Package 'crisprScore'

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Title On-Target and Off-Target Scoring Algorithms for CRISPR gRNAs

Depends R (>= 4.1), crisprScoreData (>= 1.1.3)

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Suggests BiocStyle, knitr, rmarkdown, testthat

biocViews CRISPR, FunctionalGenomics, FunctionalPrediction

Description Provides R wrappers of several on-target and off-target scoring methods for CRISPR guide RNAs (gRNAs).
The following nucleases are supported: SpCas9, AsCas12a, enAsCas12a, and Rfx-Cas13d (CasRx).
The available on-target cutting efficiency scoring methods are RuleSet1, RuleSet3, DeepHF, enPAM+GB, and CRISPRscan. Both the CFD and MIT scoring methods are available for off-target
specificity prediction. The package also provides a Lindel-derived score to predict the probability of a gRNA to produce indels inducing a frameshift for the Cas9 nuclease.
Note that DeepHF and enPAM+GB are not available on Windows machines.

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Encoding UTF-8

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URL https://github.com/crisprVerse/crisprScore/issues

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`getCasRxRFScores` *Calculate on-target sgRNA activity scores for CasRx using CasRx-RF*

Description

Calculate on-target sgRNA activity scores for CasRx (RfxCas13d) using the CasRx-RF algorithm.

Usage

```
getCasRxRFScores(
  mrnaSequence,
  directRepeat = "aacccctaccaactggtcggggtttgaaac",
  binaries = NULL,
  sort = FALSE,
  verbose = TRUE
)
```

Arguments

mrnaSequence	A DNAStringSet represeting the mRNA sequence for which to extract spacer sequences and calculate scores.
directRepeat	String specifying the direct repeat used in the CasRx construct.
binaries	Named list of paths for binaries needed for CasRx-RF. Names of the list must be "RNAfold", "RNAhybrid", and "RNAplfold". Each list element is a string specifying the path of the binary. If NULL (default), binaries must be available on the PATH.
sort	Should spacers be sorted by score? FALSE by default.
verbose	Should messages be printed to console? TRUE by default.

Details

The function first extracts all 23mer spacer sequences targeting the mRNA sequence, and scores them for on-target activity.

Value

A data.frame with the following columns:

- ID Character vector specifying spacer ID.
- spacer 23-mer spacer sequence.
- pfs_site coordinate of the protospacer flanking sequence (PFS).
- protospacer 23-mer protospacer sequence (reverse complement of the spacer sequence).
- PFS PFS nucleotide.
- score Raw score (not standardized).
- standardizedScore Score standardized between 0 and 1.
- quartile Quartile score (1 to 4, with 4 being the best quartile.

A scores closer to 1 indicates higher predicted on-target activity.

Author(s)

Jean-Philippe Fortin

References

Wessels HH, Méndez-Mancilla A, Guo X, et al. Massively parallel Cas13 screens reveal principles for guide RNA design. Nat biotechnol. 2020 Jun;38(6):722-7.

Examples

```
if (interactive()){
    fasta <- file.path(system.file(package="crisprScore"),
        "casrxrf/test.fa")
    mrnaSequence <- Biostrings::readDNAStringSet(filepath=fasta,
        format="fasta",
        use.names=TRUE)
    results <- getCasRxRFScores(mrnaSequence)
}
```

`getCFDScores` *Calculate CFD off-target specificity scores*

Description

Calculate cutting frequency determination (CFD) off-target specificity scores for CRISPR/Cas9 or CRISPR/CasRX.

Usage

```
getCFDScores(spacers, protospacers, pams, nuclease = c("SpCas9", "CasRx"))
```

Arguments

`spacers`	Character vector of 20bp spacer sequences. Must be in 5' to 3' direction. For SpCas9, must be of length 20bp. For CasRx, must be at most of length 27bp.
`protospacers`	Character vector of 20bp protospacer sequences (target sequences). Must be in 5' to 3' direction.
`pams`	Character vector of PAM sequences.
`nuclease`	String specifying the nuclease. Either "SpCas9" (default) or "CasRx".

