Package 'MultiAssayExperiment'

April 10, 2023

Title Software for the integration of multi-omics experiments in
Bioconductor

Version 1.24.0

Description MultiAssayExperiment harmonizes data management of
multiple experimental assays performed on an overlapping set of specimens.
It provides a familiar Bioconductor user experience by extending concepts
from SummarizedExperiment, supporting an open-ended mix of standard data
classes for individual assays, and allowing subsetting by genomic ranges
or rownames. Facilities are provided for reshaping data into wide and
long formats for adaptability to graphing and downstream analysis.

Depends R (>= 4.2.0), SummarizedExperiment (>= 1.3.81)

Imports methods, GenomicRanges (>= 1.25.93), BiocBaseUtils,
BiocGenerics, DelayedArray, S4Vectors (>= 0.23.19), IRanges,
Biobase, stats, tidyr, utils

Suggests BiocStyle, HDF5Array (>= 1.19.17), knitr, maftools (>=
2.7.10), rmarkdown, R.rsp, RaggedExperiment, UpSetR, survival,
survminer, testthat

biocViews Infrastructure, DataRepresentation

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Encoding UTF-8

VignetteBuilder knitr, R.rsp

URL http://waldronlab.io/MultiAssayExperiment/

Video https://youtu.be/w6HWAHaDpyk, https://youtu.be/Vh0hVVUKKFM

BugReports https://github.com/waldronlab/MultiAssayExperiment/issues

Collate 'ExperimentList-class.R' 'MultiAssayExperiment-class.R'
'MatchedAssayExperiment-class.R' 'subsetBy-methods.R'
'MultiAssayExperiment-subset.R'
'MultiAssayExperiment-methods.R'
'MultiAssayExperiment-helpers.R' 'MultiAssayExperiment-pkg.R'
'MultiAssayExperimentToMAF.R' 'assay-methods.R' 'data.R'
'hasAssay.R' 'listToMap.R' 'mapToList.R' 'prepMultiAssay.R'
'reexports.R' 'saveHDF5MultiAssayExperiment.R' 'upsetSamples.R'
'utilities.R'

RoxygenNote 7.2.1

git_url https://git.bioconductor.org/packages/MultiAssayExperiment

git_branch RELEASE_3_16

git_last_commit 7f63e33

git_last_commit_date 2022-11-01

Date/Publication 2023-04-10

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R topics documented:

MultiAssayExperiment-package

MultiAssayExperiment: Build an integrative multi-assay container

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Description

MultiAssayExperiment allows the manipulation of related multiassay datasets with partially overlapping samples, associated metadata at the level of an entire study, and at the level of the "biological unit". The biological unit may be a patient, plant, yeast strain, etc.

Details

The package hierarchy of information:

- study

- experiments

- samples

Author(s)

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- MultiAssay SIG <biocmultiassay@googlegroups.com> [contributor]

See Also

Useful links:

- <http://waldronlab.io/MultiAssayExperiment/>

- Report bugs at <https://github.com/waldronlab/MultiAssayExperiment/issues>

ExperimentList *Represent multiple experiments as a List-derivative* ExperimentList

---

Description

The `ExperimentList` class can contain several different types of data. The only requirements for an `ExperimentList` class are that the objects contained have the following set of methods: `dim`, `[`, `dimnames`

Usage

```
ExperimentList(...)
```

Arguments

```
...                A named list class object
```

Value

A `ExperimentList` class object of experiment data

Examples

```
## Create an empty ExperimentList instance
ExperimentList()

## Create array matrix and AnnotatedDataFrame to create an ExpressionSet class
arraydat <- matrix(data = seq(101, length.out = 20), ncol = 4,
    dimnames = list(
        c("ENST00000294241", "ENST00000355076",
        "ENST00000383706","ENST00000234812", "ENST00000383323"),
        c("array1", "array2", "array3", "array4")
    ))

colDat <- data.frame(slope53 = rnorm(4),
    row.names = c("array1", "array2", "array3", "array4"))

## SummarizedExperiment constructor
exprdat <- SummarizedExperiment::SummarizedExperiment(arraydat,
    colData = colDat)

## Create a sample methylation dataset
methyldat <- matrix(data = seq(1, length.out = 25), ncol = 5,
    dimnames = list(
        c("ENST00000355076", "ENST00000383706",
          "ENST00000383323", "ENST00000234812", "ENST00000294241"),
        c("methyl1", "methyl2", "methyl3",
          "methyl4", "methyl5")
    ))

## Create a sample RNASeqGene dataset
rnadat <- matrix(
    data = sample(c(46851, 5, 19, 13, 2197, 507,
        84318, 126, 17, 21, 23979, 614), size = 20, replace = TRUE),
    ncol = 4,
    dimnames = list(
        c("XIST", "RPS4Y1", "KDM5D", "ENST00000383323", "ENST00000234812"),
        c("samparray1", "samparray2", "samparray3", "samparray4")
    ))

## Create a mock RangedSummarizedExperiment from a data.frame
rangedat <- data.frame(chr="chr2", start = 11:15, end = 12:16,
    strand = c("+", "-", "+", "*", "."),
    samp0 = c(0,0,1,1,1), samp1 = c(1,0,1,0,1), samp2 = c(0,1,0,1,0),
    row.names = c(paste0("ENST", "00000", 135411:135414), "ENST00000383323"))

rangeSE <- SummarizedExperiment::makeSummarizedExperimentFromDataFrame(rangedat)

## Combine to a named list and call the ExperimentList constructor function
assayList <- list(Affy = exprdat, Methyl450k = methyldat, RNASeqGene = rnadat,
                GISTIC = rangeSE)

## Use the ExperimentList constructor
ExpList <- ExperimentList(assayList)
```

