Format
A list object.

Author(s)
Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>

___

Description
This is a character vector that can be loaded by 'data(encode_library)'. The names of this vector are the same as the names for encode_motif. The entries of this vector are the corresponding motif information parsed from the raw file.

Format
A character vector.

Author(s)
Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>
GetIUPACSequence  

*Get the IUPAC sequence of a motif.*

**Description**

Convert the position weight matrix of a motif to the IUPAC sequence.

**Usage**

```r
GetIUPACSequence(pwm, prob = 0.25)
```

**Arguments**

- `pwm` The position weight matrix, with the columns representing A, C, G, T.
- `prob` The probability threshold. Default: 0.25.

**Value**

A character string.

**Author(s)**

Sunyoung Shin `<sunyoung.shin@utdallas.edu>`, Chandler Zuo `<chandler.c.zuo@gmail.com>`

**Examples**

```r
data(example)
GetIUPACSequence(motif_library[[1]], prob = 0.2)
```

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**jaspar_motif**


**Description**

This motif library can be loaded by `data(jaspar_library)`.

**Format**

A list object.

**Author(s)**

Sunyoung Shin `<sunyoung.shin@utdallas.edu>`, Chandler Zuo `<chandler.c.zuo@gmail.com>`
**jaspar_motifinfo**


**Description**

This is a character vector that be loaded by 'data(jaspar_library)'. The names of this vector are the same as the names for jaspar_motif. The entries of this vector are the corresponding motif information parsed from the raw file.

**Format**

A character vector.

**Author(s)**

Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>

---

**LoadFastaData**

Load the SNP data from fasta files.

**Description**

Load SNP data.

**Usage**

LoadFastaData(ref.filename = NULL, snp.filename = NULL, ref.urlname = NULL, snp.urlname = NULL, snpids = NULL, default.par = FALSE)

**Arguments**

- ref.filename: a fastq file name for the reference allele sequences.
- snp.filename: a fastq file name for the SNP allele sequences.
- ref.urlname: URL of a fastq file for the reference allele sequences.
- snp.urlname: URL of a fastq file for the SNP allele sequences.
- snpids: SNP IDs
- default.par: A boolean for whether using the default Markov parameters. Default: FALSE.
LoadMotifLibrary

Value
A list object containing the following components:

- sequence_matrix: A list of integer vectors representing the deroxyribose sequence around each SNP.
- a1: An integer vector for the deroxyribose at the SNP location on the reference genome.
- a2: An integer vector for the deroxyribose at the SNP location on the SNP genome.

The results are coded as: "A"-1, "C"-2, "G"-3, "T"-4.

Author(s)
Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>

Examples

LoadFastaData(
  ref.urlname="http://pages.stat.wisc.edu/~keles/atSNP-Data/sample_1.fasta",
  snp.urlname="http://pages.stat.wisc.edu/~keles/atSNP-Data/sample_2.fasta")

LoadMotifLibrary(filename = NULL, urlname = NULL, tag = "MOTIF",
  transpose = FALSE, field = 2, sep = c("\t", ""), skipcols = 0,
  skiprows = 2, pseudocount = 0)

Description
Load the file for position weight matrices for motifs.

Usage

LoadMotifLibrary(filename = NULL, urlname = NULL, tag = "MOTIF",
  transpose = FALSE, field = 2, sep = c("\t", ""), skipcols = 0,
  skiprows = 2, pseudocount = 0)

Arguments

- filename: a MEME format file name.
- urlname: URL containing a MEME format file.
- tag: A string that marks the description line of the position weight matrix.
- transpose: If TRUE (default), then the position weight matrix should have 4 columns. Otherwise, it should have 4 rows.
- field: The index of the field in the description line, separated by space, that indicates the motif name.
- sep: A vector of chars for the string separators to parse each lines of the matrix. Default: c("", "").
- skipcols: Number of columns to be skipped in the position weight matrix.
- skiprows: Number of description lines before each position weight matrix.
- pseudocount: An integer for the pseudocount added to each of the original matrices. Default: 0. Recommended to be 1 if the original matrices are position frequency matrices.
Details