Value

getCFDScores returns a data.frame with `spacer`, `protospacer`, and `score` columns. The CFD score takes on a value between 0 and 1. For a given pair (on-target, off-target), a higher CFD score indicates a higher likelihood for the nuclease to cut at the off-target. Non-canonical PAM sequences are taken into account by the CFD algorithm.

Author(s)

Jean-Philippe Fortin

References

Doench, J., Fusi, N., Sullender, M. et al. Optimized sgRNA design to maximize activity and minimize off-target effects of CRISPR-Cas9. Nat Biotechnol 34, 184–191 (2016). https://doi.org/10.1038/nbt.3437.

Examples

```
# Calculating MIT scores for two off-targets with respect to
# one spacer sequence:
spacer <- "AGGTGTAGTGTGTGTGATAA"
protospacer1 <- "CGGTGTAGTGTGTGTGATAA"
protospacer2 <- "CGGTGTCGTGTGTGTGATAA"
results <- getCFDScores(spacers=spacer,
    protospacers=c(protospacer1, protospacer2),
    pams=c("AGG", "CGG")
)
```

`getCRISPRaterScores` *Calculate on-target sgRNA activity scores for Cas9 using CRISPRater*

Description

Calculate on-target sgRNA activity scores for CRISPR/Cas9-induced knockout using the DeepHF scoring method. Both U6 and T7 promoters are supported. Three different versions of the SpCas9 nuclease are supported: wildtype (WT-SpCas9), high-fidelity Cas9 (SpCas9-HF1) and enhanced Cas9 (eSpCas9). Currently not supported on Windows machines.

Usage

```
getCRISPRaterScores(sequences)
```

Arguments

`sequences`	Character vector of 20bp protospacer sequences.

Details

Input sequences for CRISPRater scoring must be 20 spacer sequences.

Value

getCrisprRaterScores returns a data.frame with `sequence` and `score` columns. The CRISPRater score takes on a value between 0 and 1. A higher score indicates higher knockout efficiency.

Author(s)

Jean-Philippe Fortin

References

Labuhn M, Adams FF, Ng M, et al. Refined sgRNA efficacy prediction improves large-and small-scale CRISPR–Cas9 applications. Nucleic acids research. 2018 Feb 16;46(3):1375-85.

Examples

```
spacer  <- "ATCGATGCTGATGCTAGATA" #20bp
results <- getCRISPRaterScores(spacer)
```

`getCRISPRscanScores` *Calculate on-target sgRNA activity scores for Cas9 using CRISPRscan*

Description

Calculate on-target sgRNA activity scores for CRISPR/Cas9-induced knockout using the CRISPRscan scoring method. The method is also know as the Moreno-Mateos score. The CRISPRscan algorithm was trained using in vitro transcription of sgRNAs using a T7 promoter, and might therefore be suboptimal to predict sgRNA activity when expressed from U6 promoter.

Usage

```
getCRISPRscanScores(sequences)
```

Arguments

`sequences`	Character vector of 35bp sequences needed for CRISPRscan scoring, see details below.

Details

The input sequences for Rule Set 1 scoring require 6 nucleotides upstream of the protospacer sequence, the protospacer sequence itself (23 nucleotides) and 6 nucleootides downstream of the protospacer sequence, for a total of 35 nucleotides: [6nt][20nt-spacer][NGG][6nt]. Note that a canonical PAM sequence (NGG) is required for CRISPRscan.

Value

getCRISPRscanScores returns a data.frame with `sequence` and `score` columns. The CRISPRscan score takes on a value between 0 and 1. A higher score indicates higher knockout efficiency.

Author(s)

Jean-Philippe Fortin

References

Moreno-Mateos MA, et al. CRISPRscan: designing highly efficient sgRNAs for CRISPR-Cas9 targeting in vivo. Nature methods. 2015 Oct;12(10):982-8.

Examples

```
flank5 <- "ACCTGG" #6bp
spacer <- "ATCGATGCTGATGCTAGATA" #20bp
pam    <- "AGG" #3bp
flank3 <- "TTGAGC" #6bp
input  <- paste0(flank5, spacer, pam, flank3)
results <- getCRISPRscanScores(input)
```

`getDeepHFScores` *Calculate on-target sgRNA activity scores for Cas9 using DeepHF*

Description

Calculate on-target sgRNA activity scores for CRISPR/Cas9-induced knockout using the DeepHF scoring method. Both U6 and T7 promoters are supported. Three different versions of the SpCas9 nuclease are supported: wildtype (WT-SpCas9), high-fidelity Cas9 (SpCas9-HF1) and enhanced Cas9 (eSpCas9). Currently not supported on Windows machines.

