Package 'single'

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Type Package

Title Accurate consensus sequence from nanopore reads of a gene library

Version 1.4.0

biocViews Software, Sequencing

Depends R (>= 4.0)

Description Accurate consensus sequence from nanopore reads of a DNA gene library. SINGLe corrects for systematic errors in nanopore sequencing reads of gene libraries and it retrieves true consensus sequences of variants identified by a barcode, needing only a few reads per variant. More information in preprint doi: https://doi.org/10.1101/2020.03.25.007146.

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Encoding UTF-8

LazyData true

Imports Biostrings, BiocGenerics, dplyr, GenomicAlignments,IRanges, methods, reshape2, rlang, Rsamtools, stats, stringr, tidyr, utils

Suggests BiocStyle, knitr, rmarkdown

VignetteBuilder knitr

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R topics documented:

`ascii_v` *ASCII code*

Description

Vector ascii

Usage

```
ascii_v
```

Format

Named character vector of length 94. Names are ascii character and value is the probability of error.

`bases` *Bases*

Description

Vector A C G T -

Usage

```
bases
```

Format

Character vector of length 5

`evaluate_fits` *Evaluate SINGLE fits*

Description

Evaluates SINGLe for pos, nucleotides and QUAL in the given ranges.

Usage

```
evaluate_fits(
  pos_range,
  q_range,
  output_file,
  data_fits,
  ref_seq,
  verbose = FALSE,
  save = FALSE
)
```

Arguments

`pos_range`	Numeric vector. Positions to evaluate.
`q_range`	Numeric vector. QUAL to evaluate.
`output_file`	File name for output, if save=TRUE.
`data_fits`	Data.frame with columns position nucleotide slope intercept as the one returned by fit_logregr
`ref_seq`	DNAStringSet containing the true reference sequence.
`verbose`	Logical.
`save`	Logical. Should results be saved in output_file?

Value

data.frame with SINGLE fits evaluated for pos_range and q_range.

Examples

```
refseq_fasta = system.file("extdata", "ref_seq.fasta", package = "single")
ref_seq = Biostrings::readDNAStringSet(refseq_fasta)
fits_file <- system.file("extdata","fits_example.txt",package = "single")
fits <- read.table(fits_file, header=TRUE)
evaluated_fits <- evaluate_fits(pos_range = c(1,5),q_range = c(0,10),
                    data_fits = fits,ref_seq = ref_seq)
```

`fit_logregr` *Fit SINGLE's logistic regression*

Description

This is an auxiliary function in single package. It takes counts_pnq and for each position and nucleotide it fits SINGLE's logistic regression.

Usage

```
fit_logregr(
  counts_pnq,
  ref_seq,
  p_prior_errors,
  p_prior_mutations,
  save = FALSE,
  output_file_fits,
  output_file_data,
  verbose = FALSE,
  keep_fit_quality = FALSE
)
```

Arguments

`counts_pnq`	Data frame with columns position nucleoide quality counts, as returned by pileup_by_QUAL
`ref_seq`	DNAStringSet containing the true reference sequence.
`p_prior_errors`	Data frame with columns position nucleotide prior.error, as the one returned by p_prior_errors().
`p_prior_mutations`	Data frame with columns wt.base, nucleotide and p_mutation (probaility of mutation), as the one returned by p_prior_mutations().
`save`	Logical. Should data be saved in a output_file?
`output_file_fits`	File into which save the single fits if save=TRUE
`output_file_data`	File into which save the fitted data if save=TRUE
`verbose`	Logical.
`keep_fit_quality`	Logical. Should parameters related to the quality of the fit be returned in extra columns of the output?

Value

data.frame with columns position, nucleotide, slope and intercept (of the sigmoidal regression).