This function reads the formatted file containing motif information and convert them into a list of position weight matrices. The list of arguments should provide enough flexibility of importing a varying number of formats. Some examples are the following: For MEME format, the suggested arguments are: tag = 'Motif', skiprows = 2, skipcols = 0, transpose = FALSE, field = 2, sep = ‘ ’; For motif files from JOHNSON lab (i.e. http://johnsonlab.ucsf.edu/mochi_files/JASPAR_motifs_H_sapiens.txt), the suggested arguments are: tag = '/NAME', skiprows = 1, skipcols = 0, transpose = FALSE, field = 2, sep = "t"; For JASPAR pfm matrices (i.e. http://jaspar.genereg.net/download/CORE/JASPAR 2018_CORE_vertebrates_non-redundant_pfms_jaspar.txt), the suggested arguments are: tag = ">", skiprows = 1, skipcols = 0, transpose = TRUE, field = 1, sep = "\t"; For the TRANSFAC library provided by UCF bioinformatics groups (i.e. http://gibbs.biomed.ucf.edu/PreDREM/download/nonredundantmotif.transfac), the suggested arguments are: tag = "DE", skiprows = 1, skipcols = 1, transpose = FALSE, field = 2, sep = "\t".

Value

A list object of position weight matrices.

Author(s)

Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>

Examples

```r
pwms <- LoadMotifLibrary(
  urlname="http://pages.stat.wisc.edu/~keles/atSNP-Data/pfm_vertebrates.txt",
  tag = ">", transpose = FALSE, field = 1, sep = c("\t", " ", ">"),
  skipcols = 1, skiprows = 1, pseudocount = 1)
```

---

**LoadSNPData**

Load the SNP information and code the genome sequences around the SNP locations.

Description

Load the SNP data.

Usage

```r
LoadSNPData(filename = NULL,
  genome.lib = "BSgenome.Hsapiens.UCSC.hg38",
  snp.lib = "SNPlocs.Hsapiens.dbSNP144.GRCh38", snpids = NULL,
  half.window.size = 30, default.par = FALSE, mutation = FALSE, ...)
```
LoadSNPData

Arguments

filename
A table containing the SNP information. Must contain at least five columns with exactly the following names:

- chr: chromosome.
- snp: The nucleotide position of the SNP.
- snpid: The names of the SNPs.
- a1: The deoxyribose for one allele.
- a2: The deoxyribose for the other allele.

If this file exists already, it is used to extract the SNP information. Otherwise, SNP information extracted using argument `snpids` is outputted to this file.

genome.lib
A string of the library name for the genome version. Default: "BSgenome.Hsapiens.UCSC.hg38".

snp.lib
A string of the library name to obtain the SNP information based on rs ids. Default: "SNPlocs.Hsapiens.dbSNP144.GRCh38".

snpids
A vector of rs ids for the SNPs. This argument is overridden if the file with name `filename` exists.

half.window.size
An integer for the half window size around the SNP within which the motifs are matched. Default: 30.

default.par
A boolean for whether using the default Markov parameters. Default: FALSE.

mutation
A boolean for whether this is mutation data. See details for more information. Default: FALSE.

... Other parameters passed to `read.table`.

Details

This function extracts the nucleotide sequence within a window around each SNP and code them using 1-A, 2-C, 3-G, 4-T.

There are two ways of obtaining the nucleotide sequences. If `filename` is not NULL and the file exists, it should contain the positions and alleles for each SNP. Based on such information, the sequences around SNP positions are extracted using the Bioconductor annotation package specified by `genome.lib`. Users should make sure that this annotation package corresponds to the correct species and genome version of the actual data. Alternatively, users can also provide a vector of rs ids via the argument `snpids`. The SNP locations and allele information is then obtained via the Bioconductor annotation package specified by `snp.lib`, and passed on to the package specified by `genome.lib` to further obtain the nucleotide sequences.

If `mutation`=FALSE (default), this function assumes that the data is for SNP analysis, and the reference genome should be consistent with either the a1 or a2 nucleotide. When extracting the genome sequence around each SNP position, this function compares the nucleotide at the SNP location on the reference genome with both a1 and a2 to distinguish between the reference allele and the SNP allele. If the nucleotide extracted from the reference genome does not match either a1 or a2, the SNP is discarded. The discarded SNPs are in the `rsid.rm` field in the output.

Alternatively, if `mutation`=TRUE, this function assumes that the data is for general single nucleotide mutation analysis. After extracting the genome sequence around each SNP position, it replaces
the nucleotide at the SNP location by the a1 nucleotide as the 'reference' allele sequence, and by the a2 nucleotide as the 'snp' allele sequence. It does NOT discard the sequence even if neither a1 or a2 matches the reference genome. When this data set is used in other functions, such as `ComputeMotifScore`, `ComputePValues`, all the results (i.e. affinity scores and their p-values) for the reference allele are indeed for the a1 allele, and results for the SNP allele are indeed for the a2 allele.