Usage

```
getDeepHFScores(
  sequences,
  enzyme = c("WT", "ESP", "HF"),
  promoter = c("U6", "T7"),
  condaEnv
)
```

Arguments

`sequences`	Character vector of 23bp protospacer sequences.
`enzyme`	Character string specifying the Cas9 variant. Wildtype Cas9 (WT) by default, see details below.
`promoter`	Character string speciyfing promoter used for expressing sgRNAs for wildtype Cas9 (must be either "U6" or "T7"). "U6" by default.
`condaEnv`	String specifying the path of the conda environment needed to run the DeepHF calculations. See the crisprScore vignette for instructions on how to build the environment.

Details

Input sequences for DeepHF scoring must be 23bpprotospacer sequences (20bp spacer sequences + 3bp PAM sequences). Only canonical PAM sequences (NGG) are allowed. Users can specify for which Cas9 they wish to score sgRNAs by using the argument `enzyme`: "WT" for Wildtype Cas9 (WT-SpCas9), "HF" for high-fidelity Cas9 (SpCas9-HF), or "ESP" for enhanced Cas9 (eSpCas9). For wildtype Cas9, users can also specify the promoter used for expressing sgRNAs using the argument `promoter` ("U6" by default).

Value

getDeepHFScores returns a data.frame with `sequence` and `score` columns. The DeepHF score takes on a value between 0 and 1. A higher score indicates higher knockout efficiency.

Author(s)

Jean-Philippe Fortin

References

Wang, D., Zhang, C., Wang, B. et al. Optimized CRISPR guide RNA design for two high-fidelity Cas9 variants by deep learning. Nat Commun 10, 4284 (2019). https://doi.org/10.1038/s41467-019-12281-8

Examples

```
if (interactive()){
spacer  <- "ATCGATGCTGATGCTAGATA" #20bp
pam     <- "AGG" #3bp
input   <- paste0(spacer, pam)
condaEnv <- "/Users/fortin946/miniforge3/envs/deephf-env"

# Wiltype Cas9 using U6 promoter:
results <- getDeepHFScores(input, condaEnv=condaEnv)

# Wiltype Cas9 using T7 promoter:
results <- getDeepHFScores(input, promoter="T7", condaEnv=condaEnv)

#' High-fidelity Cas9:
results <- getDeepHFScores(input, enzyme="HF",condaEnv=condaEnv)

#' Enhanced Cas9:
results <- getDeepHFScores(input, enzyme="ESP",condaEnv=condaEnv)
}
```

---

getEnPAMGBScores *Calculate on-target sgRNA activity scores for enCas12a using enPAM+GB*

Description

Calculate on-target sgRNA activity scores for CRISPR/Cas12a-induced knockout using the enPAM+GB scoring method. Currently not supported on Windows machines.

Usage

```
getEnPAMGBScores(sequences, condaEnv)
```

Arguments

sequences	Character vector of 34bp sequences needed for enPAM+GB scoring, see details below.
condaEnv	String specifying the path of the conda environment needed to run the enPAM+GB calculations. See the crisprScore vignette for instructions on how to build the environment.

Details

The input sequences for enPAM+GB scoring require 4 nucleotides upstream of the protospacer sequence, the protospacer sequence itself (4bp PAM sequence + 23bp spacer sequence) and 3 nucleotides downstream of the protospacer sequence, for a total of 34 nucleotides. Both canonical and non-canonical PAM sequences can be provided.

Value

getEnPAMGBScores returns a data.frame with `sequence` and `score` columns.

Author(s)

Jean-Philippe Fortin

References

DeWeirdt, P.C., Sanson, K.R., Sangree, A.K. et al. Optimization of AsCas12a for combinatorial genetic screens in human cells. Nat Biotechnol 39, 94–104 (2021). https://doi.org/10.1038/s41587-020-0600-6.