Examples

```
refseq_fasta <- system.file("extdata", "ref_seq.fasta", package = "single")
ref_seq = Biostrings::readDNAStringSet(refseq_fasta)
train_reads_example <- system.file("extdata", "train_seqs_500.sorted.bam",
                                   package = "single")
counts_pnq <- pileup_by_QUAL(bam_file=train_reads_example,
    pos_start=1,pos_end=10)
p_prior_mutations <- p_prior_mutations(rates.matrix = mutation_rate,
    mean.n.mut = 5,ref_seq = ref_seq)
p_prior_errors <- p_prior_errors(counts_pnq=counts_pnq)
fits <- fit_logregr(counts_pnq = counts_pnq,ref_seq=ref_seq,
    p_prior_errors = p_prior_errors,p_prior_mutations = p_prior_mutations)
```

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glm.predict. *Computes prior probability of mutations*

Description

This is an auxiliary function in single package. It evaluates the sigmoidal function given by the parameters slope and intercept on x.

Usage

```
glm.predict.(x, slope, intercept)
```

Arguments

x	Numeric. Values to evaluate.
slope	Slope of the sigmoidal function to evaluate.
intercept	Intercept of the sigmoidal function to evaluate.

Value

Numeric.

Examples

```
x = c(-10:10)
y = glm.predict.(x,1,2)
plot(x,y)
```

list_mismatches *Lists mismatches between two DNAstrings*

Description

This is an auxiliary function in single package, to list the mutations of two DNAstrings.

Usage

```
list_mismatches(ref, seq)
```

Arguments

ref	DNAString, reference sequence.
seq	DNAString, target sequence, same length as ref.

Value

Character vector containing Nucleotide in ref Position Nucleotide in seq. If ref and seq are equal, it returns NA.

Examples

```
ref = Biostrings::DNAString("AAAA")
seq = Biostrings::DNAString("AGAT")
list_mismatches(ref,seq)
list_mismatches(ref,ref)
```

mutation_rate *mutation_rate*

Description

Mutational rate matrix for error-prone PCR, obtained from GeneMorph II Random Mutagenesis Kit.

Usage

```
mutation_rate
```

Format

matrix size 4x5

Source

https://www.agilent.com/cs/library/usermanuals/public/200550.pdf

pileup_by_QUAL *Pileup by QUAL*

Description

To explain

Usage

```
pileup_by_QUAL(
  bam_file,
  QUAL_values = seq(93, 0),
  pos_start = NA,
  pos_end = NA
)
```

Arguments

bam_file	Bam file to pile up
QUAL_values	Numeric vector. QUAL values to analyze in the data.
pos_start	Numeric. Position to start analyzing, counting starts from 1 and it refers to reference used for minimap2 alignment.
pos_end	Numeric. Position to stop analyzing, counting starts from 1 and it refers to reference used for minimap2 alignment.

Value

data.frame with columns strand,pos,nucleotide,QUAL,countss

Examples

```
refseq_fasta <- system.file("extdata", "ref_seq.fasta", package = "single")
train_reads_example <- system.file("extdata", "train_seqs_500.sorted.bam",
                                   package = "single")
counts_pnq <- pileup_by_QUAL(bam_file=train_reads_example,
    pos_start=1,pos_end=10)
head(counts_pnq)
```

p_prior_errors *Computes prior probability of errors*

Description

This is an auxiliary function in single package. It takes a data frame with counts by position, nucleotide and Qscore and it summarises it into proportion of nucleotide counts by position.

Usage

```
p_prior_errors(counts_pnq, output_file = NULL, save = FALSE)
```

Arguments

counts_pnq	Data frame with columns position nucleoide quality counts, as returned by parse_countspnq
output_file	File name for output, if save=TRUE.
save	Logical. Should data be saved in a output_file?

Value

Data frame with columns position nucleotide prior.error.

Examples

```
refseq_fasta <- system.file("extdata", "ref_seq.fasta", package = "single")
train_reads_example <- system.file("extdata", "train_seqs_500.sorted.bam",
                                   package = "single")
counts_pnq <- pileup_by_QUAL(train_reads_example,pos_start=1,pos_end=10)
p_prior_errors <- p_prior_errors(counts_pnq=counts_pnq)
head(p_prior_errors)
```

p_prior_mutations *Computes prior probability of mutations*

Description

This is an auxiliary function in single package. It computes the prior probability of mutation in a gene library.

