

# Package ‘VariantAnnotation’

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**Type** Package

**Title** Annotation of Genetic Variants

**Description** Annotate variants, compute amino acid coding changes,  
predict coding outcomes

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**License** Artistic-2.0

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(>= 1.1.3), GenomicRanges (>= 1.19.47), SummarizedExperiment  
(>= 0.3.1), Rsamtools (>= 1.19.52)

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(>= 2.3.25), XVector (>= 0.5.6), Biostrings (>= 2.33.5),  
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**Video** [https://www.youtube.com/watch?v=Ro0IHQ\\_J--I&list=UUqaMSQd\\_h-2EDGsU6WDiX0Q](https://www.youtube.com/watch?v=Ro0IHQ_J--I&list=UUqaMSQd_h-2EDGsU6WDiX0Q)

**NeedsCompilation** yes

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filterVcf	<i>Filter VCF files</i>
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**Description**

Filter Variant Call Format (VCF) files from one file to another

**Usage**

```
## S4 method for signature 'character'
filterVcf(file, genome, destination, ..., verbose = TRUE,
          index = FALSE, prefilters = FilterRules(), filters = FilterRules(),
          param = ScanVcfParam())
```

```
## S4 method for signature 'TabixFile'
filterVcf(file, genome, destination, ..., verbose = TRUE,
          index = FALSE, prefilters = FilterRules(), filters = FilterRules(),
          param = ScanVcfParam())
```

**Arguments**

file	A character(1) file path or <a href="#">TabixFile</a> specifying the VCF file to be filtered.
genome	A character(1) identifier
destination	A character(1) path to the location where the filtered VCF file will be written.
...	Additional arguments, possibly used by future methods.
verbose	A logical(1) indicating whether progress messages should be printed.
index	A logical(1) indicating whether the filtered file should be compressed and indexed (using <a href="#">bgzip</a> and <a href="#">indexTabix</a> ).
prefilters	A <a href="#">FilterRules</a> instance contains rules for filtering un-parsed lines of the VCF file.
filters	A <a href="#">FilterRules</a> instance contains rules for filtering fully parsed VCF objects.
param	A <a href="#">ScanVcfParam</a> instance restricting input of particular info or geno fields, or genomic locations. Applicable when applying a filter only. Prefiltering involves a grep of unparsed lines in the file; indexing is not used.

**Details**

This function transfers content of one VCF file to another, removing records that fail to satisfy `prefilters` and `filters`. Filtering is done in a memory efficient manner, iterating over the input VCF file in chunks of default size 100,000 (when invoked with `character(1)` for `file`) or as specified by the `yieldSize` argument of `TabixFile` (when invoked with `TabixFile`).

There are up to two passes. In the first pass, unparsed lines are passed to `prefilters` for filtering, e.g., searching for a fixed character string. In the second pass lines successfully passing `prefilters` are parsed into VCF instances and made available for further filtering. One or both of `prefilter` and `filter` can be present.

Filtering works by removing the rows (variants) that do not meet a criteria. Because this is a row-based approach and samples are column-based most genotype filters are only meaningful for single-sample files. If a single samples fails the criteria the entire row (all samples) are removed. The case where genotype filtering is effective for multiple samples is when the criteria is applied across samples and not to the individual (e.g., keep rows where all samples have  $DP > 10$ ).

**Value**

The destination file path as a `character(1)`.

**Author(s)**

Martin Morgan and Paul Shannon

**See Also**

[readVcf](#), [writeVcf](#).

**Examples**

```

fl <- system.file("extdata", "chr22.vcf.gz", package="VariantAnnotation")

## -----
## Filter for SNVs in a defined set of ranges:
## -----

if (require(TxDb.Hsapiens.UCSC.hg19.knownGene)) {

  txdb <- TxDb.Hsapiens.UCSC.hg19.knownGene
  exons <- exons(txdb)
  exons22 <- exons[seqnames(exons) == "chr22"]
  seqlevelsStyle(exons22) <- "NCBI" ## match chrom names in VCF file

  ## Range-based filter:
  withinRange <- function(rng)
    function(x) x

  ## The first filter identifies SNVs and the second applies the
  ## range restriction.
  filters <- FilterRules(list(
    isSNV = isSNV,
    withinRange = withinRange(exons22)))

  ## Apply
  ## Not run:
  filt1 <- filterVcf(fl, "hg19", tempfile(), filters=filters, verbose=TRUE)

  ## End(Not run)
}

## -----
## Using a pre-filter and filter:
## -----

## Low coverage exome snp filter:
lowCoverageExomeSNP = function(x) grepl("LOWCOV,EXOME", x, fixed=TRUE)

## The pre-filter identifies low coverage exome snps and the filter
## identifies variants with INFO variable VT = SNP.
pre <- FilterRules(list(lowCoverageExomeSNP = lowCoverageExomeSNP))
filt <- FilterRules(list(VTisSNP = function(x) info(x)$VT == "SNP"))

## Apply
filt2 <- filterVcf(fl, "hg19", tempfile(), prefilters=pre, filters=filt)

## Filtered results
vcf <- readVcf(filt2, "hg19")

```

---

genotypeToSnpMatrix    *Convert genotype calls from a VCF file to a SnpMatrix object*

---

### Description

Convert an array of genotype calls from the "GT", "GP", or "GL" FORMAT field of a VCF file to a [SnpMatrix](#).

### Usage

```
## S4 method for signature 'CollapsedVCF'
genotypeToSnpMatrix(x, uncertain=FALSE, ...)
## S4 method for signature 'array'
genotypeToSnpMatrix(x, ref, alt, ...)
```

### Arguments

x	A CollapsedVCF object or a array of genotype data from the "GT", "GP", or "GL" FORMAT field of a VCF file. This array is created with a call to readVcf and can be accessed with geno(<VCF>).
uncertain	A logical indicating whether the genotypes to convert should come from the "GT" field (uncertain=FALSE) or the "GP" or "GL" field (uncertain=TRUE).
ref	A DNASTringSet of reference alleles.
alt	A DNASTringSetList of alternate alleles.
...	Additional arguments, passed to methods.

### Details

genotypeToSnpMatrix converts an array of genotype calls from the "GT", "GP", or "GL" FORMAT field of a VCF file into a [SnpMatrix](#). The following caveats apply,

- no distinction is made between phased and unphased genotypes
- variants with >1 ALT allele are set to NA
- only single nucleotide variants are included; others are set to NA
- only diploid calls are included; others are set to NA

In VCF files, 0 represents the reference allele and integers greater than 0 represent the alternate alleles (i.e., 2, 3, 4 would indicate the 2nd, 3rd or 4th allele in the ALT field for a particular variant). This function only supports variants with a single alternate allele and therefore the alternate values will always be 1. Genotypes are stored in the SnpMatrix as 0, 1, 2 or 3 where 0 = missing, 1 = "0/0", 2 = "0/1" or "1/0" and 3 = "1/1". In SnpMatrix terminology, "A" is the reference allele and "B" is the risk allele. Equivalent statements to those made with 0 and 1 allele values would be 0 = missing, 1 = "A/A", 2 = "A/B" or "B/A" and 3 = "B/B".

The three genotype fields are defined as follows:

- GT : genotype, encoded as allele values separated by either of "/" or "|". The allele values are 0 for the reference allele and 1 for the alternate allele.
- GL : genotype likelihoods comprised of comma separated floating point log10-scaled likelihoods for all possible genotypes. In the case of a reference allele A and a single alternate allele B, the likelihoods will be ordered "A/A", "A/B", "B/B".
- GP : the phred-scaled genotype posterior probabilities for all possible genotypes; intended to store imputed genotype probabilities. The ordering of values is the same as for the GL field.

If uncertain=TRUE, the posterior probabilities of the three genotypes ("A/A", "A/B", "B/B") are encoded (approximately) as byte values. This encoding allows uncertain genotypes to be used in `snpStats` functions, which in some cases may be more appropriate than using only the called genotypes. The byte encoding conserves memory by allowing the uncertain genotypes to be stored in a two-dimensional raw matrix. See the `snpStats` documentation for more details.

### Value

A list with the following elements,

genotypes	The output genotype data as an object of class "SnpMatrix". The columns are snps and the rows are the samples. See ?SnpMatrix details of the class structure.
map	A DataFrame giving the snp names and alleles at each locus. The ignore column indicates which variants were set to NA (see NA criteria in 'details' section).

### Author(s)

Stephanie Gogarten and Valerie Obenchain

### References

<http://www.1000genomes.org/wiki/Analysis/Variant%20Call%20Format/vcf-variant-call-format-version-41>

### See Also

`readVcf`, `VCF`, `SnpMatrix`

### Examples

```
## -----
## Non-probability based snp encoding using "GT"
## -----
fl <- system.file("extdata", "ex2.vcf", package="VariantAnnotation")
vcf <- readVcf(fl, "hg19")

## This file has no "GL" or "GP" field so we use "GT".
geno(vcf)

## Convert the "GT" FORMAT field to a SnpMatrix.
mat <- genotypeToSnpMatrix(vcf)

## The result is a list of length 2.
```

```

names(mat)

## Compare coding in the VCF file to the SnpMatrix.
geno(vcf)$GT
t(as(mat$genotype, "character"))

## The 'ignore' column in 'map' indicates which variants
## were set to NA. Variant rs6040355 was ignored because
## it has multiple alternate alleles, microsata1 is not a
## snp, and chr20:1230237 has no alternate allele.
mat$map

## -----
## Probability-based encoding using "GL" or "GP"
## -----
## Read a vcf file with a "GL" field.
fl <- system.file("extdata", "gl_chr1.vcf", package="VariantAnnotation")
vcf <- readVcf(fl, "hg19")
geno(vcf)

## Convert the "GL" FORMAT field to a SnpMatrix
mat <- genotypeToSnpMatrix(vcf, uncertain=TRUE)

## Only 3 of the 9 variants passed the filters. The
## other 6 variants had no alternate alleles.
mat$map

## Compare genotype representations for a subset of
## samples in variant rs180734498.
## Original called genotype
geno(vcf)$GT["rs180734498", 14:16]

## Original genotype likelihoods
geno(vcf)$GL["rs180734498", 14:16]

## Posterior probability (computed inside genotypeToSnpMatrix)
GLtoGP(geno(vcf)$GL["rs180734498", 14:16, drop=FALSE])[1,]

## SnpMatrix coding.
t(as(mat$genotype, "character"))["rs180734498", 14:16]
t(as(mat$genotype, "numeric"))["rs180734498", 14:16]

## For samples NA11829 and NA11830, one probability is significantly
## higher than the others, so SnpMatrix calls the genotype. These
## calls match the original coding: "0|1" -> "A/B", "0|0" -> "A/A".
## Sample NA11831 was originally called as "0|1" but the probability
## of "0|0" is only a factor of 3 lower, so SnpMatrix calls it as
## "Uncertain" with an appropriate byte-level encoding.

```

## Description

This function is defunct. Use `GenomicFeatures::extractTranscriptSeqs()` instead.

Extract transcript sequences from a [BSgenome](#) object or an [FaFile](#).

## Usage

```
## S4 method for signature 'GRangesList,BSgenome'  
getTranscriptSeqs(query, subject, ...)  
## S4 method for signature 'GRangesList,FaFile'  
getTranscriptSeqs(query, subject, ...)  
## S4 method for signature 'GRanges,FaFile'  
getTranscriptSeqs(query, subject, ...)
```

## Arguments

query	A <a href="#">GRangesList</a> object containing exons or cds grouped by transcript.
subject	A <a href="#">BSgenome</a> object or a <a href="#">FaFile</a> from which the sequences will be taken.
...	Additional arguments

## Details

`getTranscriptSeqs` is a wrapper for the `extractTranscriptSeqs` and `getSeq` functions. The purpose is to allow sequence extraction from either a [BSgenome](#) or [FaFile](#). Transcript sequences are extracted based on the boundaries of the feature provided in the query (i.e., either exons or cds regions).

## Value

A [DNASTringSet](#) instance containing the sequences for all transcripts specified in query.

## Author(s)

Valerie Obenchain

## See Also

[predictCoding](#) [extractTranscriptSeqs](#) [getSeq](#)

## Examples

```
## See ?extractTranscriptSeqs in the GenomicFeatures package.
```



---

**GLtoGP***Convert genotype likelihoods to genotype probabilities*

---

**Description**

Convert an array of genotype likelihoods to posterior genotype probabilities.

**Usage**

```
GLtoGP(gl)
```

**Arguments**

**gl** Array of genotype likelihoods. The format can be a matrix of lists, or a three-dimensional array in which the third dimension corresponds to the probabilities for each genotype.

**Details**

Computes the probability of each genotype as  $10^x / \text{sum}(10^x)$ .

**Value**

An array of posterior genotype probabilities, in the same format as the input (matrix of lists or 3D array).

**Author(s)**

Stephanie Gogarten <sdmorris@u.washington.edu>

**See Also**

[readVcf](#), [genotypeToSnpMatrix](#)

**Examples**

```
## Read a vcf file with a "GL" field.
vcfFile <- system.file("extdata", "gl_chr1.vcf", package="VariantAnnotation")
vcf <- readVcf(vcfFile, "hg19")

## extract genotype likelihoods as a matrix of lists
gl <- geno(vcf)$GL
class(gl)
mode(gl)

# convert to posterior probabilities
gp <- GLtoGP(gl)
```

---

`isSNV`*Identification of genomic variant types.*

---

**Description**

Functions for identifying variant types such as SNVs, insertions, deletions, transitions, and structural rearrangements.

**Usage**

```
## S4 method for signature 'VRanges'
isSNV(x, ...)
## S4 method for signature 'ExpandedVCF'
isSNV(x, ...)
## S4 method for signature 'CollapsedVCF'
isSNV(x, ..., singleAltOnly = TRUE)

## S4 method for signature 'VRanges'
isInsertion(x, ...)
## S4 method for signature 'ExpandedVCF'
isInsertion(x, ...)
## S4 method for signature 'CollapsedVCF'
isInsertion(x, ..., singleAltOnly = TRUE)

## S4 method for signature 'VRanges'
isDeletion(x, ...)
## S4 method for signature 'ExpandedVCF'
isDeletion(x, ...)
## S4 method for signature 'CollapsedVCF'
isDeletion(x, ..., singleAltOnly = TRUE)

## S4 method for signature 'VRanges'
isIndel(x, ...)
## S4 method for signature 'ExpandedVCF'
isIndel(x, ...)
## S4 method for signature 'CollapsedVCF'
isIndel(x, ..., singleAltOnly = TRUE)

## S4 method for signature 'VRanges'
isDelins(x, ...)
## S4 method for signature 'ExpandedVCF'
isDelins(x, ...)
## S4 method for signature 'CollapsedVCF'
isDelins(x, ..., singleAltOnly = TRUE)

## S4 method for signature 'VRanges'
isTransition(x, ...)
```

```

## S4 method for signature 'ExpandedVCF'
isTransition(x, ...)
## S4 method for signature 'CollapsedVCF'
isTransition(x, ..., singleAltOnly = TRUE)

## S4 method for signature 'VRanges'
isSubstitution(x, ...)
## S4 method for signature 'ExpandedVCF'
isSubstitution(x, ...)
## S4 method for signature 'CollapsedVCF'
isSubstitution(x, ..., singleAltOnly = TRUE)

```

### Arguments

x	A <a href="#">VCF</a> or <a href="#">VRanges</a> object.
singleAltOnly	A logical only applicable when x is a <a href="#">CollapsedVCF</a> class. When TRUE (default) only variants with a single alternate allele are evaluated; all multi-alt variants evaluate to FALSE. When singleAltOnly=FALSE all ref / alt pairs for each variant are evaluated. If any ref / alt pairs meet the test criteria a value of TRUE is returned for the variant; this may result in a value of TRUE for a variant with a mixture of alternate alleles, some that pass the criteria and some that do not. To retain single ref / alt pairs that pass the criteria use expand on the <a href="#">CollapsedVCF</a> and then apply the test.
...	Arguments passed to other methods.