ExperimentList-class   *ExperimentList - A container for multi-experiment data*

Description

The ExperimentList class is a container that builds on the SimpleList with additional checks for consistency in experiment names and length. It contains a SimpleList of experiments with sample identifiers. One element present per experiment performed.

Convert from SimpleList or list to the multi-experiment data container. When using the **mergeReplicates** method, additional arguments are passed to the given simplify function argument (e.g., na.rm = TRUE)

Usage

```
## S4 method for signature 'ExperimentList'
show(object)

## S4 method for signature 'ExperimentList'
isEmpty(x)

## S4 method for signature 'ExperimentList'
dimnames(x)

## S4 method for signature 'ExperimentList'
colnames(x, do.NULL = TRUE, prefix = "col")

## S4 method for signature 'ExperimentList'
rownames(x, do.NULL = TRUE, prefix = "row")

## S4 method for signature 'ExperimentList'
mergeReplicates(x, replicates = list(), simplify = BiocGenerics::mean, ...)

## S4 method for signature 'ANY,missing'
assay(x, i, withDimnames = TRUE, ...)

## S4 method for signature 'ExperimentList'
assays(x, withDimnames = TRUE, ...)

## S4 method for signature 'ExperimentList,missing'
assay(x, i, withDimnames = TRUE, ...)

## S4 method for signature 'ExperimentList,numeric'
assay(x, i, withDimnames = TRUE, ...)

## S4 method for signature 'ExperimentList,character'
assay(x, i, withDimnames = TRUE, ...)
```

Arguments

`object, x`	An [ExperimentList](#) object
`do.NULL, prefix`	
	See ?base::[rownames](#) for a description of these arguments.
`replicates`	mergeReplicates: A `list` or [LogicalList](#) where each element represents a sample and a vector of repeated measurements for the sample
`simplify`	A function for merging columns where duplicates are indicated by replicates
`...`	Additional arguments. See details for more information.
`i`	A scalar `character` or `integer` index
`withDimnames`	logical (default TRUE) whether to return dimension names

Value

An `ExperimentList` class object

Methods (by generic)

- `show(ExperimentList)`: Show method for [ExperimentList](#) class
- `isEmpty(ExperimentList)`: check for zero length across all experiments
- `dimnames(ExperimentList)`: Get the dimension names for an `ExperimentList` using [CharacterList](#)
- `colnames(ExperimentList)`: Get the column names for an `ExperimentList` as a [CharacterList](#) slightly more efficiently
- `rownames(ExperimentList)`: Get the row names for an `ExperimentList` as a [CharacterList](#) slightly more efficiently
- `mergeReplicates(ExperimentList)`: Apply the mergeReplicates method on the ExperimentList elements
- `assay(x = ANY, i = missing)`: Obtain the specified assay with a `numeric` or `character` reference
- `assays(ExperimentList)`: Get the assay data from each element in the [ExperimentList](#)

coercion

Convert a `list` or S4 `List` to an ExperimentList using the as() function.

In the following example, x is either a `list` or [List](#):

```
\code{as(x, "ExperimentList")}
```

Examples

```
ExperimentList()
```

---

hasAssay   *Checking assay method for any class*

Description

The `hasAssay` function is intended for developers who would like to include new classes into a
`MultiAssayExperiment` instance. It checks the methods tables of the `assay` function for the spec-
ified class of the argument.

Usage

```
hasAssay(object)
```

Arguments

object   A `MultiAssayExperiment` or named `list` object instance

Value

A `logical` value indicating method availability

Examples

```
lst <- structure(list(), .Names=character())
hasAssay(lst)
```

---

listToMap   *Convert map from data.frame or DataFrame to list and vice versa*

Description

The `mapToList` function provides a convenient way of reordering a `data.frame` to a `list`. The
`listToMap` function does the opposite by taking a `list` and converting it to `DataFrame`.