If the input is a list of rsid's, the SNP information extracted from snp.lib may contain more than two alleles for a single location. For such cases, `LoadSNPData` first extracts all pairs of alleles associated with those locations. If 'mutation=TRUE', all those pairs are considered as pairs of reference and SNP alleles, and their information is contained in 'sequence_matrix', 'a1', 'a2' and 'snpid'. If 'mutation=FALSE', `LoadSNPData` further filters these pairs based on whether one allele matches to the reference genome nucleotide extracted from genome.lib. Only those pairs with one allele matching the reference genome nucleotide is considered as pairs of reference and SNP alleles, with their information contained in 'sequence_matrix', 'a1', 'a2' and 'snpid'.

Value

A list object containing the following components:

- **sequence_matrix**: A list of integer vectors representing the deroxyribose sequence around each SNP.
- **a1**: An integer vector for the deroxyribose at the SNP location on the reference genome.
- **a2**: An integer vector for the deroxyribose at the SNP location on the SNP genome.
- **snpid**: A string vector for the SNP rsids.
- **rsid.missing**: If the data source is a list of rsids, this field records rsids for SNPs that are discarded because they are not in the reference genome.
- **rsid.duplicate**: If the data source is a list of rsids, this field records rsids for SNPs that based on the SNPlocs package, this locus has more than 2 alleles.
- **rsid.na**: This field records rsids for SNPs that are discarded because the nucleotide sequences contain none ACGT characters.
- **rsid.rm**: If the data source is a table and mutation=FALSE, this field records rsids for SNPs that are discarded because the nucleotide on the reference genome matches neither 'a1' or 'a2' in the data source.

The results are coded as: "A"-1, "C"-2, "G"-3, "T"-4.

Author(s)

Chandler Zuo <chandler.c.zuo@gmail.com>

Examples

```r
## Not run: LoadSNPData(snpids = c("rs53576", "rs7412"),
genome.lib = "BSgenome.Hsapiens.UCSC.hg38", snp.lib = 
"SNPlocs.Hsapiens.dbSNP144.GRCh38", half.window.size = 30, default.par = TRUE
, mutation = FALSE)
## End(Not run)
```
**MatchSubsequence**

*Compute the matching subsequence.*

**Description**

This function combines the SNP set, the motif library and the affinity score table and produce the matching subsequence found at each SNP location for each motif.

**Usage**

```
MatchSubsequence(snp.tbl, motif.scores, motif.lib, snpids = NULL,
                 motifs = NULL, ncores = 1)
```

**Arguments**

- **snp.tbl**
  A data.frame with the following information:
  - `snpid` SNP id.
  - `ref_seq` Reference allele nucleotide sequence.
  - `snp_seq` SNP allele nucleotide sequence.
  - `ref_seq_rev` Reference allele nucleotide sequence on the reverse strand.
  - `snp_seq_rev` SNP allele nucleotide sequence on the reverse strand.

- **motif.scores**
  A data.frame with the following information:
  - `motif` Name of the motif.
  - `motif_len` Length of the motif.
  - `ref_start`, `ref_end`, `ref_strand` Location of the best matching subsequence on the reference allele.
  - `snp_start`, `snp_end`, `snp_strand` Location of the best matching subsequence on the SNP allele.
  - `log_lik_ref` Log-likelihood score for the reference allele.
  - `log_lik_snp` Log-likelihood score for the SNP allele.
  - `log_lik_ratio` The log-likelihood ratio.
  - `log_enhance_odds` Difference in log-likelihood ratio between SNP allele and reference allele based on the best matching subsequence on the reference allele.
  - `log_reduce_odds` Difference in log-likelihood ratio between reference allele and SNP allele based on the best matching subsequence on the SNP allele.

- **motif.lib**
  A list of the position weight matrices for the motifs.

- **snpids**
  A subset of snpids to compute the subsequences. Default: NULL, when all SNPs are computed.

- **motifs**
  A subset of motifs to compute the subsequences. Default: NULL, when all motifs are computed.

- **ncores**
  The number of cores used for parallel computing.
motif_library

Value

A data.frame containing all columns in both snp.tbl and motif.scores. In addition, the following columns are added:

- ref_match_seq: Best matching subsequence on the reference allele.
- snp_match_seq: Best matching subsequence on the SNP allele.
- ref_seq_snp_match: Subsequence on the reference allele corresponding to the best matching location on the SNP allele.
- snp_seq_ref_match: Subsequence on the SNP allele corresponding to the best matching location on the reference allele.