### Details

All functions return a logical vector the length of x. Variants in gvcf files with NON\_REF alt alleles return TRUE; structural variants return FALSE.

- isSNV: Reference and alternate alleles are both a single nucleotide long.
- isInsertion: Reference allele is a single nucleotide and the alternate allele is greater (longer) than a single nucleotide and the first nucleotide of the alternate allele matches the reference.
- isDeletion: Alternate allele is a single nucleotide and the reference allele is greater (longer) than a single nucleotide and the first nucleotide of the reference allele matches the alternate.
- isIndel: The variant is either a deletion or insertion as determined by isDeletion and isInsertion.
- isDelins: The variant is a deletion followed by an insertion, either of them involving two or more nucleotides.
- isSubstitution: Reference and alternate alleles are the same length (1 or more nucleotides long).
- isTransition: Reference and alternate alleles are both a single nucleotide long. The reference-alternate pair interchange is of either two-ring purines (A <-> G) or one-ring pyrimidines (C <-> T).

### Value

A logical vector the same length as x.

**Author(s)**

Michael Lawrence, Valerie Obenchain and Robert Castelo

**Examples**

```
f1 <- system.file("extdata", "ex2.vcf", package="VariantAnnotation")
## -----
## VCF objects
## -----
vcf <- readVcf(f1, "hg19")
DataFrame(ref(vcf), alt(vcf))

## This vcf has transitions in row 2 and 3. When 'singleAltOnly=TRUE'
## only the row 2 variant is identified:
isTransition(vcf)

## Both row 2 and 3 are identified when 'singleAltOnly=FALSE':
isTransition(vcf, singleAltOnly=FALSE)

## Expand the CollapsedVCF to ExpandedVCF
evcf <- expand(vcf)

## All ref / alt pairs are now expanded and there is no need to
## use 'singleAltOnly'. The return length is now 7 instead of 5:
transition <- isTransition(evcf)
transition
DataFrame(ref(evcf)[transition], alt(evcf)[transition])

## -----
## VRanges objects
## -----
## A VRanges object holds data from a VCF class in a completely
## 'flat' fashion. INFO and FORMAT variables for all subjects are
## 'repped' out such that each row is a unique combination of data.
vr <- as(vcf, "VRanges")
isSNV(vr, singleAltOnly=FALSE)
```

---

locateVariants

*Locate variants*

---

**Description**

Variant location with respect to gene function

**Usage**

```
locateVariants(query, subject, region, ...)
## S4 method for signature 'VCF,TxDb,VariantType'
locateVariants(query, subject, region, ...,
```

```

    cache=new.env(parent=emptyenv()), ignore.strand=FALSE, asHits=FALSE)
## S4 method for signature 'GRanges,TxDb,VariantType'
locateVariants(query, subject, region, ...,
    cache=new.env(parent=emptyenv()), ignore.strand=FALSE, asHits=FALSE)

```

### Arguments

query	A <a href="#">Ranges</a> , <a href="#">GRanges</a> or <a href="#">VCF</a> object containing the variants. Metadata columns are allowed but ignored. NOTE: Zero-width ranges are treated as width-1 ranges; start values are decremented to equal the end value.
subject	A <a href="#">TxDb</a> or <a href="#">GRangesList</a> object that serves as the annotation. GFF files can be converted to <a href="#">TxDb</a> objects with <code>makeTxDbFromGFF()</code> in the <code>GenomicFeatures</code> package.
region	An instance of one of the 8 <code>VariantType</code> classes: <code>CodingVariants</code> , <code>IntronVariants</code> , <code>FiveUTRVariants</code> , <code>ThreeUTRVariants</code> , <code>IntergenicVariants</code> , <code>SpliceSiteVariants</code> , <code>PromoterVariants</code> , <code>AllVariants</code> . All objects can be instantiated with no arguments, e.g., <code>CodingVariants()</code> will create an object of <code>CodingVariants</code> . <code>AllVariants</code> , <code>PromoterVariants</code> and <code>IntergenicVariants</code> have upstream and downstream arguments. For <code>PromoterVariants</code> and <code>IntergenicVariants</code> these are single integer values $\geq 0$ . For <code>AllVariants</code> these are integer vectors of length 2 named 'promoter' and 'intergenic'. See <code>?upstream</code> for more details. When using <code>AllVariants</code> , a range in query may fall in multiple regions (e.g., 'intergenic' and 'promoter'). In this case the result will have a row for each match. All data in the row will be equivalent except the <code>LOCATION</code> column.
...	Additional arguments passed to methods
cache	An environment into which required components of subject are loaded. Provide, and re-use, a cache to speed repeated queries to the same subject across different query instances.
ignore.strand	A logical indicating if strand should be ignored when performing overlaps.
asHits	A logical indicating if the results should be returned as a <a href="#">Hits</a> object. Not applicable when region is <code>AllVariants</code> or <code>IntergenicVariants</code> .

### Details

**Range representation :** The ranges in query should reflect the position(s) of the reference allele. For snps the range will be of width 1. For range insertions or deletions the reference allele could be a sequence such as GGTG in which case the width of the range should be 4.

**Location :** Possible locations are 'coding', 'intron', 'threeUTR', 'fiveUTR', 'intergenic', 'spliceSite', or 'promoter'.

Overlap operations for 'coding', 'intron', 'threeUTR', and 'fiveUTR' require variants to fall completely within the defined region to be classified as such.

To be classified as a 'spliceSite' the variant must overlap with any portion of the first 2 or last 2 nucleotides in an intron.

'intergenic' variants are ranges that do not fall within a defined gene region. 'transcripts by gene' are extracted from the annotation and overlapped with the variant positions. Variants

with no overlaps are classified as intergenic. When available, gene IDs for the flanking genes are provided as PRECEDEID and FOLLOWID. upstream and downstream arguments define the acceptable distance from the query for the flanking genes. PRECEDEID and FOLLOWID results are lists and contain all genes that fall within the defined distance. See examples for how to compute the distance from ranges to PRECEDEID and FOLLOWID.

'promoter' variants fall within a specified range upstream and downstream of the transcription start site. Ranges values can be set with the upstream and downstream arguments when creating the PromoterVariants() or AllVariants() classes.

**Subject as GRangesList :** The subject can be a TxDb or GRangesList object. When using a GRangesList the type of data required is driven by the VariantType class. Below is a description of the appropriate GRangesList for each VariantType.

**CodingVariants :** coding (CDS) by transcript

**IntronVariants :** introns by transcript

**FiveUTRVariants :** five prime UTR by transcript

**ThreeUTRVariants :** three prime UTR by transcript

**IntergenicVariants :** transcripts by gene

**SpliceSiteVariants :** introns by transcript

**PromoterVariants :** list of transcripts

**AllVariants :** no GRangesList method available

**Using the cache :** When processing multiple VCF files performance is enhanced by specifying an environment as the cache argument. This cache is used to store and reuse extracted components of the subject (TxDb) required by the function. The first call to the function (i.e., processing the first VCF file in a list of many) populates the cache; repeated calls to locateVariants will access these objects from the cache vs re-extracting the same information.

## Value

A GRanges object with a row for each variant-transcript match. Strand of the output is from the subject hit except in the case of IntergenicVariants. For intergenic, multiple precede and follow gene ids are returned for each variant. When ignore.strand=TRUE the return strand is \* because genes on both strands are considered and it is possible to have a mixture. When ignore.strand=FALSE the strand will match the query because only genes on the same strand are considered.

Metadata columns are LOCATION, QUERYID, TXID, GENEID, PRECEDEID, FOLLOWID and CDSID. Results are ordered by QUERYID, TXID and GENEID. Columns are described in detail below.

**LOCATION** Possible locations are 'coding', 'intron', 'threeUTR', 'fiveUTR', 'intergenic', 'splice-Site' and 'promoter'.

To be classified as 'coding', 'intron', 'threeUTR' or 'fiveUTR' the variant must fall completely within the region.

'intergenic' variants do not fall within a transcript. The 'GENEID' for these positions are NA. Lists of flanking genes that fall within the distance defined by upstream and downstream are given as 'PRECEDEID' and 'FOLLOWID'.

A 'spliceSite' variant overlaps any portion of the first 2 or last 2 nucleotides of an intron.

**LOCSTART, LOCEND** Genomic position in LOCATION-centric coordinates. If LOCATION is 'intron', these are intron-centric coordinates, if LOCATION is 'coding' then cds-centric. All coordinates are relative to the start of the transcript. SpliceSiteVariants, IntergenicVariants and

PromoterVariants have no formal extraction ‘by transcript’ so for these variants LOCSTART and LOCEND are NA. Coordinates are computed with mapToTranscripts; see ?mapToTranscripts in the GenomicFeatures package for details.

QUERYID The QUERYID column provides a map back to the row in the original query. If the query was a VCF object this index corresponds to the row in the GRanges object returned by the rowRanges accessor.

TXID The transcript id taken from the TxDb object.

CDSID The coding sequence id(s) taken from the TxDb object.

GENEID The gene id taken from the TxDb object.

PRECEDEID IDs for all genes the query precedes within the defined upstream and downstream distance. Only applicable for ‘intergenic’ variants.

FOLLOWID IDs for all genes the query follows within the defined upstream and downstream distance. Only applicable for ‘intergenic’ variants.

All ID values will be ‘NA’ for variants with a location of transcript\_region or NA.

### Author(s)

Valerie Obenchain

### See Also

- The [readVcf](#) function.
- The [predictCoding](#) function.
- The promoters function on the [intra-range-methods](#) man page in the GenomicRanges package.

### Examples

```
library(TxDb.Hsapiens.UCSC.hg19.knownGene)
txdb <- TxDb.Hsapiens.UCSC.hg19.knownGene

## -----
## Variants in all gene regions
## -----
## Read variants from a VCF file.
fl <- system.file("extdata", "gl_chr1.vcf",
                  package="VariantAnnotation")
vcf <- readVcf(fl, "hg19")

## Often the seqlevels in the VCF file do not match those in the TxDb.
head(seqlevels(vcf))
head(seqlevels(txdb))
intersect(seqlevels(vcf), seqlevels(txdb))

## Rename seqlevels with renameSeqlevels().
vcf <- renameSeqlevels(vcf, paste0("chr", seqlevels(vcf)))

## Confirm.
intersect(seqlevels(vcf), seqlevels(txdb))
```

```

## Overlaps for all possible variant locations.
loc_all <- locateVariants(vcf, txdb, AllVariants())
table(loc_all$LOCATION)

## -----
## Variants in intergenic regions
## -----
## Intergenic variants do not overlap a gene range in the
## annotation and therefore 'GENEID' is always NA. Flanking genes
## that fall within the 'upstream' and 'downstream' distances are
## reported as PRECEDEID and FOLLOWID.
region <- IntergenicVariants(upstream=70000, downstream=70000)
loc_int <- locateVariants(vcf, txdb, region)
mcols(loc_int)[c("LOCATION", "PRECEDEID", "FOLLOWID")]

## Distance to the flanking genes can be computed for variants that
## have PRECEDEID(s) or FOLLOWID(s). Each variant can have multiple
## flanking id's so we first expand PRECEDEID and the corresponding
## variant ranges.
p_ids <- unlist(loc_int$PRECEDEID, use.names=FALSE)
exp_ranges <- rep(loc_int, elementLengths(loc_int$PRECEDEID))

## Provide the variant GRanges as 'x' and the TxDb annotation as 'y'
## to distance(). The 'id' and 'type' arguments describe an id found
## in the TxDb. See the '?nearest-methods' man page in GenomicFeatures
## for details.
p_dist <- distance(exp_ranges, txdb, id=p_ids, type="gene")
head(p_dist)

## Expanded view of ranges, gene id and distance:
exp_ranges$PRECEDE_DIST <- p_dist
exp_ranges

## Collapsed view of ranges, gene id and distance:
loc_int$PRECEDE_DIST <- relist(p_dist, loc_int$PRECEDEID)
loc_int

## -----
## GRangesList as subject
## -----
## When 'subject' is a GRangesList the GENEID is unavailable and
## will always be reported as NA. This is because the GRangesList
## objects are extractions of region-by-transcript, not region-by-gene.
## Not run:
cdsbytx <- cdsBy(txdb)
locateVariants(vcf, cdsbytx, CodingVariants())

intbytx <- intronsByTranscript(txdb)
locateVariants(vcf, intbytx, IntronVariants())

## End(Not run)

```



```

## -----
## Using the cache
## -----
## When processing multiple VCF files, the 'cache' can be used
## to store the extracted components of the TxDb
## (i.e., cds by tx, introns by tx etc.). This avoids having to
## re-extract these GRangesLists during each loop.
## Not run:
myenv <- new.env()
files <- list(vcf1, vcf2, vcf3)
lapply(files,
  function(fl) {
    vcf <- readVcf(fl, "hg19")
    ## modify seqlevels to match TxDb
    seqlevels(vcf_mod) <- paste0("chr", seqlevels(vcf))
    locateVariants(vcf_mod, txdb, AllVariants(), cache=myenv)
  })

## End(Not run)

## -----
## Parallel implmentation
## -----
## Not run:
library(BiocParallel)

## A connection to a TxDb object is established when
## the package is loaded. Because each process reading from an
## sqlite db must have a unique connection the TxDb
## object cannot be passed as an argument when running in
## parallel. Instead the package must be loaded on each worker.

## The overhead of the multiple loading may defeat the
## purpose of running the job in parallel. An alternative is
## to instead pass the appropriate GRangesList as an argument.
## The details section on this man page under the heading
## 'Subject as GRangesList' explains what GRangesList is
## appropriate for each variant type.

## A. Passing a GRangesList:

fun <- function(x, subject, ...)
  locateVariants(x, subject, IntronVariants())

library(TxDb.Hsapiens.UCSC.hg19.knownGene)
grl <- intronsByTranscript(TxDb.Hsapiens.UCSC.hg19.knownGene)
mclapply(c(vcf, vcf), fun, subject=grl)

## B. Passing a TxDb:

## Forking:
## In the case of forking, the TxDb cannot be loaded

```

```

## in the current workspace.
## To detach the NAMESPACE:
##   unloadNamespace("TxDb.Hsapiens.UCSC.hg19.knownGene")

fun <- function(x) {
  library(TxDb.Hsapiens.UCSC.hg19.knownGene)
  locateVariants(x, TxDb.Hsapiens.UCSC.hg19.knownGene,
                 IntronVariants())
}
mclapply(c(vcf, vcf), fun)

## Clusters:
cl <- makeCluster(2, type = "SOCK")
fun <- function(query, subject, region) {
  library(VariantAnnotation)
  library(TxDb.Hsapiens.UCSC.hg19.knownGene)
  locateVariants(query, TxDb.Hsapiens.UCSC.hg19.knownGene, region)
}
parLapply(cl, c(vcf, vcf), fun, region=IntronVariants())
stopCluster(cl)

## End(Not run)

```

---

PolyPhenDb-class

*PolyPhenDb objects*


---

## Description

The PolyPhenDb class is a container for storing a connection to a PolyPhen sqlite database.