Usage

```
listToMap(listmap, fill = TRUE)

mapToList(dfmap, assayCol = "assay")
```

Arguments

`listmap`	A named `list` object containing DataFrames with "primary" and "colname" columns
`fill`	logical(1) Whether to fill the map with an empty `DataFrame` when empty elements are present in the input list
`dfmap`	A `data.frame` or `DataFrame` object with identifiers in the first column
`assayCol`	A character vector of length one indicating the assay names column

Value

A [DataFrame](#) class object of names

A `list` object of DataFrames for each assay

Functions

- `listToMap()`: The inverse of the listToMap operation

Examples

```
example("MultiAssayExperiment")

## Create a sampleMap from a list using the listToMap function
sampMap <- listToMap(maplist)

## The inverse operation is also available
maplist <- mapToList(sampMap)
```

MatchedAssayExperiment-class

MatchedAssayExperiment - A matched-samples MultiAssayExperiment class

---

Description

This class supports the use of matched samples where an equal number of observations per biological unit are present in all assays.

Usage

```
MatchedAssayExperiment(...)
```

Arguments

`...`	Either a single MultiAssayExperiment or the components to create a valid MultiAssayExperiment

Value

A `MatchedAssayExperiment` object

Functions

- `MatchedAssayExperiment()`: Construct a `MatchedAssayExperiment` class from [MultiAssayExperiment](#)

See Also

[MultiAssayExperiment](#)

Examples

```
data("miniACC")
acc <- as(miniACC, "MatchedAssayExperiment")
acc
```

---

miniACC   *Adrenocortical Carcinoma (ACC) MultiAssayExperiment*

Description

A `MultiAssayExperiment` object providing a reduced version of the TCGA ACC dataset for all 92 patients. RNA-seq, copy number, and somatic mutations are included only for genes whose proteins are included in the reverse-phase protein array. The MicroRNA-seq dataset is also included, with infrequently expressed microRNA removed. Clinical, pathological, and subtype information are provided by `colData(miniACC)`, and some additional details are provided by metadata(miniACC).

Usage

```
data("miniACC")
```

Format

A `MultiAssayExperiment` with 5 experiments, providing:

RNASeq2GeneNorm RNA-seq count data: an `ExpressionSet` with 198 rows and 79 columns

gistict Reccurent copy number lesions identified by GISTIC2: a `SummarizedExperiment` with 198 rows and 90 columns

RPPAArray Reverse Phase Protein Array: an `ExpressionSet` with 33 rows and 46 columns. Rows are indexed by genes, but protein annotations are available from featureData(miniACC[["RPPAArray"]]). The source of these annotations is noted in abstract(miniACC[["RPPAArray"]])

Mutations Somatic mutations: a `matrix` with 223 rows and 90 columns. 1 for any kind of non-silent mutation, zero for silent (synonymous) or no mutation.

miRNASeqGene microRNA sequencing: an `ExpressionSet` with 471 rows and 80 columns. Rows not having at least 5 counts in at least 5 samples were removed.

Author(s)

Levi Waldron <lwaldron.research@gmail.com>

Source

https://github.com/waldronlab/multiassayexperiment-tcga

References

Zheng S *et al.*: Comprehensive Pan-Genomic Characterization of Adrenocortical Carcinoma. Cancer Cell 2016, 29:723-736.

Examples

```
data("miniACC")
metadata(miniACC)
colnames(colData(miniACC))
table(miniACC$vital_status)
longFormat(
    miniACC["MAPK3", , ],
    colDataCols = c("vital_status", "days_to_death")
)

wideFormat(
    miniACC["MAPK3", , ],
    colDataCols = c("vital_status", "days_to_death")
)
```

MultiAssayExperiment *Construct an integrative representation of multi-omic data with* MultiAssayExperiment

---

Description

The constructor function for the [MultiAssayExperiment-class](#) combines multiple data elements from the different hierarchies of data (study, experiments, and samples). It can create instances where neither a sampleMap or a colData set is provided. Please see the MultiAssayExperiment API documentation for more information.

Usage

```
MultiAssayExperiment(
  experiments = ExperimentList(),
  colData = S4Vectors::DataFrame(),
 sampleMap = S4Vectors::DataFrame(assay = factor(), primary = character(), colname =
    character()),
  metadata = list(),
  drops = list()
)
```

Arguments

experiments	A list or [ExperimentList](#) of all combined experiments
colData	A [DataFrame](#) or data.frame of characteristics for all biological units
sampleMap	A DataFrame or data.frame of assay names, sample identifiers, and colname samples
metadata	An optional argument of "ANY" class (usually list) for content describing the experiments
drops	A list of unmatched information (included after subsetting)

Value

A MultiAssayExperiment object that can store experiment and phenotype data

colData

The 'colData' input can be either 'DataFrame' or 'data.frame' with subsequent coercion to DataFrame. The rownames in the 'colData' must match the colnames in the experiments if no sampleMap is provided.

experiments

The 'experiments' input can be of class [SimpleList](#) or 'list'. This input becomes the [ExperimentList](#). Each element of the input 'list' or 'List' must be named, rectangular with two dimensions, and have 'dimnames'.

sampleMap

The [sampleMap](#) can either be input as 'DataFrame' or 'data.frame' with eventual coercion to 'DataFrame'. The 'sampleMap' relates biological units and biological measurements within each assay. Each row in the 'sampleMap' is a single such link. The standard column names of the 'sampleMap' are "assay", "primary", and "colname". Note that the "assay" column is a factor corresponding to the names of each experiment in the 'ExperimentList'. In the case where these names do not match between the 'sampleMap' and the experiments, the documented experiments in the 'sampleMap' take precedence and experiments are dropped by the harmonization procedure. The constructor function will generate a 'sampleMap' in the case where it is not provided and this method may be a 'safer' alternative for creating the 'MultiAssayExperiment' (so long as the rownames are identical in the 'colData', if provided). An empty 'sampleMap' may produce empty experiments if the levels of the "assay" factor in the 'sampleMap' do not match the names in the 'ExperimentList'.