Examples

```
if (interactive()){
flank5 <- "CATG" #4bp
pam    <- "TTTT" #4bp
spacer <- "TTTGGGAACCAATCGATAATCAC" #23bp
flank3 <- "ATT" #3bp
input  <- paste0(flank5, pam, spacer, flank3)
condaEnv <- "/Users/fortin946/miniforge3/envs/enpamgb-env"
results <- getEnPAMGBScores(input, condaEnv)
}
```

---

getLindelScores — *Predict frameshift ratios from CRISPR/Cas9 indel prediction using Lindel*

Description

Predict frameshift ratios from CRISPR/Cas9 indel prediction using the Lindel prediction algorithm.

Usage

```
getLindelScores(sequences, condaEnv)
```

Arguments

sequences	Character vector of 65bp sequences needed for Lindel scoring, see details below.
condaEnv	String specifying the path of the conda environment needed to run the DeepHF calculations. See the crisprScore vignette for instructions on how to build the environment.

Details

The input sequences for Lindel scoring require 13 nucleotides upstream of the protospacer sequence, the protospacer sequence itself (23 nucleotides) and 29 nucleootides downstream of the protospacer sequence, for a total of 65 nucleotides. Note that only canonical PAM sequences (NGG) are accepted by Lindel.

Value

A data.frame with predicted frameshift ratio (between 0 and 1). A higher ratio indicates a greater chance of a frameshift indel introduced by CRISPR/Cas9-induced double-strand breaks.

Author(s)

Jean-Philippe Fortin

References

Wei Chen, Aaron McKenna, Jacob Schreiber, Maximilian Haeussler, Yi Yin, Vikram Agarwal, William Stafford Noble, Jay Shendure, Massively parallel profiling and predictive modeling of the outcomes of CRISPR/Cas9-mediated double-strand break repair, Nucleic Acids Research, Volume 47, Issue 15, 05 September 2019, Pages 7989–8003, https://doi.org/10.1093/nar/gkz487.

Examples

```
if (interactive()){
flank5 <- "ACCTTTTAATCGA" #13bp
spacer <- "TGCTGATGCTAGATATTAAG" #20bp
pam    <- "TGG" #3bp
flank3 <- "CTTTTAATCGATGCTGATGCTAGATATTA" #29bp
input <- paste0(flank5, spacer, pam, flank3)
condaEnv <- "/Users/fortin946/miniforge3/envs/deephf-env"
results <- getLindelScores(input, condaEnv=condaEnv)
}
```

getMITScores *Calculate MIT off-target specificity scores for CRISPR/Cas9*

Description

Calculate MIT off-target specificity scores for CRISPR/Cas9.

Usage

```
getMITScores(spacers, protospacers, pams, includeDistance = TRUE)
```

Arguments

spacers	Character vector of 20bp spacer sequences.
protospacers	Character vector of 20bp protospacer sequences for off-targets.
pams	Character vector of 3nt PAM sequences.
includeDistance	Should distance between mismatches be considered during scoring? TRUE by default.

Value

getMITScores returns a data.frame with `spacer`, `protospacer`, and `score` columns. The MIT score takes on a value between 0 and 1. For a given pair (on-target, off-target), a higher MIT score indicates a higher likelihood for the Cas9 nuclease to cut at the off-target. Non-canonical PAM sequences are taken into account by the MIT algorithm.

Author(s)

Jean-Philippe Fortin

References

Hsu, P., Scott, D., Weinstein, J. et al. DNA targeting specificity of RNA-guided Cas9 nucleases. Nat Biotechnol 31, 827–832 (2013). https://doi.org/10.1038/nbt.2647.

Examples

```
# Calculating MIT scores for two off-targets with respect to
# one spacer sequence:
spacer <- "AGGTGTAGTGTGTGTGATAA"
protospacer1 <- "CGGTGTAGTGTGTGTGATAA"
protospacer2 <- "CGGTGTCGTGTGTGTGATAA"
pams <- c("AGG", "CGG")
results <- getMITScores(spacers=spacer,
    protospacers=c(protospacer1, protospacer2),
    pams=pams
)
```

`getRuleSet1Scores` *Calculate on-target sgRNA activity scores for Cas9 using Rule Set 1*

Description

Calculate on-target sgRNA activity scores for CRISPR/Cas9-induced knockout using the Rule Set 1 scoring method. The Rule Set 1 algorithm was an early on-target efficiency method developed by the Doench lab.