Usage

```
p_prior_mutations(
  rates.matrix,
  mean.n.mut,
  ref_seq,
  save = FALSE,
  output_file = "tablePriorMutations.txt"
)
```

Arguments

rates.matrix	Mutation rate matrix: 4x5 matrix, each row/col representing a nucleotide (col adds deletion), and the values is the mutational rate from row to col.
mean.n.mut	Mean number of mutations expected (one number).
ref_seq	DNAStringSet containing the true reference sequence.
save	Logical. Should data be saved in a output_file?
output_file	File name for output, if save=TRUE.

Value

Data frame with columns wt.base (wild type nucleotide), nucleotide (mutated nucleotide), p_mutation (probaility of mutation)

Examples

```
refseq_fasta <- system.file("extdata", "ref_seq.fasta", package = "single")
ref_seq <- Biostrings::subseq(Biostrings::readDNAStringSet(refseq_fasta), 1,10)
train_reads_example <- system.file("extdata", "train_seqs_500.sorted.bam",
                                   package = "single")
counts_pnq <- pileup_by_QUAL(train_reads_example,pos_start=1,pos_end=10)
p_prior_mutations <- p_prior_mutations(rates.matrix = mutation_rate,
    mean.n.mut = 5,ref_seq = ref_seq)
head(p_prior_mutations)
```

---

single_consensus_byBarcode

Compute SINGLE consensus

Description

Main function to compute consensus after correcting reads by a SINGLE model.

Usage

```
single_consensus_byBarcode(
  barcodes_table,
  sequences,
  readID_col = 1,
  bcID_col = 2,
  header = TRUE,
  dec = ".",
  sep = " ",
  verbose = TRUE
)
```

Arguments

barcodes_table	data.frame or file name containing the names of the reads and the barcode associated (or any grouping tag).
sequences	QualityScaledDNAStringSet or fastq file name. Contains sequences from which compute weighted consensus.
readID_col, bcID_col	Numeric. Columns where the reads id and the barcode (or grouping tag) are, in the barcodes_table
header, dec, sep	Arguments for read.table(barcodes_table)
verbose	Logical.

Value

DNAStringSet with consensus sequences

Examples

```
pos_start=1
pos_end = 100
barcodes_file =  system.file("extdata", "Barcodes_table.txt",package = "single")
reads_single = system.file("extdata", "corrected_seqs.fastq", package = "single")
single_consensus_byBarcode(barcodes_file,reads_single, verbose = FALSE)
```

---

single_evaluate *Evaluate SINGLE model*

Description

Main function to evaluate a gene library using a SINGLE model.

Usage

```
single_evaluate(
  bamfile,
  single_fits,
  refseq_fasta,
  pos_start = NULL,
  pos_end = NULL,
  gaps_weights,
  save = FALSE,
  output_file,
  verbose = FALSE,
  save_original_scores = FALSE
)
```

Arguments

bamfile	File containing the counts per position returned by samtools mpileup
single_fits	Results of the SINGLE model as returned by single_train(). It can be either the output data.frame or the saved file.
refseq_fasta	Fasta file containing reference sequence
pos_start	Numeric. Position to start analyzing, counting starts from 1 and it refers to reference used for minimap2 alignment.
pos_end	Numeric. Position to stop analyzing, counting starts from 1 and it refers to reference used for minimap2 alignment.
gaps_weights	One of "minimum","none","mean". How to assign qscores to deletions.
save	Logical. Should data be saved in a output_file?
output_file	File name for output, if save=TRUE.
verbose	Logical
save_original_scores	Logical. Should original Qscores be saved? If TRUE, they are stored in file whose name finishes in _original.fastq

Details

Before running single_evaluate_function you have to align your INPUT data to a REFERENCE using minimap2 and count the nucleotides per position using samtools using these lines:

`minimap2 -ax map-ont --sam-hit-only REFERENCE.fasta INPUT.fastq >ALIGNMENT.sam`

`samtools view -S -b ALIGNMENT.sam > ALIGNMENT.bam`

`samtools sort ALIGNMENT.bam -o ALIGNMENT.sorted.bam`

`samtools mpileup -Q 0 ALIGNMENT.sorted.bam > COUNTS.txt`

Value

Creates file output_prefix_corrected.txt with the Qscores re-scaled by SINGLE. Columns are SeqID position nucleotide isWT original_quality p_SINGLe