See Also

[MultiAssayExperiment-class](#)

Examples

```
## Run the example ExperimentList
example("ExperimentList")
```

```
## Create sample maps for each experiment
exprmap <- data.frame(
    primary = c("Jack", "Jill", "Barbara", "Bob"),
    colname = c("array1", "array2", "array3", "array4"),
    stringsAsFactors = FALSE)

methylmap <- data.frame(
    primary = c("Jack", "Jack", "Jill", "Barbara", "Bob"),
    colname = c("methyl1", "methyl2", "methyl3", "methyl4", "methyl5"),
    stringsAsFactors = FALSE)

rnamap <- data.frame(
    primary = c("Jack", "Jill", "Bob", "Barbara"),
    colname = c("samparray1", "samparray2", "samparray3", "samparray4"),
    stringsAsFactors = FALSE)

gistmap <- data.frame(
    primary = c("Jack", "Bob", "Jill"),
    colname = c("samp0", "samp1", "samp2"),
    stringsAsFactors = FALSE)

## Combine as a named list and convert to a DataFrame
maplist <- list(Affy = exprmap, Methyl450k = methylmap,
    RNASeqGene = rnamap, GISTIC = gistmap)

## Create a sampleMap
sampMap <- listToMap(maplist)
## Create an example phenotype data
colDat <- data.frame(sex = c("M", "F", "M", "F"), age = 38:41,
    row.names = c("Jack", "Jill", "Bob", "Barbara"))

## Create a MultiAssayExperiment instance
mae <- MultiAssayExperiment(experiments = ExpList, colData = colDat,
    sampleMap = sampMap)
```

MultiAssayExperiment-class

> *MultiAssayExperiment - An integrative multi-assay class for experiment data*

Description

The MultiAssayExperiment class can be used to manage results of diverse assays on a collection of specimen. Currently, the class can handle assays that are organized instances of SummarizedExperiment, ExpressionSet, matrix, RaggedExperiment (inherits from GRangesList), and RangedVcfStack. Create new MultiAssayExperiment instances with the homonymous constructor, minimally with the argument ExperimentList, potentially also with the arguments colData (see section below) and sampleMap.

Usage

```
## S4 method for signature 'MultiAssayExperiment'
show(object)

## S4 method for signature 'MultiAssayExperiment'
length(x)

## S4 method for signature 'MultiAssayExperiment'
names(x)

## S4 method for signature 'MultiAssayExperiment'
updateObject(object, ..., verbose = FALSE)

## S4 method for signature 'MultiAssayExperiment'
dimnames(x)

## S4 method for signature 'MultiAssayExperiment'
c(x, ..., sampleMap = NULL, mapFrom = NULL)

## S4 method for signature 'MultiAssayExperiment'
exportClass(
  object,
  dir = tempdir(),
  fmt,
  ext,
  match = FALSE,
  verbose = TRUE,
  ...
)

## S4 method for signature 'MultiAssayExperiment'
assays(x, withDimnames = TRUE, ...)

## S4 method for signature 'MultiAssayExperiment,missing'
assay(x, i, withDimnames = TRUE, ...)

## S4 method for signature 'MultiAssayExperiment,numeric'
assay(x, i, withDimnames = TRUE, ...)

## S4 method for signature 'MultiAssayExperiment,character'
assay(x, i, withDimnames = TRUE, ...)
```

Arguments

`object, x`	A `MultiAssayExperiment` object
`...`	Additional arguments for supporting functions. See details.
`verbose`	logical(1) Whether to print additional information (default TRUE)

sampleMap	c method: a `sampleMap` `list` or `DataFrame` to guide merge
mapFrom	Either a `logical`, `character`, or `integer` vector indicating the experiment(s) that have an identical colname order as the experiment input(s). If using a character input, the name must match exactly.
dir	character(1) A directory for saving exported data (default: 'tempdir()')
fmt	character(1) or function() Either a format character atomic as supported by 'write.table' either ('csv', or 'tsv') or a function whose first two arguments are 'object to save' and 'file location'
ext	character(1) A file extension supported by the format argument
match	logical(1) Whether to coerce the current object to a 'MatchedAssayExperiment' object (default: FALSE)
withDimnames	logical (default TRUE) whether to return dimension names included in the object
i	An integer or character scalar indicating the assay to return

Details

The dots (...) argument allows the user to specify additional arguments in several instances.