## Details

PolyPhen (Polymorphism Phenotyping) is a tool which predicts the possible impact of an amino acid substitution on the structure and function of a human protein by applying empirical rules to the sequence, phylogenetic and structural information characterizing the substitution.

PolyPhen makes its predictions using UniProt features, PSIC profiles scores derived from multiple alignment and matches to PDP or PQS structural databases. The procedure can be roughly outlined in the following steps, see the references for complete details,

- sequence-based characterization of substitution site
- calculation of PSIC profile scores for two amino acid variants
- calculation of structural parameters and contacts
- prediction

PolyPhen uses empirically derived rules to predict that a non-synonymous SNP is

- probably damaging : it is with high confidence supposed to affect protein function or structure
- possibly damaging : it is supposed to affect protein function or structure

- benign : most likely lacking any phenotypic effect
- unknown : when in some rare cases, the lack of data do not allow PolyPhen to make a prediction

## Methods

In the code below, x is a PolyPhenDb object.

`metadata(x)`: Returns x's metadata in a data frame.

`columns(x)`: Returns the names of the columns that can be used to subset the data columns. For column descriptions see `?PolyPhenDbColumns`.

`keys(x)`: Returns the names of the keys that can be used to subset the data rows. The keys values are the rsid's.

`select(x, keys = NULL, columns = NULL, ...)`: Returns a subset of data defined by the character vectors `keys` and `columns`. If no keys are supplied, all rows are returned. If no columns are supplied, all columns are returned. See `?PolyPhenDbColumns` for column descriptions.

`duplicateRSID(x)`: Returns a named list of duplicate rsid groups. The names are the keys, the list elements are the rsid's that have been reported as having identical chromosome position and alleles and therefore translating into the same amino acid residue substitution.

## Author(s)

Valerie Obenchain

## References

PolyPhen Home: <http://genetics.bwh.harvard.edu/pph2/dokuwiki/>

Adzhubei IA, Schmidt S, Peshkin L, Ramensky VE, Gerasimova A, Bork P, Kondrashov AS, Sunyaev SR. Nat Methods 7(4):248-249 (2010).

Ramensky V, Bork P, Sunyaev S. Human non-synonymous SNPs: server and survey. Nucleic Acids Res 30(17):3894-3900 (2002).

Sunyaev SR, Eisenhaber F, Rodchenkov IV, Eisenhaber B, Tumanyan VG, Kuznetsov EN. PSIC: profile extraction from sequence alignments with position-specific counts of independent observations. Protein Eng 12(5):387-394 (1999).

## See Also

`?PolyPhenDbColumns`

## Examples

```
library(PolyPhen.Hsapiens.dbSNP131)

## metadata
metadata(PolyPhen.Hsapiens.dbSNP131)

## available rsid's
```

```

head(keys(PolyPhen.Hsapiens.dbSNP131))

## column descriptions found at ?PolyPhenDbColumns
columns(PolyPhen.Hsapiens.dbSNP131)

## subset on keys and columns
subst <- c("AA1", "AA2", "PREDICTION")
rsids <- c("rs2142947", "rs4995127", "rs3026284")
select(PolyPhen.Hsapiens.dbSNP131, keys=rsids, columns=subst)

## retrieve substitution scores
subst <- c("IDPMAX", "IDPSNP", "IDQMIN")
select(PolyPhen.Hsapiens.dbSNP131, keys=rsids, columns=subst)

## retrieve the PolyPhen-2 classifiers
subst <- c("PPH2CLASS", "PPH2PROB", "PPH2FPR", "PPH2TPR", "PPH2FDR")
select(PolyPhen.Hsapiens.dbSNP131, keys=rsids, columns=subst)

## duplicate groups of rsid's
duplicateRSID(PolyPhen.Hsapiens.dbSNP131, c("rs71225486", "rs1063796"))

```

---

PolyPhenDbColumns

*PolyPhenDb Columns*

---

## Description

Description of the PolyPhen Sqlite Database Columns

### Column descriptions

These column names are displayed when columns is called on a PolyPhenDb object.

- rsid : rsid

Original query :

- OSNPID : original SNP identifier from user input
- OSNPACC : original protein identifier from user input
- OPOS : original substitution position in the protein sequence from user input
- OAA1 : original wild type (reference) aa residue from user input
- OAA2 : original mutant (reference) aa residue from user input

Mapped query :

- SNPID : SNP identifier mapped to dbSNP rsID if available, otherwise same as o\_snp\_id. This value was used as the rsid column
- ACC : protein UniProtKB accession if known protein, otherwise same as o\_acc

- POS : substitution position mapped to UniProtKB protein sequence if known, otherwise same as o\_pos
- AA1 : wild type aa residue
- AA2 : mutant aa residue
- NT1 : wild type allele nucleotide
- NT2 : mutant allele nucleotide

PolyPhen-2 prediction :

- PREDICTION : qualitative ternary classification FPR thresholds

PolyPhen-1 prediction :

- BASEDON : prediction basis
- EFFECT : predicted substitution effect on the protein structure or function

PolyPhen-2 classifiers :

- PPH2CLASS : binary classifier outcome ("damaging" or "neutral")
- PPH2PROB : probability of the variation being damaging
- PPH2FPR : false positive rate at the pph2\_prob level
- PPH2TPR : true positive rate at the pph2\_prob level
- PPH2FDR : false discovery rate at the pph2\_prob level

UniProtKB-SwissProt derived protein sequence annotations :

- SITE : substitution SITE annotation
- REGION : substitution REGION annotation
- PHAT : PHAT matrix element for substitution in the TRANSMEM region

Multiple sequence alignment scores :

- DSCORE : difference of PSIC scores for two aa variants (Score1 - Score2)
- SCORE1 : PSIC score for wild type aa residue (aa1)
- SCORE2 : PSIC score for mutant aa residue (aa2)
- NOBS : number of residues observed at the substitution position in the multiple alignment (sans gaps)

Protein 3D structure features :

- NSTRUCT : initial number of BLAST hits to similar proteins with 3D structures in PDB
- NFILT : number of 3D BLAST hits after identity threshold filtering
- PDBID : protein structure identifier from PDB
- PDBPOS : position of substitution in PDB protein sequence
- PDBCH : PDB polypeptide chain identifier
- IDENT : sequence identity between query and aligned PDB sequences
- LENGTH : PDB sequence alignment length

- NORMACC : normalized accessible surface
- SECSTR : DSSP secondary structure assignment
- MAPREG : region of the phi-psi (Ramachandran) map derived from the residue dihedral angles
- DVOL : change in residue side chain volume
- DPROP : change in solvent accessible surface propensity resulting from the substitution
- BFACT : normalized B-factor (temperature factor) for the residue
- HBONDS : number of hydrogen sidechain-sidechain and sidechain-mainchain bonds formed by the residue
- AVENHET : average number of contacts with heteroatoms per residue
- MINDHET : closest contact with heteroatom
- AVENINT : average number of contacts with other chains per residue
- MINDINT : closest contact with other chain
- AVENSIT : average number of contacts with critical sites per residue
- MINDSIT : closest contact with a critical site

Nucleotide sequence features (CpG/codon/exon junction) :

- TRANSV : whether substitution is a transversion
- CODPOS : position of the substitution within the codon
- CPG : whether or not the substitution changes CpG context
- MINDJNC : substitution distance from exon/intron junction

Pfam protein family :

- PFAMHIT : Pfam identifier of the query protein

Substitution scores :

- IDPMAX : maximum congruency of the mutant aa residue to all sequences in multiple alignment
- IDPSNP : maximum congruency of the mutant aa residue to the sequence in alignment with the mutant residue
- IDQMIN : query sequence identity with the closest homologue deviating from the wild type aa residue

Comments :

- COMMENTS : Optional user comments

### **Author(s)**

Valerie Obenchain

### **See Also**

?PolyPhenDb

---

predictCoding	<i>Predict amino acid coding changes for variants</i>
---------------	---

---

## Description

Predict amino acid coding changes for variants a coding regions

## Usage

```
## S4 method for signature 'CollapsedVCF,TxDb,ANY,missing'
predictCoding(query, subject, seqSource, varAllele, ..., ignore.strand=FALSE)
## S4 method for signature 'ExpandedVCF,TxDb,ANY,missing'
predictCoding(query, subject, seqSource, varAllele, ..., ignore.strand=FALSE)
## S4 method for signature 'Ranges,TxDb,ANY,DNAStringSet'
predictCoding(query, subject, seqSource, varAllele, ..., ignore.strand=FALSE)
## S4 method for signature 'GRanges,TxDb,ANY,DNAStringSet'
predictCoding(query, subject, seqSource, varAllele, ..., ignore.strand=FALSE)
## S4 method for signature 'VRanges,TxDb,ANY,missing'
predictCoding(query, subject, seqSource, varAllele, ..., ignore.strand=FALSE)
```

## Arguments

query	<p>A <a href="#">VCF</a>, <a href="#">Ranges</a>, <a href="#">GRanges</a> or <a href="#">VRanges</a> instance containing the variants to be annotated. If query is a <a href="#">Ranges</a> or <a href="#">VRanges</a> it is coerced to a <a href="#">GRanges</a>. If a <a href="#">VCF</a> is provided the <a href="#">GRanges</a> returned by the <code>rowRanges()</code> accessor will be used. All metadata columns are ignored.</p> <p>When query is not a VCF object a <code>varAllele</code> must be provided. The <code>varAllele</code> must be a <a href="#">DNAStringSet</a> the same length as the query. If there are multiple alternate alleles per variant the query must be expanded to one row per each alternate allele. See examples.</p> <p>NOTE: Variants are expected to conform to the VCF specs as described on the 1000 Genomes page (see references). Indels must include the reference allele; zero-width ranges are not valid and return no matches.</p>
subject	A <a href="#">TxDb</a> object that serves as the annotation. GFF files can be converted to <a href="#">TxDb</a> objects with <code>makeTxDbFromGFF()</code> in the <a href="#">GenomicFeatures</a> package.
seqSource	A <a href="#">BSgenome</a> instance or an <a href="#">FaFile</a> to be used for sequence extraction.
varAllele	<p>A <a href="#">DNAStringSet</a> containing the variant (alternate) alleles. The length of <code>varAllele</code> must equal the length of query. Missing values are represented by a zero width empty element. Ranges with missing <code>varAllele</code> values are ignored; those with an 'N' character are not translated.</p> <p>When the query is a VCF object the <code>varAllele</code> argument will be missing. This value is taken internally from the VCF with <code>alt(&lt;VCF&gt;)</code>.</p>
...	Additional arguments passed to methods. Arguments <code>genetic.code</code> and <code>if.fuzzy.codon</code> are supported for the <code>translate</code> function.

`ignore.strand` A logical indicating if strand should be ignored when performing overlaps. When `ignore.strand == TRUE` the query strand is set to '\*' and can overlap with any strand of the subject. The return GRanges reflects the strand of the subject hit, however, the positions and alleles reported are computed as if both were from the '+' strand.

`ignore.strand == FALSE` requires the query and subject to have compatible strand. Again the return GRanges reports the strand of the subject hit but in this case positions and alleles are computed according to the strand of the subject.

## Details

This function returns the amino acid coding for variants that fall completely 'within' a coding region. The reference sequences are taken from a fasta file or [BSgenome](#). The width of the reference is determined from the start position and width of the range in the query. For guidance on how to represent an insertion, deletion or substitution see the 1000 Genomes VCF format (references).

Variant alleles are taken from the `varAllele` when supplied. When the query is a VCF object the `varAllele` will be missing. This value is taken internally from the VCF with `alt(<VCF>)`. The variant allele is substituted into the reference sequences and transcribed. Transcription only occurs if the substitution, insertion or deletion results in a new sequence length divisible by 3.

When the query is an unstranded (\*) GRanges `predictCoding` will attempt to find overlaps on both the positive and negative strands of the subject. When the subject hit is on the negative strand the return `varAllele` is reverse complemented. The strand of the returned GRanges represents the strand of the subject hit.

## Value

A [GRanges](#) with a row for each variant-transcript match. The result includes only variants that fell within coding regions. The strand of the output GRanges represents the strand of the subject hit.

At a minimum, the metadata columns (accessible with `mcols`) include,

`varAllele` Variant allele. This value is reverse complemented for an unstranded query that overlaps a subject on the negative strand.

`QUERYID` Map back to the row in the original query

`TXID` Internal transcript id from the annotation

`CDSID` Internal coding region id from the annotation

`GENEID` Internal gene id from the annotation

`CDSLLOC` Variant location in coding region-based coordinates. This position is relative to the start of the coding (cds) region defined in the subject annotation.

`PROTEINLOC` Variant codon triplet location in coding region-based coordinates. This position is relative to the start of the coding (cds) region defined in the subject annotation.

`CONSEQUENCE` Possible values are 'synonymous', 'nonsynonymous', 'frameshift', 'nonsense' and 'not translated'. Variant sequences are translated only when the codon sequence is a multiple of 3. The value will be 'frameshift' when a sequence is of incompatible length. 'not translated' is used when `varAllele` is missing or there is an 'N' in the sequence. 'nonsense' is used for premature stop codons.



**REFCODON** The reference codon sequence. This range is typically greater than the width of the range in the GRanges because it includes all codons involved in the sequence modification. If the reference sequence is of width 2 but the alternate allele is of width 4 then at least two codons must be included in the REFSEQ.

**VARCODON** This sequence is the result of inserting, deleting or replacing the position(s) in the reference sequence alternate allele. If the result of this substitution is not a multiple of 3 it will not be translated.

**REFAA** The reference amino acid column contains the translated REFSEQ. When translation is not possible this value is missing.

**VARAA** The variant amino acid column contains the translated VARSEQ. When translation is not possible this value is missing.