Usage

```
getRuleSet1Scores(sequences)
```

Arguments

`sequences`	Character vector of 30bp sequences needed for Rule Set 1 scoring, see details below.

Details

The input sequences for Rule Set 1 scoring require 4 nucleotides upstream of the protospacer sequence, the protospacer sequence itself (23 nucleotides) and 3 nucleootides downstream of the protospacer sequence, for a total of 30 nucleotides: [4nt][20nt-spacer][NGG][3nt]. Note that a canonical PAM sequence (NGG) is required for Rule Set 1.

Value

getRuleSet1Scores returns a data.frame with `sequence` and `score` columns. The Rule Set 1 score takes on a value between 0 and 1. A higher score indicates higher knockout efficiency.

Author(s)

Jean-Philippe Fortin

References

Doench, John G., et al. Rational design of highly active sgRNAs for CRISPR-Cas9–mediated gene inactivation. Nat Biotech 32, 1262-1267 (2014). https://doi.org/10.1038/nbt.3026.

Examples

```
flank5 <- "ACCT" #4bp
spacer <- "ATCGATGCTGATGCTAGATA" #20bp
pam    <- "AGG" #3bp
flank3 <- "TTG" #3bp
input  <- paste0(flank5, spacer, pam, flank3)
results <- getRuleSet1Scores(input)
```

`getRuleSet3Scores` *Calculate on-target sgRNA activity scores for SpCas9 using Rule Set 3*

Description

Calculate on-target sgRNA activity scores for CRISPR/Cas9-induced knockout using the Rule Set 3 scoring method.

Usage

```
getRuleSet3Scores(
  sequences,
  tracrRNA = c("Hsu2013", "Chen2013"),
  mode = c("sequence", "target"),
  condaEnv
)
```

Arguments

`sequences`	Character vector of 30bp sequences needed for Rule Set 3 scoring, see details below.
`tracrRNA`	String specifying which tracrRNA is used. Must be either "Hsu2013" (default) or "Chen2013".
`mode`	String specifying which prediction mode is used. Must be either "sequence" (default) or "target".
`condaEnv`	String specifying the path of the conda environment needed to run the DeepHF calculations. See the crisprScore vignette for instructions on how to build the environment.

Details

The input sequences for Rule Set 3 scoring require 4 nucleotides upstream of the protospacer sequence, the protospacer sequence itself (20bp spacer sequence + 3bp PAM sequence) and 3 nucleootides downstream of the protospacer sequence, for a total of 30 nucleotides.

Value

getRuleSet3Scores returns a data.frame with `sequence` and `score` columns. The getRuleSet3Scores score is similar to a Z-score.A higher score indicates higher knockout efficiency.

Author(s)

Jean-Philippe Fortin

References

doi: https://doi.org/10.1101/2022.06.27.497780

Examples

```
if (interactive()){
flank5 <- "ACCG" #4bp
spacer <- "AATCGATGCTGATGCTAGAT" #20bp
pam    <- "AGG" #3bp
flank3 <- "AAT" #3bp
input  <- paste0(flank5, spacer, pam, flank3)
condaEnv <- "/Users/fortin946/miniforge3/envs/rs3-env"
results <- getRuleSet3Scores(input, condaEnv=condaEnv, tracrRNA="Chen2013")
}
```

`scoringMethodsInfo` *data.frame detailing available scoring methods*

Description

data.frame detailing available scoring methods with information needed to extract nucleotide sequences needed by each scoring algorithm.

Usage

```
data(scoringMethodsInfo)
```

Format

A data frame with 6 columns:

method name of the scoring method

nuclease nuclease compatible with the scoring method

left upstream offset (relative to PAM site) to extract nucleotide sequence needed for scoring

right downstream offset (relative to PAM site) to extract nucleotide sequence needed for scoring

type type of the scoring algorithm (on-target or off-target)

label proper case-sensitive method name for labeling

len length of the nucleotide sequence needed for scoring

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