- subsetting **[**: additional arguments sent to [findOverlaps](#).
- mergeReplicates: used to specify arguments for the `simplify` functional argument
- assay: may contain withDimnames, which is forwarded to assays
- combining **c**: compatible MultiAssayExperiment classes passed on to the [ExperimentList](#) constructor, can be a `list`, [List](#), or a series of named arguments. See the examples below.

Value

A `MultiAssayExperiment` object

Methods (by generic)

- show(MultiAssayExperiment): Show method for a MultiAssayExperiment
- length(MultiAssayExperiment): Get the length of ExperimentList
- names(MultiAssayExperiment): Get the names of the ExperimentList
- updateObject(MultiAssayExperiment): Update old serialized MultiAssayExperiment objects to new API
- dimnames(MultiAssayExperiment): Get the dimension names for a MultiAssayExperiment object
- c(MultiAssayExperiment): Add a supported data class to the ExperimentList
- exportClass(MultiAssayExperiment): Export data from class to a series of text files
- assays(MultiAssayExperiment): Obtain a [SimpleList](#) of assay data for all available experiments in the object
- assay(x = MultiAssayExperiment, i = missing): Convenience function for extracting the assay of the first element (default) in the ExperimentList. A numeric or character index can also be provided

Slots

ExperimentList A `ExperimentList` class object for each assay dataset

colData A `DataFrame` of all clinical/specimen data available across experiments

sampleMap A `DataFrame` of translatable identifiers of samples and participants

metadata Additional data describing the `MultiAssayExperiment` object

drops A metadata `list` of dropped information

colData

The `colData` slot is a collection of primary specimen data valid across all experiments. This slot is strictly of class `DataFrame` but arguments for the constructor function allow arguments to be of class data.frame and subsequently coerced.

ExperimentList

The `ExperimentList` slot is designed to contain results from each experiment/assay. It contains a `SimpleList`.

sampleMap

The `sampleMap` contains a `DataFrame` of translatable identifiers of samples and participants or biological units. The standard column names of the sampleMap are "assay", "primary", and "colname". Note that the "assay" column is a factor corresponding to the names of each experiment in the ExperimentList. In the case where these names do not match between the sampleMap and the experiments, the documented experiments in the sampleMap take precedence and experiments are dropped by the harmonization procedure. The constructor function will generate a sampleMap in the case where it is not provided and this method may be a 'safer' alternative for creating the MultiAssayExperiment (so long as the rownames are identical in the colData, if provided). An empty sampleMap may produce empty experiments if the levels of the "assay" factor in the sampleMap do not match the names in the ExperimentList.

coercion

Convert a `list` or S4 `List` to a MultiAssayExperiment object using the as function.

In the following example, x is either a `list` or List:

`as(x, "MultiAssayExperiment")`

Convert a `MultiAssayExperiment` to MAF class object using the as function.

In the following example, x is a MultiAssayExperiment:

`MultiAssayExperimentToMAF(x)`

See Also

MultiAssayExperiment-methods for slot modifying methods, MultiAssayExperiment API

Examples

```
example("MultiAssayExperiment")

## Subsetting
# Rows (i) Rows/Features in each experiment
mae[1, , ]
mae[c(TRUE, FALSE), , ]

# Columns (j) Rows in colData
mae[, rownames(colData(mae))[3:2],  ]

# Assays (k)
mae[, , "Affy"]

## Complete cases (returns logical vector)
completes <- complete.cases(mae)
compMAE <- mae[, completes, ]
compMAE
colData(compMAE)

example("MultiAssayExperiment")

## Add an experiment
test1 <- mae[[1L]]
colnames(test1) <- rownames(colData(mae))

## Combine current MultiAssayExperiment with additional experiment
## (no sampleMap)
c(mae, newExperiment = test1)

test2 <- mae[[3L]]
c(mae, newExp = test2, mapFrom = 3L)

## Add experiment using experiment name in mapFrom
c(mae, RNASeqGeneV2 = test2, mapFrom = "RNASeqGene")
```

MultiAssayExperiment-helpers

A group of helper functions for manipulating and cleaning a MultiAs-sayExperiment

Description

A set of helper functions were created to help clean and manipulate a MultiAssayExperiment object. intersectRows also works for ExperimentList objects.

- complete.cases: Returns a logical vector corresponding to 'colData' rows that have data across all experiments

- isEmpty: Returns a logical TRUE value for zero length MultiAssayExperiment objects

- intersectRows: Takes all common rows across experiments, excludes experiments with empty rownames

- intersectColumns: A wrapper for complete.cases to return a MultiAssayExperiment with only those biological units that have measurements across all experiments

- replicated: Identifies, via logical vectors, colnames that originate from a single biological unit within each assay

- replicates: Provides the replicate colnames found with the replicated function by their name, empty list if none

- anyReplicated: Displays which assays have replicate measurements

- mergeReplicates: A function that combines replicated / repeated measurements across all experiments and is guided by the replicated return value

- longFormat: A MultiAssayExperiment method that returns a small and skinny [DataFrame]. The colDataCols arguments allows the user to append colData columns to the data.