### Author(s)

Michael Lawrence and Valerie Obenchain

### References

<http://www.1000genomes.org/wiki/analysis/variant-call-format/> <http://vcftools.sourceforge.net/specs.html>

### See Also

[readVcf](#), [locateVariants](#), [refLocsToLocalLocs](#) [getTranscriptSeqs](#)

### Examples

```
library(BSgenome.Hsapiens.UCSC.hg19)
library(TxDb.Hsapiens.UCSC.hg19.knownGene)
txdb <- TxDb.Hsapiens.UCSC.hg19.knownGene

## -----
## VCF object as query
## -----
## Read variants from a VCF file
fl <- system.file("extdata", "chr22.vcf.gz", package="VariantAnnotation")
vcf <- readVcf(fl, "hg19")

## Rename seqlevels in the VCF object to match those in the TxDb.
vcf <- renameSeqlevels(vcf, "chr22")
## Confirm common seqlevels
intersect(seqlevels(vcf), seqlevels(txdb))

## When 'query' is a VCF object the varAllele argument is missing.
coding1 <- predictCoding(vcf, txdb, Hsapiens)
head(coding1, 3)

## Exon-centric or cDNA locations:
exonsbytx <- exonsBy(txdb, "tx")
cDNA <- mapToTranscripts(coding1[!duplicated(ranges(coding1))], exonsbytx)
```

```

coding1$cDNA <- ranges(cDNA)[togroup(coding1$QUERYID)]

## -----
## GRanges object as query
## -----
## A GRanges can also be used as the 'query'. The seqlevels in the VCF
## were adjusted in previous example so the GRanges extracted with
## has the correct seqlevels.
rd <- rowRanges(vcf)

## The GRanges must be expanded to have one row per alternate allele.
## Variants 1, 2 and 10 have two alternate alleles.
altallele <- alt(vcf)
eltlen <- elementLengths(altallele)
rd_exp <- rep(rd, eltlen)

## Call predictCoding() with the expanded GRanges and the unlisted
## alternate allele as the 'varAllele'.
coding2 <- predictCoding(rd_exp, txdb, Hsapiens, unlist(altallele))

```

---

probabilityToSnpMatrix

*Convert posterior genotype probability to a SnpMatrix object*

---

## Description

Convert a matrix of posterior genotype probabilities  $P(AA)$ ,  $P(AB)$ ,  $P(BB)$  to a [SnpMatrix](#).

## Usage

```
probabilityToSnpMatrix(probs)
```

## Arguments

**probs** Matrix with three columns for the posterior probabilities of the three genotypes: "P(A/A)", "P(A/B)", "P(B/B)". Each row must sum to 1.

## Details

probabilityToSnpMatrix converts a matrix of posterior probabilities of genotype calls into a [SnpMatrix](#).

## Value

An object of class "SnpMatrix" with one row (one sample). Posterior probabilities are encoded (approximately) as byte values, one per SNP. See the help page for [SnpMatrix](#) for complete details of the class structure.

**Author(s)**

Stephanie Gogarten <sdmorris@u.washington.edu>

**See Also**

[genotypeToSnpMatrix](#), [SnpMatrix](#)

**Examples**

```
probs <- matrix(c(1,0,0,
                 0,1,0,
                 0,0,1,
                 NA,NA,NA),
               ncol=3, byrow=TRUE,
               dimnames=list(1:4,c("A/A","A/B","B/B")))
sm <- probabilityToSnpMatrix(probs)
as(sm, "character")
```

---

PROVEANdb-class

*PROVEANdb objects*

---

**Description**

The PROVEANdb class is a container for storing a connection to a PROVEAN sqlite database.

**Details**

The SIFT tool is no longer actively maintained. A few of the original authors have started the PROVEAN (Protein Variation Effect Analyzer) project. PROVEAN is a software tool which predicts whether an amino acid substitution or indel has an impact on the biological function of a protein. PROVEAN is useful for filtering sequence variants to identify nonsynonymous or indel variants that are predicted to be functionally important.

See the web pages for a complete description of the methods.

- PROVEAN Home: <http://provean.jcvi.org/index.php/>
- SIFT Home: <http://sift.jcvi.org/>

Though SIFT is not under active development, the PROVEAN team still provides the SIFT scores in the pre-computed downloads. This package, `SIFT.Hsapiens.dbSNP137`, contains both SIFT and PROVEAN scores. One notable difference between this and the previous SIFT database package is that keys in `SIFT.Hsapiens.dbSNP132` are rs IDs whereas in `SIFT.Hsapiens.dbSNP137` they are NCBI dbSNP IDs.

## Methods

In the code below, `x` is a PROVEANdb object.

`metadata(x)`: Returns `x`'s metadata in a data frame.

`columns(x)`: Returns the names of the columns that can be used to subset the data columns.

`keys(x, keytype="DBSNPID", ...)`: Returns the names of the keys that can be used to subset the data rows. For SIFT.Hsapiens.dbSNP137 the keys are NCBI dbSNP ids.

`keytypes(x)`: Returns the names of the columns that can be used as keys. For SIFT.Hsapiens.dbSNP137 the NCBI dbSNP ids are the only keytype.

`select(x, keys = NULL, columns = NULL, keytype = "DBSNPID", ...)`: Returns a subset of data defined by the character vectors `keys` and `columns`. If no keys are supplied, all rows are returned. If no columns are supplied, all columns are returned.

## Author(s)

Valerie Obenchain

## References

The PROVEAN tool has replaced SIFT: <http://provean.jcvi.org/about.php>

Choi Y, Sims GE, Murphy S, Miller JR, Chan AP (2012) Predicting the Functional Effect of Amino Acid Substitutions and Indels. PLoS ONE 7(10): e46688.

Choi Y (2012) A Fast Computation of Pairwise Sequence Alignment Scores Between a Protein and a Set of Single-Locus Variants of Another Protein. In Proceedings of the ACM Conference on Bioinformatics, Computational Biology and Biomedicine (BCB '12). ACM, New York, NY, USA, 414-417.

Kumar P, Henikoff S, Ng PC. Predicting the effects of coding non-synonymous variants on protein function using the SIFT algorithm. Nat Protoc. 2009;4(7):1073-81

Ng PC, Henikoff S. Predicting the Effects of Amino Acid Substitutions on Protein Function Annu Rev Genomics Hum Genet. 2006;7:61-80.

Ng PC, Henikoff S. SIFT: predicting amino acid changes that affect protein function. Nucleic Acids Res. 2003 Jul 1;31(13):3812-4.

## Examples

```
if (require(SIFT.Hsapiens.dbSNP137)) {
  ## metadata
  metadata(SIFT.Hsapiens.dbSNP137)

  ## keys are the DBSNPID (NCBI dbSNP ID)
  dbsnp <- keys(SIFT.Hsapiens.dbSNP137)
  head(dbsnp)
  columns(SIFT.Hsapiens.dbSNP137)

  ## Return all columns. Note that the key, DBSNPID,
  ## is always returned.
  select(SIFT.Hsapiens.dbSNP137, dbsnp[10])
}
```

```

## subset on keys and cols
cols <- c("VARIANT", "PROVEANPRED", "SIFTAPRED")
select(SIFT.Hsapiens.dbSNP137, dbsnp[20:23], cols)
}

```

---

readVcf	<i>Read VCF files</i>
---------	-----------------------

---

## Description

Read Variant Call Format (VCF) files

## Usage

```

## S4 method for signature 'TabixFile,ANY,ScanVcfParam'
readVcf(file, genome, param,
        ..., row.names=TRUE)
## S4 method for signature 'TabixFile,ANY,RangedData'
readVcf(file, genome, param,
        ..., row.names=TRUE)
## S4 method for signature 'TabixFile,ANY,RangesList'
readVcf(file, genome, param,
        ..., row.names=TRUE)
## S4 method for signature 'TabixFile,ANY,GRanges'
readVcf(file, genome, param,
        ..., row.names=TRUE)
## S4 method for signature 'TabixFile,ANY,GRangesList'
readVcf(file, genome, param,
        ..., row.names=TRUE)
## S4 method for signature 'TabixFile,ANY,missing'
readVcf(file, genome, param,
        ..., row.names=TRUE)
## S4 method for signature 'character,ANY,ANY'
readVcf(file, genome, param,
        ..., row.names=TRUE)
## S4 method for signature 'character,ANY,missing'
readVcf(file, genome, param,
        ..., row.names=TRUE)
## S4 method for signature 'character,missing,missing'
readVcf(file, genome, param,
        ..., row.names=TRUE)

## Lightweight functions to read a single variable
readInfo(file, x, param=ScanVcfParam(), ..., row.names=TRUE)
readGeno(file, x, param=ScanVcfParam(), ..., row.names=TRUE)
readGT(file, nucleotides=FALSE, param=ScanVcfParam(), ..., row.names=TRUE)

```

**Arguments**

file	A <a href="#">TabixFile</a> instance or character() name of the VCF file to be processed. When ranges are specified in param, file must be a <a href="#">TabixFile</a> . Use of the <a href="#">TabixFile</a> methods are encouraged as they are more efficient than the character() methods. See ? <a href="#">TabixFile</a> and ? <a href="#">indexTabix</a> for help creating a <a href="#">TabixFile</a> .
genome	A character or Seqinfo object. <ul style="list-style-type: none"> <li>• character: Genome identifier as a single string or named character vector. Names of the character vector correspond to chromosome names in the file. This identifier replaces the genome information in the VCF Seqinfo (i.e., seqinfo(vcf)).</li> <li>• Seqinfo: When genome is provided as a Seqinfo it is propagated to the VCF output. If seqinfo information can be obtained from the file, (i.e., seqinfo(scanVcfHeader(fl)) is not empty), the output Seqinfo is a product of merging the two. If a param (i.e., ScanVcfParam) is used in the call to readVcf, the seqlevels of the param ranges must be present in genome.</li> </ul>
param	A instance of <a href="#">ScanVcfParam</a> , GRanges, GRangesList, RangedData or RangesList. VCF files can be subset on genomic coordinates (ranges) or elements in the VCF fields. Both genomic coordinates and VCF elements can be specified in a <a href="#">ScanVcfParam</a> . See ? <a href="#">ScanVcfParam</a> for details.
x	character name of single info or geno field to import. Applicable to readInfo and readGeno only.
row.names	A logical specifying if rownames should be returned. In the case of readVcf, rownames appear on the GRanges returned by the rowRanges accessor.
nucleotides	A logical indicating if genotypes should be returned as nucleotides instead of the numeric representation. Applicable to readGT only.
...	Additional arguments, passed to methods.

**Details**

**Data Import: VCF object:** readVcf imports records from bzip compressed or uncompressed VCF files. Data are parsed into a [VCF](#) object using the file header information if available. To import a subset of ranges the VCF must have a [Tabix](#) index file. An index file can be created with [bzip](#) and [indexTabix](#) functions.

The readInfo, readGeno and readGT functions are lightweight versions of readVcf and import a single variable. The return object is a vector, matrix or [CompressedList](#) instead of a [VCF](#) class.

readVcf calls [scanVcf](#), the details of which can be found with ?[scanVcf](#).

**Header lines (aka Meta-information):** readVcf() reads and parses fields according to the multiplicity and data type specified in the header lines. Fields without header lines are skipped (not read or parsed). To see what fields are present in the header use scanVcfHeader(). See ?[VCFHeader](#) for more details.

Passing verbose = TRUE to readVcf() prints the fields with header lines that will be parsed by readVcf.

**Data type:** CHROM, POS, ID and REF fields are used to create the GRanges stored in the VCF object and accessible with the rowRanges accessor.

REF, ALT, QUAL and FILTER are parsed into the DataFrame in the fixed slot. Because ALT can have more than one value per variant it is represented as a DNAStrngSetList. REF is a DNAStrngSet, QUAL is numeric and FILTER is a character. Accessors include fixed, ref, alt, qual, and filt.

Data from the INFO field can be accessed with the info accessor. Genotype data (i.e., data immediately following the FORMAT field in the VCF) can be accessed with the geno accessor. INFO and genotype data types are determined according to the 'Number' and 'Type' information in the file header as follows:

'Number' should only be 0 when 'Type' is 'flag'. These fields are parsed as logical vectors.

If 'Number' is 1, 'info' data are parsed into a vector and 'geno' into a matrix.

If 'Number' is >1, 'info' data are parsed into a DataFrame with the same number of columns. 'geno' are parsed into an array with the same dimensions as 'Number'. Columns of the 'geno' matrices are the samples.

If 'Number' is '.', 'A' or 'G', both 'info' and 'geno' data are parsed into a matrix.

When the header does not contain any 'INFO' lines, the data are returned as a single, unparsed column.

**Missing data:** Missing data in VCF files are represented by a dot ("."). readVcf retains the dot as a character string for data type character and converts it to NA for data types numeric or double.

Because the data are stored in rectangular data structures there is a value for each info and geno field element in the VCF class. If the element was missing or was not collected for a particular variant the value will be NA.

**Efficient Usage:** Subsets of data (i.e., specific variables, positions or samples) can be read from a VCF file by providing a ScanVcfParam object in the call to readVcf. Other lightweight options are the readGT, readInfo and readGeno functions which return data as a matrix instead of the VCF class.

Another option for handling large files is to iterate through the data in chunks by setting the yieldSize parameter in a TabixFile object. Iteration can be through all data fields or a subset defined by a ScanVcfParam. See example below, 'Iterating through VCF with yieldSize'.

## Value

readVcf returns a [VCF](#) object. See ?VCF for complete details of the class structure. readGT, readInfo and readGeno return a matrix.

**rowRanges:** The CHROM, POS, ID and REF fields are used to create a GRanges object. Ranges are created using POS as the start value and width of the reference allele (REF). The IDs become the rownames. If they are missing (i.e., '.') a string of CHROM:POS\_REF/ALT is used instead. The genome argument is stored in the seqinfo of the GRanges and can be accessed with genome(<VCF>).

One metadata column, paramRangeID, is included with the rowRanges. This ID is meaningful when multiple ranges are specified in the ScanVcfParam and distinguishes which records match each range.

**fixed:** REF, ALT, QUAL and FILTER fields of the VCF are parsed into a DataFrame.

REF is returned as a DNAStrngSet. ALT will be a character vector for structural variants and a DNAStrngSetList otherwise. '\*' characters are treated as missings and become an empty character in a DNAStrngSetList. 'I' characters are treated as undefined and become a '.' in a DNAStrngSetList.

**info:** Data from the INFO field of the VCF is parsed into a DataFrame.

**geno:** If present, the genotype data are parsed into a list of matrices or arrays. Each list element represents a field in the FORMAT column of the VCF file. Rows are the variants, columns are the samples.

**colData:** This slot contains a DataFrame describing the samples. If present, the sample names following FORMAT in the VCF file become the row names.

**metadata:** Header information present in the file is put into a list in metadata.

See references for complete details of the VCF file format.

### Author(s)

Valerie Obenchain>

### References

<http://vcftools.sourceforge.net/specs.html> outlines the VCF specification.

<http://samtools.sourceforge.net/mpileup.shtml> contains information on the portion of the specification implemented by bcftools.

<http://samtools.sourceforge.net/> provides information on samtools.