Author(s)

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Examples

```r
data(example)
MatchSubsequence(motif_scores$snp.tbl, motif_scores$motif.scores,
                  motif_library, ncores=2)
```

---

**motif_library**

_A sample motif library._

---

Description

A list of the position weight matrices corresponding to motifs, loaded by `data(example)`.

Format

A list object.

Author(s)

Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>
motif_scores

Description

This data.frame object loaded by 'data(example)' contains information about MYC_disc1 match to rs53576.

Format

A data.frame object.

Author(s)

Sanjaly Patel <sanjaly.patel@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>

motif_scores

Scores for the sample snp data computed based on the motif data.

Description

This list object loaded by 'data(example)' contains two fields:

snp.tbl A data.frame containing the sequence of nucleobases around each SNP.
motif.scores A data.frame containing the likelihood scores computed for each SNP and each motif.

Format

A data.frame object.

Author(s)

Sanjaly Patel <sanjaly.patel@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>
plotMotifMatch

Plot sequence logos of the position weight matrix of the motif and sequences of its corresponding best matching augmented subsequence on the reference and SNP allele.

Description

Plot the best matching augmented subsequences on the reference and SNP alleles. Plot sequence logos of the position weight matrix of the motif to the corresponding positions of the best matching subsequences on the references and SNP alleles.

Usage

plotMotifMatch(motif.match, motif.lib, cex.main = 2, ...)

Arguments

motif.match a single row of dtMotifMatch output in data.frame format
motif.lib A list of position weight matrices
cex.main The size of the main title.
... Other parameters passed to plotMotifLogo.

Value

Sequence logo stacks: Reference subsequences, sequence logo of reference allele matching position weight matrix, SNP subsequences, sequence logo of SNP allele matching position weight matrix

Author(s)

Sunyoung Shin<sunyoung.shin@utdallas.edu>

Examples

data(example)
plotMotifMatch(motif_match, motif.lib = motif_library)
prior

Default stationary distribution for nucleotide sequences in the reference genome.

Description

This parameter is fitted using 61bp windowns around the SNPs in the NHGRI catalog. Loaded by 'data(default_par)'.

Format

A numeric vector.

Author(s)

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snpInfo

A data set for SNP information.

Description

This list object loaded by 'data(example)' contains three fields:

- sequence_matrix: A sequence matrix, coded by 1-A, 2-C, 3-G, 4-T, with each column corresponding to a subsequence of 61 bases.
- transition: The transition matrix used in the Markov model.
- prior: The stationary distribution used in the Markov model.

Format

A list object.

Author(s)

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snp_tbl

A data frame for SNP information.

Description

This data frame is loaded by 'data(example)'. It is a table including the following columns:

- `chr`: The chromosome.
- `snp`: The SNP location coordinate.
- `snpid`: The SNP label.
- `a1,a2`: The nucleotide on the reference and SNP allele.

Format

A data.frame object.

Author(s)

Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>

transition

Default transition probability matrix for nucleotide sequences in the reference genome.

Description

This parameter is fitted using 61bp windowns around the SNPs in the NHGRI catalog. Loaded by 'data(default_par)'.

Format

A 4 by 4 numeric matrix.

Author(s)

Sunyoung Shin <sunyoung.shin@utdallas.edu>, Chandler Zuo <chandler.c.zuo@gmail.com>
Index

* GenomeAnnotation
  atSNP-package, 2
* LogoPlot
  atSNP-package, 2
* MotifAnnotation
  atSNP-package, 2
  atSNP-package, 2
  ComputeMotifScore, 2, 3, i3
  ComputePValues, 2, 4, i3
  dtMotifMatch, 3, 5
  encode_motif, 7, 7
  encode_motifinfo, 7
  GetIUPACSequence, 3, 8
  jaspar_motif, 8, 9
  jaspar_motifinfo, 9
  LoadFastaData, 2, 9
  LoadMotifLibrary, 2, 3, 5, 10
  LoadSNPData, 2, 3, 5, 11, i3
  MatchSubsequence, 3, 6, 14
  motif_library, 15
  motif_match, 16
  motif_scores, 16
  plotMotifMatch, 3, 17
  prior, 18
  read.table, 12
  snp_tbl, 19
  snpInfo, 18
  transition, 19