- wideFormat: A function to reshape the data in a MultiAssayExperiment to a "wide" format [DataFrame]. Each row in the DataFrame represents an observation (corresponding to an entry in the colData). If replicates are present, their data will be appended at the end of the corresponding row and will generate additional NA data. It is recommended to remove or consolidate technical replicates with mergeReplicates. Optional colDataCols can be added when the original object is a MultiAssayExperiment.

- hasRowRanges: A function that identifies ExperimentList elements that have a [rowRanges] method

- getWithColData: A convenience function for extracting an assay and associated colData

- renamePrimary: A convenience function to rename the primary biological units as represented in the rownames(colData)

- renameColname: A convenience function to rename the colnames of a particular assay

Usage

```
## S4 method for signature 'MultiAssayExperiment'
complete.cases(...)

## S4 method for signature 'MultiAssayExperiment'
isEmpty(x)

intersectRows(x)

intersectColumns(x)

replicated(x)

## S4 method for signature 'MultiAssayExperiment'
replicated(x)

anyReplicated(x)
```

```
## S4 method for signature 'MultiAssayExperiment'
anyReplicated(x)

replicates(x, ...)

## S4 method for signature 'MultiAssayExperiment'
replicates(x, ...)

mergeReplicates(x, replicates = list(), simplify = BiocGenerics::mean, ...)

## S4 method for signature 'MultiAssayExperiment'
mergeReplicates(
  x,
  replicates = replicated(x),
  simplify = BiocGenerics::mean,
  ...
)

## S4 method for signature 'ANY'
mergeReplicates(x, replicates = list(), simplify = BiocGenerics::mean, ...)

longFormat(object, colDataCols = NULL, i = 1L)

wideFormat(
  object,
  colDataCols = NULL,
  check.names = TRUE,
  collapse = "_",
  i = 1L
)

hasRowRanges(x)

## S4 method for signature 'MultiAssayExperiment'
hasRowRanges(x)

## S4 method for signature 'ExperimentList'
hasRowRanges(x)

getWithColData(x, i, mode = c("append", "replace"), verbose = FALSE)

renamePrimary(x, value)

renameColname(x, i, value)

splitAssays(x, hitList)
```

```
## S4 method for signature 'MultiAssayExperiment'
splitAssays(x, hitList)

makeHitList(x, patternList)
```

Arguments

`...`	Additional arguments. See details for more information.
`x`	A MultiAssayExperiment or ExperimentList
`replicates`	A list of [LogicalList](s) indicating multiple / duplicate entries for each biological unit per assay, see `replicated` (default `replicated(x)`).
`simplify`	A function for merging repeat measurements in experiments as indicated by the `replicated` method for `MultiAssayExperiment`
`object`	Any supported class object
`colDataCols`	A `character`, `logical`, or `numeric` index for `colData` columns to be included
`i`	longFormat: The i-th assay in [SummarizedExperiment](-like objects. A vector input is supported in the case that the SummarizedExperiment object(s) has more than one assay (default 1L), renameColname: Either a `numeric` or `character` index indicating the assay whose colnames are to be renamed
`check.names`	(logical default TRUE) Column names of the output `DataFrame` will be checked for syntactic validity and made unique, if necessary
`collapse`	(character default "_") A single string delimiter for output column names. In `wideFormat`, experiments and rownames (and when replicate samples are present, colnames) are seperated by this delimiter
`mode`	String indicating how [MultiAssayExperiment] column-level metadata should be added to the [SummarizedExperiment] `colData`.
`verbose`	logical(1) Whether to 'suppressMessages' on subsetting operations in 'getWith-ColData' (default FALSE)
`value`	renamePrimary: A `character` vector of the same length as the existing `rownames(colData)` to use for replacement, renameColname: A `CharacterList` or `list` with matching `lengths` to replace `colnames(x)`
`hitList`	a named `list` or `List` of logical vectors that indicate groupings in the assays
`patternList`	a named `list` or `List` of atomic character vectors that are the input to `grepl` for identifying groupings in the assays

Details

The `replicated` function finds replicate measurements in each assay and returns a list of [Logi-calList](s. Each element in a single [LogicalList] corresponds to a biological or *primary* unit as in the `sampleMap`. Below is a small graphic for one particular biological unit in one assay, where the logical vector corresponds to the number of measurements/samples in the assay:

```
>       replicated(MultiAssayExperiment)
(list str)        '-- $ AssayName
(LogicalList str)       '-- [[ "Biological Unit" ]]
Replicated if sum(...) > 1            '-- TRUE TRUE FALSE FALSE
```

anyReplicated determines if any of the assays have at least one replicate. *Note*. These methods are not available for the ExperimentList class due to a missing sampleMap structure (by design).

The replicates function (noun) returns the colnames from the sampleMap that were identified as replicates. It returns a list of [CharacterList](s)s for each assay present in the MultiAssayExperiment and an inner entry for each biological unit that has replicate observations in that assay.

The mergeReplicates function is a house-keeping method for a MultiAssayExperiment where only complete.cases are returned. This by-assay operation averages replicate measurements (by default) and columns are aligned by the row order in colData. Users can provide their own function for merging replicates with the simplify functional argument. Additional inputs ... are sent to the 'simplify' function.