### See Also

[indexTabix](#), [TabixFile](#), [scanTabix](#), [scanBcf](#), [expand](#), [CollapsedVCF-method](#)

### Examples

```
f1 <- system.file("extdata", "ex2.vcf", package="VariantAnnotation")
vcf <- readVcf(f1, "hg19")
## vcf <- readVcf(f1, c("20"="hg19")) ## 'genome' as named vector

## -----
## Header and genome information
## -----
vcf

## all header information
hdr <- header(vcf)

## header information for 'info' and 'fixed' fields
info(hdr)
fixed(hdr)

## -----
## Accessors
```



```

## -----
## fixed fields together
head(fixed(vcf), 5)

## fixed fields separately
filt(vcf)
ref(vcf)

## info data
info(hdr)
info(vcf)
info(vcf)$DP

## geno data
geno(hdr)
geno(vcf)
head(geno(vcf)$GT)

## genome
unique(genome(rowRanges(vcf)))

## -----
## Data subsets with lightweight read* functions
## -----

## Import a single 'info' or 'geno' variable
DP <- readInfo(fl, "DP")
HQ <- readGeno(fl, "HQ")

## Import GT as numeric representation
GT <- readGT(fl)
## Import GT as nucleotides
GT <- readGT(fl, nucleotides=TRUE)

## -----
## Data subsets with ScanVcfParam
## -----

## Subset on genome coordinates:
## 'file' must have a Tabix index
rngs <- GRanges("20", IRanges(c(14370, 1110000), c(17330, 1234600)))
names(rngs) <- c("geneA", "geneB")
param <- ScanVcfParam(which=rngs)
compressVcf <- bgzip(fl, tempfile())
idx <- indexTabix(compressVcf, "vcf")
tab <- TabixFile(compressVcf, idx)
vcf <- readVcf(tab, "hg19", param)

## When data are subset by range ('which' argument in ScanVcfParam),
## the 'paramRangeID' column provides a map back to the original
## range in 'param'.
rowRanges(vcf)[,"paramRangeID"]
vcfWhich(param)

```

```

## Subset on samples:
## Consult the header for the sample names.
samples(hdr)
## Specify one or more names in 'samples' in a ScanVcfParam.
param <- ScanVcfParam(samples="NA00002")
vcf <- readVcf(tab, "hg19", param)
geno(vcf)$GT

## Subset on 'fixed', 'info' or 'geno' fields:
param <- ScanVcfParam(fixed="ALT", geno=c("GT", "HQ"), info=c("NS", "AF"))
vcf_tab <- readVcf(tab, "hg19", param)
info(vcf_tab)
geno(vcf_tab)

## No ranges are specified in the 'param' so tabix file is not
## required. Instead, the uncompressed VCF can be used as 'file'.
vcf_fname <- readVcf(fl, "hg19", param)

## The header will always contain information for all variables
## in the original file regardless of how the data were subset.
## For example, all 'geno' fields are listed in the header
geno(header(vcf_fname))

## but only 'GT' and 'HQ' are present in the VCF object.
geno(vcf_fname)

## Subset on both genome coordinates and 'info', 'geno' fields:
param <- ScanVcfParam(geno="HQ", info="AF", which=rngs)
vcf <- readVcf(tab, "hg19", param)

## When any of 'fixed', 'info' or 'geno' are omitted (i.e., no
## elements specified) all records are retrieved. Use NA to indicate
## that no records should be retrieved. This param specifies
## all 'fixed' fields, the "GT" 'geno' field and none of 'info'.
ScanVcfParam(geno="GT", info=NA)

## -----
## Iterate through VCF with 'yieldSize'
## -----
fl <- system.file("extdata", "chr22.vcf.gz", package="VariantAnnotation")
param <- ScanVcfParam(fixed="ALT", geno=c("GT", "GL"), info=c("LDAF"))
tab <- TabixFile(fl, yieldSize=4000)
open(tab)
while (nrow(vcf_yield <- readVcf(tab, "hg19", param=param)))
  cat("vcf dim:", dim(vcf_yield), "\n")
close(tab)

## -----
## Debugging with 'verbose'
## -----
## readVcf() uses information in the header lines to parse the data to
## the correct number and type. Fields without header lines are skipped.

```

```

## If a call to readVcf() results in no info(VCF) or geno(VCF) data the
## file may be missing header lines. Set 'verbose = TRUE' to get
## a listing of fields found in the header.

## readVcf(myfile, "mygenome", verbose=TRUE)

## Header fields can also be discovered with scanVcfHeader().
hdr <- scanVcfHeader(f1)
geno(hdr)

```

---

scanVcf

*Import VCF files*


---

## Description

Import Variant Call Format (VCF) files in text or binary format

## Usage

```

scanVcfHeader(file, ...)
## S4 method for signature 'character'
scanVcfHeader(file, ...)

scanVcf(file, ..., param)
## S4 method for signature 'character,ScanVcfParam'
scanVcf(file, ..., param)
## S4 method for signature 'character,missing'
scanVcf(file, ..., param)
## S4 method for signature 'connection,missing'
scanVcf(file, ..., param)

## S4 method for signature 'TabixFile'
scanVcfHeader(file, ...)
## S4 method for signature 'TabixFile,missing'
scanVcf(file, ..., param)
## S4 method for signature 'TabixFile,ScanVcfParam'
scanVcf(file, ..., param)
## S4 method for signature 'TabixFile,GRanges'
scanVcf(file, ..., param)
## S4 method for signature 'TabixFile,RangedData'
scanVcf(file, ..., param)
## S4 method for signature 'TabixFile,RangesList'
scanVcf(file, ..., param)

## S4 method for signature 'TabixFile'
scanVcfHeader(file, ...)
## S4 method for signature 'TabixFile,missing'
scanVcf(file, ..., param)

```

```
## S4 method for signature 'TabixFile,ScanVcfParam'
scanVcf(file, ..., param)
## S4 method for signature 'TabixFile,GRanges'
scanVcf(file, ..., param)
## S4 method for signature 'TabixFile,RangedData'
scanVcf(file, ..., param)
## S4 method for signature 'TabixFile,RangesList'
scanVcf(file, ..., param)
```

### Arguments

file	For scanVcf and scanVcfHeader, the character() file name, <a href="#">TabixFile</a> , or class connection (file() or bgzip()) of the ‘VCF’ file to be processed.
param	A instance of <a href="#">ScanVcfParam</a> influencing which records are parsed and the ‘INFO’ and ‘GENO’ information returned.
...	Additional arguments for methods

### Details

The argument param allows portions of the file to be input, but requires that the file be bgzip’d and indexed as a [TabixFile](#).

scanVcf with param="missing" and file="character" or file="connection" scan the entire file. With file="connection", an argument n indicates the number of lines of the VCF file to input; a connection open at the beginning of the call is open and incremented by n lines at the end of the call, providing a convenient way to stream through large VCF files.

The INFO field of the scanned VCF file is returned as a single ‘packed’ vector, as in the VCF file. The GENO field is a list of matrices, each matrix corresponds to a field as defined in the FORMAT field of the VCF header. Each matrix has as many rows as scanned in the VCF file, and as many columns as there are samples. As with the INFO field, the elements of the matrix are ‘packed’. The reason that INFO and GENO are returned packed is to facilitate manipulation, e.g., selecting particular rows or samples in a consistent manner across elements.

### Value

scanVcfHeader returns a VCFHeader object with header information parsed into five categories, samples, meta, fixed, info and geno. Each can be accessed with a ‘getter’ of the same name (e.g., info(<VCFHeader>)).

scanVcf returns a list, with one element per range. Each list has 7 elements, obtained from the columns of the VCF specification:

**rowRanges** GRanges instance derived from CHROM, POS, ID, and the width of REF

**REF** reference allele

**ALT** alternate allele

**QUAL** phred-scaled quality score for the assertion made in ALT

**FILTER** indicator of whether or not the position passed all filters applied

**INFO** additional information

**GENO** genotype information immediately following the FORMAT field in the VCF

The GENO element is itself a list, with elements corresponding to those defined in the VCF file header. For scanVcf, elements of GENO are returned as a matrix of records x samples; if the description of the element in the file header indicated multiplicity other than 1 (e.g., variable number for “A”, “G”, or “.”), then each entry in the matrix is a character string with sub-entries comma-delimited.

### Author(s)

Martin Morgan and Valerie Obenchain>

### References

<http://vcftools.sourceforge.net/specs.html> outlines the VCF specification.

<http://samtools.sourceforge.net/mpileup.shtml> contains information on the portion of the specification implemented by bcftools.

<http://samtools.sourceforge.net/> provides information on samtools.

### See Also

[readVcf BcfFile TabixFile](#)

### Examples

```
f1 <- system.file("extdata", "ex2.vcf", package="VariantAnnotation")
scanVcfHeader(f1)
vcf <- scanVcf(f1)
## value: list-of-lists
str(vcf)
names(vcf[[1]][["GENO"]])
vcf[[1]][["GENO"]][["GT"]]
```

---

ScanVcfParam-class      *Parameters for scanning VCF files*

---

### Description

Use ScanVcfParam() to create a parameter object influencing which records and fields are imported from a VCF file. Record parsing is based on genomic coordinates and requires a Tabix index file. Individual VCF elements can be specified in the ‘fixed’, ‘info’, ‘geno’ and ‘samples’ arguments.

**Usage**

```
ScanVcfParam(fixed=character(), info=character(), geno=character(),
             samples=character(), trimEmpty=TRUE, which, ...)
```

```
## Getters and Setters
```

```
vcfFixed(object)
vcfFixed(object) <- value
vcfInfo(object)
vcfInfo(object) <- value
vcfGeno(object)
vcfGeno(object) <- value
vcfSamples(object)
vcfSamples(object) <- value
vcfTrimEmpty(object)
vcfTrimEmpty(object) <- value
vcfWhich(object)
vcfWhich(object) <- value
```

**Arguments**

<code>fixed</code>	A <code>character()</code> vector of fixed fields to be returned. Possible values are ALT, QUAL and FILTER. The CHROM, POS, ID and REF fields are needed to create the GRanges of variant locations. Because these are essential fields there is no option to request or omit them. If not specified, all fields are returned; if <code>fixed=NA</code> only REF is returned.
<code>info</code>	A <code>character()</code> vector naming the 'INFO' fields to return. <code>scanVcfHeader()</code> returns a vector of available fields. If not specified, all fields are returned; if <code>info=NA</code> no fields are returned.
<code>geno</code>	A <code>character()</code> vector naming the 'GENO' fields to return. <code>scanVcfHeader()</code> returns a vector of available fields. If not specified, all fields are returned; if <code>geno=NA</code> no fields are returned and requests for specific samples are ignored.
<code>samples</code>	A <code>character()</code> vector of sample names to return. <code>samples(scanVcfHeader())</code> returns all possible names. If not specified, data for all samples are returned; if either <code>samples=NA</code> or <code>geno=NA</code> no fields are returned. Requests for specific samples when <code>geno=NA</code> are ignored.
<code>trimEmpty</code>	A <code>logical(1)</code> indicating whether 'GENO' fields with no values should be returned.
<code>which</code>	A <a href="#">GRanges</a> or <a href="#">RangedData</a> describing the sequences and ranges to be queried. Variants whose POS lies in the interval(s) [ <code>start</code> , <code>end</code> ] are returned. If <code>which</code> is not specified all ranges are returned.
<code>object</code>	An instance of class <code>ScanVcfParam</code> .
<code>value</code>	An instance of the corresponding slot, to be assigned to <code>object</code> .
<code>...</code>	Arguments passed to methods.

## Objects from the Class

Objects can be created by calls of the form `ScanVcfParam()`.

## Slots

**which:** Object of class "RangesList" indicating which reference sequence and coordinate variants must overlap.

**fixed:** Object of class "character" indicating fixed fields to be returned.

**info:** Object of class "character" indicating portions of 'INFO' to be returned.

**geno:** Object of class "character" indicating portions of 'GENO' to be returned.

**samples:** Object of class "character" indicating the samples to be returned.

**trimEmpty:** Object of class "logical" indicating whether empty 'GENO' fields are to be returned.

## Functions and methods

See 'Usage' for details on invocation.

Constructor:

**ScanVcfParam:** Returns a ScanVcfParam object. The which argument to the constructor can be one of several types, as documented above.

Accessors:

**vcfFixed, vcfInfo, vcfGeno, vcfSamples, vcfTrimEmpty, vcfWhich:** Return the corresponding field from object.

Methods:

**show** Compactly display the object.

## Author(s)

Martin Morgan and Valerie Obenchain

## See Also

[readVcf](#)

## Examples

```
ScanVcfParam()

fl <- system.file("extdata", "structural.vcf", package="VariantAnnotation")
compressVcf <- bgzip(fl, tempfile())
idx <- indexTabix(compressVcf, "vcf")
tab <- TabixFile(compressVcf, idx)
## -----
## 'which' argument
## -----
## To subset on genomic coordinates, supply an object
```

```

## containing the ranges of interest. These ranges can
## be given directly to the 'param' argument or wrapped
## inside ScanVcfParam() as the 'which' argument.

## When using a list, the outer list names must correspond to valid
## chromosome names in the vcf file. In this example they are "1"
## and "2".
gr1 <- GRanges("1", IRanges(13219, 2827695, name="regionA"))
gr2 <- GRanges(rep("2", 2), IRanges(c(321680, 14477080),
                                     c(321689, 14477090), name=c("regionB", "regionC")))
grl <- GRangesList("1"=gr1, "2"=gr2)
vcf <- readVcf(tab, "hg19", grl)

## Names of the ranges are in the 'paramRangeID' metadata column of the
## GRanges object returned by the rowRanges() accessor.
rowRanges(vcf)

## which can be used for subsetting the VCF object
vcf[rowRanges(vcf)$paramRangeID == "regionA"]

## When using ranges, the seqnames must correspond to valid
## chromosome names in the vcf file.
gr <- unlist(grl, use.names=FALSE)
vcf <- readVcf(tab, "hg19", gr)

## -----
## 'fixed', 'info', 'geno' and 'samples' arguments
## -----
## This param specifies the "GT" 'geno' field for a single sample
## and the subset of ranges in 'which'. All 'fixed' and 'info' fields
## will be returned.
ScanVcfParam(geno="GT", samples="NA00002", which=gr)

## Here two 'fixed' and one 'geno' field are specified
ScanVcfParam(fixed=c("ALT", "QUAL"), geno="GT", info=NA)

## Return only the 'fixed' fields
ScanVcfParam(geno=NA, info=NA)

```

---

SIFTDb-class

*SIFTDb objects*


---

## Description

The SIFTDb class is a container for storing a connection to a SIFT sqlite database.

## Details

SIFT is a sequence homology-based tool that sorts intolerant from tolerant amino acid substitutions and predicts whether an amino acid substitution in a protein will have a phenotypic effect. SIFT



is based on the premise that protein evolution is correlated with protein function. Positions important for function should be conserved in an alignment of the protein family, whereas unimportant positions should appear diverse in an alignment.

SIFT uses multiple alignment information to predict tolerated and deleterious substitutions for every position of the query sequence. The procedure can be outlined in the following steps,

- search for similar sequences
- choose closely related sequences that may share similar function to the query sequence
- obtain the alignment of the chosen sequences
- calculate normalized probabilities for all possible substitutions from the alignment.

Positions with normalized probabilities less than 0.05 are predicted to be deleterious, those greater than or equal to 0.05 are predicted to be tolerated.

## Methods

In the code below, `x` is a SIFTdb object.

`metadata(x)`: Returns `x`'s metadata in a data frame.

`columns(x)`: Returns the names of the columns that can be used to subset the data columns.

`keys(x)`: Returns the names of the keys that can be used to subset the data rows. The keys values are the rsid's.