Examples

```
refseq_fasta = system.file("extdata", "ref_seq_10bases.fasta", package = "single")
train_file <- system.file("extdata", "train_example.txt", package = "single")
train <- read.table(train_file, header=TRUE)
test_reads_example <- system.file("extdata", "test_sequences.sorted.bam",
   package = "single")
corrected_reads <- single_evaluate(bamfile = test_reads_example,
                 single_fits = train,refseq_fasta = refseq_fasta,
                 pos_start=1,pos_end=10,gaps_weights = "minimum")
corrected_reads
```

`single_train` *Train SINGLE model*

Description

Main function to train a SINGLE model in a set of reads of a reference / wild type sequence. To get the input data you will need to run before a minimap2 alignment and samtools counts.

Usage

```
single_train(
  bamfile,
  output = "results",
  refseq_fasta,
  rates.matrix = NULL,
  mean.n.mutations = NULL,
  pos_start = NULL,
  pos_end = NULL,
  verbose = TRUE,
  save_partial = FALSE,
  save_final = FALSE
)
```

Arguments

`bamfile`	File containing the counts per position returned by samtools mpileup
`output`	String. Prefix for output files
`refseq_fasta`	Fasta file containing reference sequence
`rates.matrix`	Mutation rate matrix: 4x5 matrix, each row/col representing a nucleotide (col adds deletion), and the values is the mutational rate from row to col.
`mean.n.mutations`	Mean number of mutations expected (one number).
`pos_start`	Numeric. Position to start analyzing, counting starts from 1 and it refers to reference used for minimap2 alignment.
`pos_end`	Numeric. Position to stop analyzing, counting starts from 1 and it refers to reference used for minimap2 alignment.
`verbose`	Logical.
`save_partial`	Logical. Should partial results be saved in files?
`save_final`	Logical. Should final fits be saved in a file?

Details

Before running single_train_function you have to align your INPUT data to a REFERENCE using minimap2 and count the nucleotides per position using samtools using these lines:

```
minimap2 -ax map-ont --sam-hit-only REFERENCE.fasta INPUT.fastq >ALIGNMENT.sam
samtools view -S -b ALIGNMENT.sam > ALIGNMENT.bam
samtools sort ALIGNMENT.bam -o ALIGNMENT.sorted.bam
samtools mpileup -Q 0 ALIGNMENT.sorted.bam > COUNTS.txt
```

Value

Creates file output_prefix_single_results.txt with SINGLE training results.

Examples

```
refseq_fasta<- system.file("extdata", "ref_seq.fasta", package = "single")
train_reads_example <- system.file("extdata", "train_seqs_500.sorted.bam",
                                   package = "single")
train <- single_train(bamfile=train_reads_example,
                  refseq_fasta=refseq_fasta,
                  rates.matrix=mutation_rate,mean.n.mutations=5.4,
                  pos_start=1,pos_end=10)
print(head(train))
```

---

weighted_consensus *Compute consensus sequence*

Description

This is an auxiliary function in single package. It computes consensus from a data.frame as the one returned by single_evaluate()

Usage

```
weighted_consensus(df, cutoff_prob = 0.2)
```

Arguments

df	data.frame with the columns: nucleotide, probability, position
cutoff_prob	Numeric. Nucleotides with probability below this number will be removed from consensus computation.

Value

Character vector, consensus sequence

Examples

```
fastq_seqs_example <- system.file("extdata", "test_sequences.fastq",package = "single")
seqs_example <- Biostrings::readQualityScaledDNAStringSet(fastq_seqs_example)
# Using single weights
data_barcode = data.frame(
 nucleotide = unlist(sapply(as.character(seqs_example),strsplit, split="")),
 p_SINGLe=unlist(1-as(Biostrings::quality(seqs_example),"NumericList")),
 pos=rep(1:Biostrings::width(seqs_example[1]),length(seqs_example)))
weighted_consensus(df = data_barcode, cutoff_prob = 0.9)
# Replacing weights by ones
data_barcode = data.frame(
 nucleotide = unlist(sapply(as.character(seqs_example),strsplit, split="")),
 p_SINGLe=1,pos=rep(1,sum(Biostrings::width(seqs_example))))
weighted_consensus(df = data_barcode, cutoff_prob = 0)
```

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