The mergeReplicates "ANY" method consolidates duplicate measurements for rectangular data structures, returns object of the same class (endomorphic). The ellipsis or ... argument allows the user to provide additional arguments to the simplify functional argument.

The longFormat "ANY" class method, works with classes such as ExpressionSet and Summarized-Experiment as well as matrix to provide a consistent long and skinny DataFrame.

The hasRowRanges method identifies assays that support a rowRanges method *and* return a GRanges object.

Value

See the itemized list in the description section for details.

mergeReplicates

The mergeReplicates function makes use of the output from replicated which will point out the duplicate measurements by biological unit in the MultiAssayExperiment. This function will return a MultiAssayExperiment with merged replicates. Additional arguments can be provided to the simplify argument via the ellipsis (...). For example, when replicates "TCGA-B" and "TCGA-A" are found in the assay, the name of the first appearing replicate is taken (i.e., "B"). Note that a typical use case of merging replicates occurs when there are multiple measurements on the **same** sample (within the same assay) and can therefore be averaged.

longFormat

The 'longFormat' method takes data from the ExperimentList in a MultiAssayExperiment and returns a uniform DataFrame. The resulting DataFrame has columns indicating primary, rowname, colname and value. This method can optionally include columns of the MultiAssayExperiment col-Data named by colDataCols character vector argument. (MultiAssayExperiment method only). The i argument allows the user to specify the assay value for the SummarizedExperiment assay function's i argument.

wideFormat

The wideFormat function returns standardized wide DataFrame where each row represents a biological unit as in the colData. Depending on the data and setup, biological units can be patients, tumors, specimens, etc. Metadata columns are generated based on the names produced in the wide format DataFrame. These can be accessed via the mcols function. See the wideFormat section for description of the colDataCols and i arguments.

hasRowRanges

The hasRowRanges method identifies assays with associated ranged row data by directly testing the method on the object. The result from the test must be a [GRanges](#) class object to satisfy the test.

getWithColData

The getWithColData function allows the user to conveniently extract a particular assay as indicated by the i index argument. It will also attempt to provide the [colData](#) along with the extracted object using the colData<- replacement method when possible. Typically, this method is available for [SummarizedExperiment](#) and RaggedExperiment classes.

The setting of mode determines how the [colData](#) is added. If mode="append", the [MultiAssayExperiment](#) metadata is appended onto that of the [SummarizedExperiment](#). If any fields are duplicated by name, the values in the [SummarizedExperiment](#) are retained, with a warning emitted if the values are different. For mode="replace", the [MultiAssayExperiment](#) metadata replaces that of the [SummarizedExperiment](#), while for mode="none", no replacement or appending is performed.

rename*

The renamePrimary function allows the user to conveniently change the actual names of the primary biological units as seen in rownames(colData). renameColname allows the user to change the names of a particular assay based on index i. i can either be a single numeric or character value. See colnames<- method for renaming multiple colnames in a MultiAssayExperiment.

splitAssays

The splitAssays method separates columns in each of the assays based on the hitList input. The hitList can be generated using the makeHitList helper function. To use the makeHitList helper, the user should input a list of patterns that will match on the column names of each assay. These matches should be mutually exclusive as to avoid repetition of columns across assays. See the examples section.

Examples

```
example(MultiAssayExperiment)

complete.cases(mae)

isEmpty(MultiAssayExperiment())


## renaming biological units (primary)

mae2 <- renamePrimary(mae, paste0("pt", 1:4))
colData(mae2)
sampleMap(mae2)


## renaming observational units (colname)

mae2 <- renameColname(mae, i = "Affy", paste0("ARRAY", 1:4))
```

```
colnames(mae2)
sampleMap(mae2)


patts <- list(
    normals = "TCGA-OR-[A-Z0-9]{4}-11",
    tumors = "TCGA-OR-[A-Z0-9]{4}-01"
)

data("miniACC")

hits <- makeHitList(miniACC, patts)

splitAssays(miniACC, hits)
```

MultiAssayExperiment-methods
Accessing and modifying information in MultiAssayExperiment

Description

A set of accessor and setter generic functions to extract either the sampleMap, the [ExperimentList](), colData, or metadata slots of a [MultiAssayExperiment]() object