`select(x, keys = NULL, columns = NULL, ...)`: Returns a subset of data defined by the character vectors `keys` and `columns`. If no keys are supplied, all rows are returned. If no columns are supplied, all columns are returned. For column descriptions see `?SIFTdbColumns`.

## Author(s)

Valerie Obenchain

## References

SIFT Home: <http://sift.jcvi.org/>

Kumar P, Henikoff S, Ng PC. Predicting the effects of coding non-synonymous variants on protein function using the SIFT algorithm. *Nat Protoc.* 2009;4(7):1073-81

Ng PC, Henikoff S. Predicting the Effects of Amino Acid Substitutions on Protein Function *Annu Rev Genomics Hum Genet.* 2006;7:61-80.

Ng PC, Henikoff S. SIFT: predicting amino acid changes that affect protein function. *Nucleic Acids Res.* 2003 Jul 1;31(13):3812-4.

## Examples

```
if (interactive()) {  
  library(SIFT.Hsapiens.dbSNP132)  
  
  ## metadata  
  metadata(SIFT.Hsapiens.dbSNP132)
```

```

## available rsid's
head(keys(SIFT.Hsapiens.dbSNP132))

## for column descriptions see ?SIFTDbColumns
columns(SIFT.Hsapiens.dbSNP132)

## subset on keys and columns
rsids <- c("rs2142947", "rs17970171", "rs8692231", "rs3026284")
subst <- c("RSID", "PREDICTION", "SCORE")
select(SIFT.Hsapiens.dbSNP132, keys=rsids, columns=subst)
select(SIFT.Hsapiens.dbSNP132, keys=rsids[1:2])
}

```

---

SIFTDbColumns

*SIFTDb Columns*


---

## Description

Description of the SIFT Sqlite Database Columns

## Column descriptions

These column names are displayed when columns is called on a SIFTDb object.

- RSID : rsid
- PROTEINID : NCBI RefSeq protein ID
- AACHANGE : amino acid substitution; reference aa is preceding, followed by the position and finally the snp aa
- METHOD : method of obtaining related sequences using PSI-BLAST
- AA : either the reference or snp residue amino acid
- PREDICTION : SIFT prediction
- SCORE : SIFT score (range 0 to 1)
  - TOLERATED : score is greater than 0.05
  - DAMAGING : score is less than or equal to 0.05
  - NOT SCORED : no prediction is made if there are less than 2 homologous sequences that have an amino acid at the position of the given SNP or if the SIFT prediction is not available
- MEDIAN : diversity measurement of the sequences used for prediction (range 0 to 4.32)
- POSITIONSEQS : number of sequences with an amino acid at the position of prediction
- TOTALSEQS : total number of sequences in alignment

## Author(s)

Valerie Obenchain

## See Also

?SIFTDb

---

`snpSummary`*Counts and distribution statistics for SNPs in a VCF object*

---

## Description

Counts and distribution statistics for SNPs in a VCF object

## Usage

```
## S4 method for signature 'CollapsedVCF'  
snpSummary(x, ...)
```

## Arguments

`x`                    A [CollapsedVCF](#) object.  
`...`                 Additional arguments to methods.

## Details

Genotype counts, allele counts and Hardy Weinberg equilibrium (HWE) statistics are calculated for single nucleotide variants in a [CollapsedVCF](#) object. HWE has been established as a useful quality filter on genotype data. This equilibrium should be attained in a single generation of random mating. Departures from HWE are indicated by small p values and are almost invariably indicative of a problem with genotype calls.

The following caveats apply:

- No distinction is made between phased and unphased genotypes.
- Only diploid calls are included.
- Only 'valid' SNPs are included. A 'valid' SNP is defined as having a reference allele of length 1 and a single alternate allele of length 1.

Variants that do not meet these criteria are set to NA.

## Value

The object returned is a `data.frame` with seven columns.

**g00** Counts for genotype 00 (homozygous reference).

**g01** Counts for genotype 01 or 10 (heterozygous).

**g11** Counts for genotype 11 (homozygous alternate).

**a0Freq** Frequency of the reference allele.

**a1Freq** Frequency of the alternate allele.

**HWEzscore** Z-score for departure from a null hypothesis of Hardy Weinberg equilibrium.

**HWEpvalue** p-value for departure from a null hypothesis of Hardy Weinberg equilibrium.

**Author(s)**

Chris Wallace <cew54@cam.ac.uk>

**See Also**

[genotypeToSnpMatrix](#), [probabilityToSnpMatrix](#)

**Examples**

```
f1 <- system.file("extdata", "ex2.vcf", package="VariantAnnotation")
vcf <- readVcf(f1, "hg19")

## The return value is a data.frame with genotype counts
## and allele frequencies.
df <- snpSummary(vcf)
df

## Compare to ranges in the VCF object:
rowRanges(vcf)

## No statistics were computed for the variants in rows 3, 4
## and 5. They were omitted because row 3 has two alternate
## alleles, row 4 has none and row 5 is not a SNP.
```

---

summarizeVariants	<i>Summarize variants by sample</i>
-------------------	-------------------------------------

---

**Description**

Variants in a VCF file are overlapped with an annotation region and summarized by sample. Genotype information in the VCF is used to determine which samples express each variant.

**Usage**

```
## S4 method for signature 'TxDb,VCF,CodingVariants'
summarizeVariants(query, subject, mode, ...)
## S4 method for signature 'TxDb,VCF,FiveUTRVariants'
summarizeVariants(query, subject, mode, ...)
## S4 method for signature 'TxDb,VCF,ThreeUTRVariants'
summarizeVariants(query, subject, mode, ...)
## S4 method for signature 'TxDb,VCF,SpliceSiteVariants'
summarizeVariants(query, subject, mode, ...)
## S4 method for signature 'TxDb,VCF,IntronVariants'
summarizeVariants(query, subject, mode, ...)
## S4 method for signature 'TxDb,VCF,PromoterVariants'
summarizeVariants(query, subject, mode, ...)
## S4 method for signature 'GRangesList,VCF,VariantType'
summarizeVariants(query, subject, mode, ...)
```

```
## S4 method for signature 'GRangesList,VCF,function'
summarizeVariants(query, subject, mode, ...)
```

### Arguments

query	A <a href="#">TxDb</a> or <code>GRangesList</code> object that serves as the annotation. GFF files can be converted to <a href="#">TxDb</a> objects with <code>makeTxDbFromGFF()</code> in the <code>GenomicFeatures</code> package.
subject	A <a href="#">VCF</a> object containing the variants.
mode	mode can be a <code>VariantType</code> class or the name of a function. When mode is a <code>VariantType</code> class, counting is done with <code>locateVariants</code> and counts are summarized transcript-by-sample. Supported <code>VariantType</code> classes include <code>CodingVariants</code> , <code>IntronVariants</code> , <code>FiveUTRVariants</code> , <code>ThreeUTRVariants</code> , <code>SpliceSiteVariants</code> or <code>PromoterVariants</code> . <code>AllVariants()</code> and <code>IntergenicVariants</code> are not supported. See <code>?locateVariants</code> for more detail on the variant classes. mode can also be the name of any counting function that outputs a <code>Hits</code> object. Variants will be summarized by the length of the <code>GRangesList</code> annotation (i.e., 'length-of-GRangesList'-by-sample).
...	Additional arguments passed to methods such as <b>ignore.strand</b> A logical indicating if strand should be ignored when performing overlaps.

### Details

`summarizeVariants` uses the genotype information in a VCF file to determine which samples are positive for each variant. Variants are overlapped with the annotation and the counts are summarized annotation-by-sample. If the annotation is a `GRangesList` of transcripts, the count matrix will be transcripts-by-sample. If the `GRangesList` is genes, the count matrix will be gene-by-sample.

- Counting with `locateVariants()` :  
Variant counts are always summarized transcript-by-sample. When `query` is a `GRangesList`, it must be compatible with the `VariantType`-class given as the `mode` argument. The list below specifies the appropriate `GRangesList` for each mode.  
**CodingVariants** : coding (CDS) by transcript  
**IntronVariants** : introns by transcript  
**FiveUTRVariants** : five prime UTR by transcript  
**ThreeUTRVariants** : three prime UTR by transcript  
**SpliceSiteVariants** : introns by transcript  
**PromoterVariants** : list of transcripts  
When `query` is a `TxDb`, the appropriate region-by-transcript `GRangesList` listed above is extracted internally and used as the annotation.
- Counting with a user-supplied function :  
`subject` must be a `GRangesList` and `mode` must be the name of a function. The count function must take 'query' and 'subject' arguments and return a `Hits` object. Counts are summarized by the outer list elements of the `GRangesList`.

**Value**

A RangedSummarizedExperiment object with count summaries in the assays slot. The rowRanges contains the annotation used for counting. Information in colData and metadata are taken from the VCF file.

**Author(s)**

Valerie Obenchain

**See Also**

[readVcf](#), [predictCoding](#) [locateVariants](#) [summarizeVariants](#),

**Examples**

```
library(TxDb.Hsapiens.UCSC.hg19.knownGene)
txdb <- TxDb.Hsapiens.UCSC.hg19.knownGene

## Read variants from VCF.
f1 <- system.file("extdata", "chr22.vcf.gz", package="VariantAnnotation")
vcf <- readVcf(f1, "hg19")
## Rename seqlevels to match TxDb; confirm the match.
seqlevels(vcf) <- paste0("chr", seqlevels(vcf))
intersect(seqlevels(vcf), seqlevels(txdb))

## -----
## Counting with locateVariants()
## -----
## TxDb as the 'query'
coding1 <- summarizeVariants(txdb, vcf, CodingVariants())
colSums(assays(coding1)$counts)

## GRangesList as the 'query'
cdsbytx <- cdsBy(txdb, "tx")
coding2 <- summarizeVariants(cdsbytx, vcf, CodingVariants())

stopifnot(identical(assays(coding1)$counts, assays(coding2)$counts))

## Promoter region variants summarized by transcript
tx <- transcripts(txdb)
txlst <- splitAsList(tx, seq_len(length(tx)))
promoter <- summarizeVariants(txlst, vcf,
                             PromoterVariants(upstream=100, downstream=10))
colSums(assays(promoter)$counts)

## -----
## Counting with findOverlaps()
## -----

## Summarize all variants by transcript
allvariants <- summarizeVariants(txlst, vcf, findOverlaps)
colSums(assays(allvariants)$counts)
```

---

VariantAnnotation-defunct

*Defunct Functions in Package VariantAnnotation*

---

## Description

The functions or variables listed here are no longer part of VariantAnnotation.

## Details

## Defunct in > 1.15.0

- `getTranscriptSeqs` has been replaced by `extractTranscriptSeqs` in the `GenomicFeatures` package.

## Removed

- `refLocsToLocalLocs` has been replaced by `mapToTranscripts` and `pmapToTranscripts`.
- `readVcfLongForm` has been replaced by `expand`.
- `dbSNPFilter` and `regionFilter` have been replaced by `filterVcf`.
- `MatrixToSnpMatrix` has been replaced by `genotypeToSnpMatrix`.

## usage

## Defunct in > 1.15.0

- `getTranscriptSeqs()`

## Removed

- `refLocsToLocalLocs()`
- `readVcfLongForm()`
- `dbSNPFilter()`
- `regionFilter()`
- `MatrixToSnpMatrix()`

## Author(s)

Valerie Obenchain

## See Also

- [expand](#)
- [filterVcf](#)
- [genotypeToSnpMatrix](#)
- [mapToTranscripts](#)
- [extractTranscriptSeqs](#)

---

VariantType-class	<i>VariantType subclasses</i>
-------------------	-------------------------------

---

## Description

VariantType subclasses specify the type of variant to be located with locateVariants.

## Usage

```

CodingVariants()
IntronVariants()
FiveUTRVariants()
ThreeUTRVariants()
SpliceSiteVariants()
IntergenicVariants(upstream = 1e+06L, downstream = 1e+06L)
PromoterVariants(upstream = 2000L, downstream = 200L)
AllVariants(promoter = PromoterVariants(),
            intergenic = IntergenicVariants())

```

## Arguments

upstream, downstream	Single integer values representing the number of base pairs upstream of the 5'-end and downstream of the 3'-end. Used in constructing PromoterVariants() and IntergenicVariants() objects only.
promoter	PromoterVariants object with appropriate upstream and downstream values. Used when constructing AllVariants objects only.
intergenic	IntergenicVariants object with appropriate upstream and downstream values. Used when constructing AllVariants objects only.

## Details

VariantType is a virtual class inherited by the CodingVariants, IntronVariants, FiveUTRVariants, ThreeUTRVariants, SpliceSiteVariants, IntergenicVariants and AllVariants subclasses.

The subclasses are used as the region argument to locateVariants. They designate the type of variant (i.e., region of the annotation to match) when calling locateVariants.

The majority of subclasses have no slots and require no arguments for an instance to be created. PromoterVariants and IntergenicVariants accept upstream and downstream arguments that define the number of base pairs upstream from the 5'-end and downstream from the 3'-end of the transcript region. See the ?locateVariants man page for details. AllVariants accepts promoter and intergenic arguments which are PromoterVariants() and IntergenicVariants() objects with the appropriate upstream and downstream values.



**Accessors**

In the following code, `x` is a `PromoterVariants` or a `AllVariants` object.

`upstream(x)`, `upstream(x) <- value`: Gets or sets the number of base pairs defining a range upstream of the 5' end (excludes 5' start value).

`downstream(x)`, `downstream(x) <- value`: Gets or sets the number of base pairs defining a range downstream of the 3' end (excludes 3' end value).

`promoters(x)`, `promoters(x) <- value`: Gets or sets the `PromoterVariants` in the `AllVariants` object.

`intergenic(x)`, `intergenic(x) <- value`: Gets or sets the `IntergenicVariants` in the `AllVariants` object.

**Author(s)**

Valerie Obenchain

**See Also**

- The `promoters` function on the [intra-range-methods](#) man page in the `GenomicRanges` package.

**Examples**

```
CodingVariants()
SpliceSiteVariants()
PromoterVariants(upstream=1000, downstream=10000)

## Default values for PromoterVariants and IntergenicVariants
AllVariants()
## Modify 'upstream' and 'downstream' for IntergenicVariants
AllVariants(intergenic=IntergenicVariants(500, 100))
## Reset PromoterVariants on existing AllVariants object
av <- AllVariants()
av
promoter(av) <- PromoterVariants(100, 50)
av
```

---

VCF-class

*VCF class objects*

---

**Description**

The VCF class is a virtual class extended from `RangedSummarizedExperiment`. The subclasses, `CompressedVCF` and `ExtendedVCF`, are containers for holding data from Variant Call Format files.

## Details

The VCF class is a virtual class with two concrete subclasses, CollapsedVCF and ExpandedVCF.

Slots unique to VCF and subclasses,

- fixed: A [DataFrame](#) containing the REF, ALT, QUAL and FILTER fields from a VCF file.
- info: A [DataFrame](#) containing the INFO fields from a VCF file.

Slots inherited from RangedSummarizedExperiment,

- metadata: A list containing the file header or other information about the overall experiment.
- rowRanges: A [GRanges](#)-class instance defining the variant ranges and associated metadata columns of REF, ALT, QUAL and FILTER.
- colData: A [DataFrame](#)-class instance describing the samples and associated metadata.
- geno: The assays slot from RangedSummarizedExperiment has been renamed as geno for the VCF class. This slot contains the genotype information immediately following the FORMAT field in a VCF file. Each element of the list or SimpleList is a matrix or array.

It is expected that users will not create instances of the VCF class but instead one of the concrete subclasses, CollapsedVCF or ExpandedVCF. CollapsedVCF contains the ALT data as a DNASTringSetList allowing for multiple alleles per variant. The ExpandedVCF ALT data is a DNASTringSet where the ALT column has been expanded to create a flat form of the data with one row per variant-allele combination. In the case of structural variants, ALT will be a CompressedCharacterList or character in the collapsed or expanded forms.

## Constructors

```
readVcf(rowRanges = GRanges(), colData = DataFrame(), exptData = list(), fixed = DataFrame())
  Creates a CollapsedVCF class from data in a Variant Call Format file on disk.
```

```
VCF(rowRanges = GRanges(), colData = DataFrame(), exptData = list(header = VCFHeader()),
  Creates CollapsedVCF when collapsed = TRUE and an ExpandedVCF when collapsed = FALSE.
```

## Accessors

In the following code snippets `x` is a CollapsedVCF or ExpandedVCF object.

```
rowRanges(x, ..., fixed = TRUE), rowRanges(x) <- value: Gets or sets the rowRanges.
  The CHROM, POS, ID and REF fields are used to create a GRanges object. Ranges are
  created using POS as the start value and width of the reference allele (REF). The IDs become
  the rownames. If they are missing (i.e., '.') a string of CHROM:POS_REF/ALT is used
  instead. The genome argument is stored in the seqinfo of the GRanges and can be accessed
  with genome(<VCF>).
```

When `fixed = TRUE`, REF, ALT, QUAL and FILTER metadata columns are included.

One metadata column, `paramRangeID`, is included with the `rowRanges`. This ID is meaningful when multiple ranges are specified in the `ScanVcfParam` and distinguishes which records match each range.

The metadata columns can be accessed with `mcols(x)$<variable>` or the following accessors:

- `ref(x), ref(x) <- value`: Gets or sets the reference allele (REF). `value` must be a `DNAStrngSet`.
- `alt(x), alt(x) <- value`: Gets or sets the alternate allele data (ALT). When `x` is a `CollapsedVCF`, `value` must be a `DNAStrngSetList` or `CompressedCharacterList`. For `ExpandedVCF`, `value` must be a `DNAStrngSet` or `character`.
- `qual(x), qual(x) <- value`: Returns or sets the quality scores (QUAL). `value` must be an `numeric(1L)`.
- `filt(x), filt(x) <- value`: Returns or sets the filter data (FILT). `value` must be a `character(1L)`.

`fixed(x), fixed(x) <- value`: Gets or sets a `DataFrame` of REF, ALT, QUAL and FILTER only. Note these fields are displayed as metadata columns when `rowRanges(VCF)` is invoked. The fields can be replaced using `rowRanges<-` but it is more efficient to do so with `fixed<-`.

`info(x, ..., row.names = TRUE), info(x) <- value`: Gets or sets a `DataFrame` of INFO variables. Row names are added if unique and `row.names=TRUE`.

`geno(x, withDimnames=TRUE), geno(x) <- value`: Gets a `SimpleList` of genotype data. `value` is a `SimpleList`. To replace a single variable in the `SimpleList` use `geno(x)$variable <- value`; in this case `value` must be a matrix or array. By default row names are returned; to override specify `geno(vcf, withDimnames=FALSE)`.

`metadata(x)`: Gets a list of experiment-related data. By default this list includes the ‘header’ information from the VCF file. See the use of `header()` for details in extracting header information.

`colData(x), colData(x) <- value`: Gets or sets a `DataFrame` of sample-specific information. Each row represents a sample in the VCF file. `value` must be a `DataFrame` with `rownames` representing the samples in the VCF file.

`genome(x)`: Extract the genome information from the `GRanges` object returned by the `rowRanges` accessor.

`seqlevels(x)`: Extract the `seqlevels` from the `GRanges` object returned by the `rowRanges` accessor.

`strand(x)`: Extract the strand from the `GRanges` object returned by the `rowRanges` accessor.

`header(x), header(x)<- value`: Get or set the VCF header information. Replacement `value` must be a `VCFHeader` object. To modify individual elements use `info<-`, `geno<-` or `meta<-` on a ‘`VCFHeader`’ object. See `?VCFHeader` man page for details.

- `info(header(x))`
- `geno(header(x))`
- `meta(header(x))`
- `samples(header(x))`

### Subsetting and combining

In the following code `x` is a VCF object, and `...` is a list of VCF objects.

`x[i, j], x[i, j] <- value`: Gets or sets rows and columns. `i` and `j` can be integer or logical vectors. `value` is a replacement VCF object.

`cbind(...)`, `rbind(...)`: `cbind` combines objects with identical ranges (`rowRanges`) but different samples (columns in assays). The `colnames` in `colData` must match or an error is thrown. Columns with duplicate names in `fixed`, `info` and `mcols(rowRanges(VCF))` must contain the same data.

`rbind` combines objects with different ranges (`rowRanges`) and the same subjects (columns in assays). Columns with duplicate names in `colData` must contain the same data. The ‘Samples’ columns in `colData` (created by `readVcf`) are renamed with a numeric extension ordered as they were input to `rbind` e.g., “Samples.1, Samples.2, ...” etc.

metadata from all objects are combined into a `list` with no name checking.

## expand

In the following code snippets `x` is a `CollapsedVCF` object.

`expand(x, ..., row.names = FALSE)`: Expand (unlist) the ALT column of a `CollapsedVCF` object to one row per ALT value. Variables with `Number='A'` have one value per alternate allele and are expanded accordingly. The ‘AD’ genotype field is expanded into REF/ALT pairs. For all other fields, the rows are replicated to match the `elementLengths` of ALT.

The output is an `ExpandedVCF` with ALT as a `DNAStrngSet` or `character` (structural variants). By default `rownames` are `NULL`. When `row.names=TRUE` the expanded output has duplicated `rownames` corresponding to the original `x`.

## genotypeCodesToNucleotides(vcf, ...)

This function converts the ‘GT’ genotype codes in a VCF object to nucleotides. See also `?readGT` to read in only ‘GT’ data as codes or nucleotides.

## Variant Type

Functions to identify variant type include `isSNV`, `isInsertion`, `isDeletion`, `isIndel`, `isSubstitution` and `isTransition`. See the `?isSNV` man page for details.

## Arguments

**geno** A list or `SimpleList` of matrix elements, or a matrix containing the genotype information from a VCF file. If present, these data immediately follow the `FORMAT` field in the VCF.

Each element of the list must have the same dimensions, and dimension names (if present) must be consistent across elements and with the row names of `rowRanges`, `colData`.

**info** A `DataFrame` of data from the `INFO` field of a VCF file. The number of rows must match that in the `rowRanges` object.

**fixed** A `DataFrame` of `REF`, `ALT`, `QUAL` and `FILTER` fields from a VCF file. The number of rows must match that of the `rowRanges` object.

**rowRanges** A `GRanges` instance describing the ranges of interest. Row names, if present, become the row names of the VCF. The length of the `GRanges` must equal the number of rows of the matrices in `geno`.

**colData** A `DataFrame` describing the samples. Row names, if present, become the column names of the VCF.

- metadata** A list describing the header of the VCF file or additional information for the overall experiment.
- ... For `cbind` and `rbind` a list of VCF objects. For all other methods ... are additional arguments passed to methods.
- collapsed** A `logical(1)` indicating whether a `CollapsedVCF` or `ExpandedVCF` should be created. The ALT in a `CollapsedVCF` is a `DNAStrngSetList` while in a `ExpandedVCF` it is a `DNAStrngSet`.
- verbose** A `logical(1)` indicating whether messages about data coercion during construction should be printed.

**Author(s)**

Valerie Obenchain

**See Also**

[GRanges](#), [DataFrame](#), [SimpleList](#), [RangedSummarizedExperiment](#), [readVcf](#), [writeVcf](#) [isSNV](#)

**Examples**

```
f1 <- system.file("extdata", "structural.vcf", package="VariantAnnotation")
vcf <- readVcf(f1, genome="hg19")

## -----
## Accessors
## -----
## Variant locations are stored in the GRanges object returned by
## the rowRanges() accessor.
rowRanges(vcf)

## Individual fields can be extracted with ref(), alt(), qual()
## and filt().
qual(vcf)
ref(vcf)

## All 'info' fields can be extracted together along
## with the GRanges of locations.
head(info(vcf))

## All genotype fields can be seen with geno(). Individual
## fields are accessed with '$' or '[['.
geno(vcf)
identical(geno(vcf)$GQ, geno(vcf)[[2]])

## -----
## Renaming seqlevels and subsetting
## -----
## Overlap and matching operations require that the objects
## being compared have the same seqlevels (chromosome names).
## It is often the case that the seqlevels in one of the objects
## needs to be modified to match the other. In this VCF, the
```

```

## seqlevels are numbers instead of preceded by "chr" or "ch".

seqlevels(vcf)

## Rename the seqlevels to start with 'chr'.
vcf2 <- renameSeqlevels(vcf, paste0("chr", seqlevels(vcf)))
seqlevels(vcf2)

## The VCF can also be subset by seqlevel using 'keepSeqlevels'
## or 'dropSeqlevels'. See ?keepSeqlevels for details.
vcf3 <- keepSeqlevels(vcf2, "chr2")
seqlevels(vcf3)

## -----
## Header information
## -----

## Header data can be modified in the 'meta', 'info' and 'geno'
## slots of the VCFHeader object. See ?VCFHeader for details.

## Current 'info' fields.
rownames(info(header(vcf)))

## Add a new field to the header.
newInfo <- DataFrame(Number=1, Type="Integer",
                    Description="Number of Samples With Data",
                    row.names="NS")
info(header(vcf)) <- rbind(info(header(vcf)), newInfo)
rownames(info(header(vcf)))

## -----
## Collapsed and Expanded VCF
## -----

## readVCF() produces a CollapsedVCF object.
fl <- system.file("extdata", "ex2.vcf",
                 package="VariantAnnotation")
vcf <- readVcf(fl, genome="hg19")
vcf

## The ALT column is a DNASTringSetList to allow for more
## than one alternate allele per variant.
alt(vcf)

## For structural variants ALT is a CharacterList.
fl <- system.file("extdata", "structural.vcf",
                 package="VariantAnnotation")
vcf <- readVcf(fl, genome="hg19")
alt(vcf)

## ExpandedVCF is the 'flattened' counterpart of CollapsedVCF.
## The ALT and all variables with Number='A' in the header are
## expanded to one row per alternate allele.
vcfLong <- expand(vcf)

```

```

alt(vcfLong)

## Also see the ?VRanges class for an alternative form of
## 'flattened' VCF data.

## -----
## isSNV()
## -----
## NOTE: isSNV() and family have replaced restrictToSNV().
## isSNV() returns a subset VCF containing SNVs only.

vcf <- VCF(rowRanges = GRanges("chr1", IRanges(1:4*3, width=c(1, 2, 1, 1))))
alt(vcf) <- DNASTringSetList("A", c("TT"), c("G", "A"), c("TT", "C"))
ref(vcf) <- DNASTringSet(c("G", c("AA"), "T", "G"))
fixed(vcf)[c("REF", "ALT")]

## SNVs are present in rows 1 (single ALT value), 3 (both ALT values)
## and 4 (1 of the 2 ALT values).
vcf[isSNV(vcf, singleAltOnly=TRUE)]
vcf[isSNV(vcf, singleAltOnly=FALSE)] ## all 3 SNVs

```

---

VcfFile

---

*Manipulate Variant Call Format (Vcf) files.*


---

## Description

Use `VcfFile()` to create a reference to a Vcf file (and its index). Once opened, the reference remains open across calls to methods, avoiding costly index re-loading.

`VcfFileList()` provides a convenient way of managing a list of `VcfFile` instances.

## usage

```

## Constructors
VcfFile(file, index = paste(file, "tbi", sep="."), ..., yieldSize=NA_integer_) VcfFileList(..., yield-
Size=NA_integer_)
## Accessors index(object) path(object, ...) isOpen(con, rw="") yieldSize(object, ...) yieldSize(object,
...) <- value show(object)
## Opening / closing open(con, ...) close(con, ...)

```

## arguments

- `con` An instance of `VcfFile`.
- `file` A character(1) vector to the Vcf file path; can be remote (`http://`, `ftp://`).
- `index` A character(1) vector of the Vcf file index (.tbi file).
- `yieldSize` Number of records to yield each time the file is read from using `scanVcf` or `readVcf`.
- ...Additional arguments. For `VcfFileList`, this can either be a single character vector of paths to Vcf files, or several instances of `VcfFile` objects.
- `rw` character() indicating mode of file.

## Objects from the Class

Objects are created by calls of the form `VcfFile()`.

## Fields

`VcfFile` and `VcfFileList` classes inherit fields from the `TabixFile` and `TabixFileList` classes.

## Functions and methods

`VcfFile` and `VcfFileList` classes inherit methods from the `TabixFile` and `TabixFileList` classes.

Opening / closing:

**open** Opens the (local or remote) path and index. Returns a `VcfFile` instance. `yieldSize` determines the number of records parsed during each call to `scanVcf` or `readVcf`; NA indicates that all records are to be parsed.

**close** Closes the `VcfFile` con; returning (invisibly) the updated `VcfFile`. The instance may be re-opened with `open.VcfFile`.

Accessors:

**path** Returns a character(1) vector of the Vcf path name.

**index** Returns a character(1) vector of Vcf index (tabix file) name.

**yieldSize, yieldSize<-** Return or set an integer(1) vector indicating yield size.

## Author(s)

Valerie Obenchain

## Examples

```
f1 <- system.file("extdata", "chr7-sub.vcf.gz", package="VariantAnnotation",
                 mustWork=TRUE)
vcffile <- VcfFile(f1)
vcffile

param <- GRanges("7", IRanges(c(55000000, 55900000), width=10000))
vcf <- readVcf(vcffile, "hg19", param=param)
dim(vcf)
```



---

VCFHeader-class	<i>VCFHeader instances</i>
-----------------	----------------------------

---

### Description

The VCFHeader class holds Variant Call Format (VCF) file header information and is produced from a call to scanVcfHeader.

### Details

The VCFHeader class is holds header information from a from VCF file.

Slots :

reference character() vector

sample character() vector

header [DataFrameList-class](#)

### Constructor

VCFHeader(reference = character(), samples = character(), header = DataFrameList(),

### Accessors

In the following code snippets x is a VCFHeader object.

samples(x): Returns a character() vector of names of samples.

header(x): Returns all information in the header slot which includes meta, info and geno if present.

meta(x), meta(x)<- value: The getter returns a DataFrameList with possible names of META, SAMPLE and PEDIGREE. The META DataFrame is a catch-all for non-standard header fields. This includes any information represented as simple key-value pairs. The replacement value can be a DataFrame or DataFrameList.

fixed(x), fixed(x)<- value: Returns a DataFrameList of information pertaining to any of 'REF', 'ALT', 'FILTER' and 'QUAL'. Replacement value must be a DataFrameList with one or more of the following names, 'QUAL', 'FILTER', 'REF' and 'ALT'.

info(x), info(x)<- value: Gets or sets a DataFrame of 'INFO' information. Replacement value must be a DataFrame with 3 columns named 'Number', 'Type' and 'Description'.

geno(x), geno(x)<- value: Returns a DataFrame of 'FORMAT' information. Replacement value must be a DataFrame with 3 columns named 'Number', 'Type' and 'Description'.

reference(x): Returns a character() vector with names of reference sequences. Not relevant for scanVcfHeader.

**Arguments**

- reference** A character() vector of sequences.
- sample** A character() vector of sample names.
- header** A DataFrameList of parsed header lines (preceded by “##”) present in the VCF file.
- ... Additional arguments passed to methods.

**Author(s)**

Valerie Obenchain

**See Also**

[scanVcfHeader](#), [DataFrameList](#)

**Examples**

```
f1 <- system.file("extdata", "structural.vcf", package="VariantAnnotation")
hdr <- scanVcfHeader(f1)

fixed(hdr)
info(hdr)
geno(hdr)
```

---

VRanges-class

*VRanges objects*

---

**Description**

The VRanges class is a container for variant calls, including SNVs and indels. It extends GRanges to provide special semantics on top of a simple vector of genomic locations. While it is not as expressive as the VCF object, it is a simpler alternative that may be convenient for variant calling/filtering and similar exercises.

**Details**

VRanges extends GRanges to store the following components. Except where noted, the components are considered columns in the dataset, i.e., their lengths match the number of variants. Many columns can be stored as either an atomic vector or an Rle.

**ref** (character), the reference allele. The range (start/end/width) should always correspond to this sequence.

**alt** (character/Rle), the alternative allele (NA allowed). By convention there is only a single alt allele per element (row) of the VRanges. Many methods, like match, make this assumption.

**refCount** (integer/Rle), read count for the reference allele (NA allowed)

**altCount** (integer/Rle), read count for the alternative allele (NA allowed)

`totalCount` (integer/Rle), total read count at the position, must be at least `refCount+altCount` (NA allowed)

`sampleNames` (factor/Rle), name of the sample - results from multiple samples can be combined into the same object (NA allowed)

`softFilterMatrix` (matrix/FilterMatrix), variant by filter matrix, TRUE where variant passed the filter; use a [FilterMatrix](#) to store the actual `FilterRules` object that was applied

`hardFilters` (`FilterRules`) record of hard filters applied, i.e., only the variants that passed the filters are present in this object; this is the only component that is not a column, i.e., its length does not match the number of variants

Except in the special circumstances described here, a `VRanges` may be treated like a `GRanges`. The range should span the sequence in `ref`. Indels are typically represented by the VCF convention, i.e., the start position is one upstream of the event. The strand is always constrained to be positive (+).

Indels, by convention, should be encoded VCF-style, with the upstream reference base prepended to the indel sequence. The `ref/alt` for a deletion of GCGT before A might be AGCGT/A and for an insertion might be A/AGCGT. Since the range always matches the `ref` sequence, this means a deletion will be the width of the deletion + 1, and an insertion is always of width 1.

`VRanges` and the `VCF` class: The `VRanges` and `VCF` classes encode different types of information and are semantically incompatible. While methods exist for converting a `VCF` object to a `VRanges` and vice versa, information is lost in the transformation. There is no way to collapse multiple rows of a `VRanges` at the same genomic position and accurately represent missing data. For this reason, it is not reasonable to assume that an object resulting from multiple conversions (`VRanges` -> `VCF` -> `VRanges`) will be equivalent to the original.

## Constructors

`VRanges(seqnames = Rle(), ranges = IRanges(), ref = character(), alt = NA_character_, totalDepth = integer(), ...)`  
Creates a `VRanges` object.

`seqnames` Rle object, character vector, or factor containing the sequence names.

`ranges` IRanges object containing the ranges.

`ref` character vector, containing the reference allele.

`alt` character vector/Rle, containing the alternative allele (NA allowed).

`totalDepth` integer vector/Rle, containing the total read depth (NA allowed).

`refDepth` integer vector/Rle, containing the reference read depth (NA allowed).

`altDepth` integer vector/Rle, containing the reference read depth (NA allowed).

... Arguments passed to the `GRanges` constructor.

`sampleNames` character/factor vector/Rle, containing the sample names (NA allowed).

`softFilterMatrix` a matrix (typically a [FilterMatrix](#)) of dimension variant by filter, with logical values indicating whether a variant passed the filter.

`hardFilters` a [FilterRules](#), containing the filters that have already been applied to subset the object to its current state.

`makeVRangesFromGRanges(gr, ref.field="ref", ...)`

Creates a `VRanges` object from a `GRanges`.

`gr` A [GenomicRanges](#) object.

`ref.field` The character(1) name of the GRanges metadata column to be used as the VRanges ref field.

`alt.field` The character(1) name of the GRanges metadata column to be used as the VRanges alt field.

`totalDepth.field` The character(1) name of the GRanges metadata column to be used as the VRanges totalDepth field.

`refDepth.field` The character(1) name of the GRanges metadata column to be used as the VRanges refDepth field.

`altDepth.field` The character(1) name of the GRanges metadata column to be used as the VRanges altDepth field.

`sampleNames.field` The character(1) name of the GRanges metadata column to be used as the VRanges sampleNames field.

`keep.extra.columns` TRUE (the default) or FALSE. If TRUE, then the columns in `gr` that are not used to form the VRanges are retained as metadata columns. Otherwise, they will be ignored.

### Coercion

These functions/methods coerce objects to and from VRanges:

`asVCF(x, info = character(), filter = character(), meta = character())`:  
Creates a VCF object from a VRanges object. The following gives the mapping from VRanges components to VCF:

**seqnames(x)** CHROM column

**start(x)** POS column

**names(x)** ID column

**ref(x)** REF column

**alt(x)** ALT column

**totalDepth(x)** DP in FORMAT column

**altDepth(x), refDepth(x)** AD in FORMAT column

**sampleNames(x)** Names the sample columns

**softFilterMatrix(x)** FT in FORMAT column, except filters named in `filter` argument, which are considered per-position and placed in the FILTER column

**hardFilters(x)** Not yet exported

**mcols(x)** Become fields in the FORMAT column; unless they are named in the `info` argument, in which case they are considered per-position and placed in the INFO column

**metadata(x)** If named in the `meta` argument, output in the VCF header; a component is required to be coercible to a character vector of length one.

Note that `identical(x, as(as(x, "VCF"), "VRanges"))` generally return FALSE. During coercion to VCF, the "geno" components are reshaped into matrix form, with NAs filling the empty cells. The reverse coercion will not drop the NA values, so rows are added to the new VRanges. All logical values will become integers in VCF, and there is no automatic way of regenerating the logical column with the reverse coercion. There are many other cases of irreversibility.

`as(from, "VCF")`: Like calling `asVCF(from)`.

`as(from, "VRanges")`: When `from` is a VCF this coercion is essentially the inverse of `asVcf`. Information missing in the VCF is imputed as NA.

When `from` is a GRanges, metadata columns of `ref`, `alt`, `refDepth`, `altDepth`, `totalDepth` and `sampleNames` are transferred to the VRanges object. Additional metadata columns in the GRanges can be retained or dropped with `keep.extra.columns`. See also `makeVRangesFromGRanges`.

### Accessors

In addition to all of the GRanges accessors, VRanges provides the following, where `x` is a VRanges object.

`alt(x)`, `alt(x) <- value`: Get or set the alt allele (character).

`ref(x)`, `ref(x) <- value`: Get or set the ref allele (character).

`altDepth(x)`, `altDepth(x) <- value`: Get or set the alt allele read depth (integer).

`refDepth(x)`, `refDepth(x) <- value`: Get or set the ref allele read depth (integer).

`totalDepth(x)`, `totalDepth(x) <- value`: Get or set the total read depth (integer).

`altFraction(x)`: Returns `altDepth(x)/totalDepth(x)` (numeric).

`sampleNames(x)`, `sampleNames(x) <- value`: Get or set the sample names (character/factor).

`softFilterMatrix(x)`, `softFilterMatrix(x) <- value`: Gets or sets the soft filter matrix (any matrix, but ideally a `FilterMatrix`).

`resetFilter(x)`: Removes all columns from `softFilterMatrix`.

`called(x)`: Returns whether all filter results in `softFilterMatrix(x)` are TRUE for each variant.

`hardFilters(x)`, `hardFilters(x) <- value`: Gets or sets the hard filters (those applied to yield the current subset).

### Utilities and Conveniences

`match(x)`: Like GRanges `match`, except matches on the combination of chromosome, start, width, and **alt**.

`tabulate(bin)`: Finds `unique(bin)` and counts how many times each unique element occurs in `bin`. The result is stored in `mcols(bin)$sample.count`.

`softFilter(x, filters, ...)`: applies the `FilterRules` in `filters` to `x`, storing the results in `softFilterMatrix`.

### Input/Output to/from VCF

`writeVcf(obj, filename, ...)`: coerces to a VCF object and writes it to a file; see `writeVcf`.

`readVcfAsVRanges(x, genome, param = ScanVcfParam(), ...)`: Reads a VCF `x` directly into a VRanges; see `readVcf` for details on the arguments. `readVcfAsVRanges` is an alternative syntax to

```
as(readVcf(), "VRanges")
```

NOTE: By default all INFO and FORMAT fields are read in with `ScanVcfParam()`. The minimal information needed to create the VRanges can be specified as follows:

```
ScanVcfParam(fixed = "ALT", info = NA, geno = "AD"))
```

`VRangesScanVcfParam(fixed = "ALT", info = NA, geno = "AD", ...)`: (Deprecated. Use `ScanVcfParam()` instead.) Convenience constructor for a `ScanVcfParam` object that is well suited for import to a `VRanges`. The `fixed`, `info` and `geno` parameters, and anything in `...` are passed to `ScanVcfParam`.

### Variant Type

Functions to identify variant type include `isSNV`, `isInsertion`, `isDeletion`, `isIndel`, `isSubstitution` and `isTransition`. See the `?isSNV` man page for details.

### Author(s)

Michael Lawrence. `makeVRangesFromGRanges` was contributed by Thomas Sandmann.

### See Also

`VRangesList`, a list of `VRanges`; `bam_tally` in the `gmapR` package, which generates a `VRanges`.

### Examples

```
## construction
vr <- VRanges(seqnames = c("chr1", "chr2"),
              ranges = IRanges(c(1, 10), c(5, 20)),
              ref = c("T", "A"), alt = c("C", "T"),
              refDepth = c(5, 10), altDepth = c(7, 6),
              totalDepth = c(12, 17), sampleNames = letters[1:2],
              hardFilters =
                FilterRules(list(coverage = function(x) totalDepth > 10)),
              softFilterMatrix =
                FilterMatrix(matrix = cbind(depth = c(TRUE, FALSE),
                                           FilterRules(depth = function(x) altDepth(x) > 6)),
                             tumorSpecific = c(FALSE, TRUE))

## simple accessors
ref(vr)
alt(vr)
altDepth(vr)
vr$tumorSpecific
called(vr)

## coerce to VCF and write
vcf <- as(vr, "VCF")
## writeVcf(vcf, "example.vcf")
## or just
## writeVcf(vr, "example.vcf")

## other utilities
match(vr, vr[2:1])
```

---

VRangesList-class      *VRangesList objects*

---

### Description

VRangesList is a virtual class representing a list of [VRanges](#) objects and should behave much like any other derivative of List. It has both a simple and compressed implementation. VRangesList provides conveniences for manipulating sets of VRanges objects.

### Constructor

VRangesList(...): Creates a VRangesList object from VRanges objects in ....

### Utilities

stackSamples(x): Concentrates the elements in x, using names(x) to appropriately fill sampleNames in the result.

### Author(s)

Michael Lawrence

### Examples

```
## construction
example(VRanges)
vrl <- VRangesList(sampleA = vr, sampleB = vr)
stackSamples(vrl)
```

---

writeVcf      *Write VCF files*

---

### Description

Write Variant Call Format (VCF) files to disk

### Usage

```
## S4 method for signature 'VCF,character'
writeVcf(obj, filename, index = FALSE, ...)
## S4 method for signature 'VCF,connection'
writeVcf(obj, filename, index = FALSE, ...)
```

**Arguments**

obj	Object containing data to be written out. At present only accepts <a href="#">VCF</a> .
filename	The character() name of the VCF file, or a connection (e.g., <a href="#">file()</a> ), to be written out. A connection opened with open = "a" will have header information written only if the file does not already exist.
index	Whether to bgzip the output file and generate a tabix index.
...	Additional arguments, passed to methods. <ul style="list-style-type: none"> <li>• nchunk: Integer or NA. When provided this argument overrides the default chunking behavior of writeVcf, see Details section. An integer value specifies the number of records in each chunk; NA disables chunking.</li> </ul>

**Details**

A VCF file can be written out from data in a VCF file. More general methods to write out from other objects may be added in the future.

writeVcf conforms to the VCF standards on the 1000 Genomes Project web site (see references). When 'fileformat' is not present in the header data, format is written out according to the standard at the time of the Bioconductor release, e.g., for Bioconductor 3.1 the format is VCFv4.2.

Large VCF files (i.e., > 1e5 records) are written out in chunks; VCF files with < 1e5 records are not chunked. The optimal number of records per chunk depends on both the number of records and complexity of the data. Currently writeVcf determines records per chunk based on the total number of records only. To override this behavior or experiment with other values use nchunk as an integer or NA. An integer value represents the number of records per chunk regardless of the size of the VCF; NA disables all chunking.

- writeVcf(vcf, tempfile()) ## default chunking
- writeVcf(vcf, tempfile(), nchunk = 1e6) ## chunk by 1e6
- writeVcf(vcf, tempfile(), nchunk = NA) ## no chunking

**Value**

VCF file

**Author(s)**

Valerie Obenchain and Michael Lawrence

**References**

<http://vcftools.sourceforge.net/specs.html> outlines the VCF specification.

<http://samtools.sourceforge.net/mpileup.shtml> contains information on the portion of the specification implemented by bcftools.

<http://samtools.sourceforge.net/> provides information on samtools.

**See Also**

[readVcf](#)



**Examples**

```
f1 <- system.file("extdata", "ex2.vcf", package="VariantAnnotation")

out1.vcf <- tempfile()
out2.vcf <- tempfile()
in1 <- readVcf(f1, "hg19")
writeVcf(in1, out1.vcf)
in2 <- readVcf(out1.vcf, "hg19")
writeVcf(in2, out2.vcf)
in3 <- readVcf(out2.vcf, "hg19")
stopifnot(all(in2 == in3))

## write incrementally
out3.vcf <- tempfile()
con <- file(out3.vcf, open="a")
writeVcf(in1[1:2,], con)
writeVcf(in1[-(1:2),], con)
close(con)
readVcf(out3.vcf, "hg19")
```

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