Usage

```
## S4 method for signature 'MultiAssayExperiment'
sampleMap(x)

## S4 method for signature 'MultiAssayExperiment'
experiments(x)

## S4 method for signature 'MultiAssayExperiment'
colData(x, ...)

## S4 method for signature 'MultiAssayExperiment'
metadata(x)

## S4 replacement method for signature 'MultiAssayExperiment,DataFrame'
sampleMap(object) <- value

## S4 replacement method for signature 'MultiAssayExperiment,ANY'
sampleMap(object) <- value

## S4 replacement method for signature 'MultiAssayExperiment,ExperimentList'
experiments(object) <- value
```

```
## S4 replacement method for signature 'MultiAssayExperiment,List'
experiments(object) <- value

## S4 replacement method for signature 'MultiAssayExperiment,DataFrame'
colData(x) <- value

## S4 replacement method for signature 'MultiAssayExperiment,ANY'
colData(x) <- value

## S4 replacement method for signature 'MultiAssayExperiment'
metadata(x, ...) <- value

## S4 replacement method for signature 'MultiAssayExperiment'
x$name <- value

## S4 replacement method for signature 'MultiAssayExperiment'
names(x) <- value

## S4 replacement method for signature 'MultiAssayExperiment,List'
colnames(x) <- value

## S4 replacement method for signature 'MultiAssayExperiment,list'
colnames(x) <- value

## S4 method for signature 'MultiAssayExperiment'
x$name
```

Arguments

...	Argument not in use
object, x	A `MultiAssayExperiment` object
value	See details.
name	A column in `colData`

Value

Accessors: Either a `sampleMap`, `ExperimentList`, or `DataFrame` object

Setters: A `MultiAssayExperiment` object

Accessors

Eponymous names for accessing MultiAssayExperiment slots with the exception of the [ExperimentList](#) accessor named experiments.

- colData: Access the `colData` slot
- sampleMap: Access the `sampleMap` slot
- experiments: Access the [ExperimentList](#) slot

- '[[': Access the [ExperimentList](#) slot
- '$': Access a column in `colData`

Setters

Setter method values (i.e., `'function(x) <- value'`):

- experiments<-: An [`ExperimentList`](#) object containing experiment data of supported classes
- sampleMap<-: A [`DataFrame`](#) object relating samples to biological units and assays
- colData<-: A [`DataFrame`](#) object describing the biological units
- metadata<-: A `list` object of metadata
- '[[<-': Equivalent to the `experiments<-` setter method for convenience
- '$<-': A vector to replace the indicated column in `colData`

Examples

```
## Load example MultiAssayExperiment
example(MultiAssayExperiment)

## Access the sampleMap
sampleMap(mae)

## Replacement method for a MultiAssayExperiment sampleMap
sampleMap(mae) <- S4Vectors::DataFrame()

## Access the ExperimentList
experiments(mae)

## Replace with an empty ExperimentList
experiments(mae) <- ExperimentList()

## Access the metadata
metadata(mae)

## Replace metadata with a list
metadata(mae) <- list(runDate =
    format(Sys.time(), "%B %d, %Y"))

## Access the colData
colData(mae)

## Access a column in colData
mae$age

## Replace a column in colData
mae$age <- mae$age + 1
```

MultiAssayExperimentToMAF
Convert MultiAssayExperiment to MAF class

Description

Take a `MultiAssayExperiment` object with specific mutation assays and convert these into a `maftools` representation. The names provided via `synAssay` and `nonSynAssay` must match exactly those assays in the `MultiAssayExperiment`.

Usage

```
MultiAssayExperimentToMAF(x, synAssay = "maf_syn", nonSynAssay = "maf_nonSyn")
```

Arguments

x	A `MultiAssayExperiment` object
synAssay	character(1) The name of the `ExperimentList` element in the `MultiAssayExperiment` that identifies synonymous variant classifications.
nonSynAssay	character(1) The name of the `ExperimentList` element in the `MultiAssayExperiment` that identifies non-synonymous variant classifications.

---

prepMultiAssay *Prepare a* MultiAssayExperiment *instance*

Description

The purpose of this helper function is to faciltate the creation of a MultiAssayExperiment object by detecting any inconsistencies with all types of names in either the ExperimentList, the `colData`, or sampleMap.

Usage

```
prepMultiAssay(ExperimentList, colData, sampleMap, ...)
```

Arguments

ExperimentList	A `list` of all combined experiments
colData	A DataFrame of the phenotype data for all participants
sampleMap	A DataFrame of sample identifiers, assay samples, and assay names
...	Optional arguments for the `MultiAssayExperiment` constructor function such as `metadata` and `drops`.

Value

A list containing all the essential components of a MultiAssayExperiment as well as a "drops" metadata element that indicates non-matched names. The names of the resulting list correspond to the arguments of the MultiAssayExperiment constructor function.

Checks

The prepMultiAssay function checks that all columns in the sampleMap are character.

It checks that all names and lengths match in both the ExperimentList and in the unique assay names of the sampleMap.

If ExperimentList names and assay names only differ by case and are not duplicated, the function will standardize all names to lowercase.

If names cannot be matched between the colname column of the sampleMap and the colnames of the ExperimentList, those unmatched will be dropped and found in the "drops" element of the resulting list.

Names in the "primary" column of the sampleMap, will be matched to those in the colData. Unmatched "primary" column rows will be dropped from the sampleMap. Suggestions for name fixes in either the ExperimentList or colnames will be made when necessary.

Examples

```
## Run example
example("MultiAssayExperiment")

## Check if there are any inconsistencies within the different names
preparedMAE <- prepMultiAssay(ExpList, colDat, sampMap)

## Results in a list of components for the MultiAssayExperiment constructor
## function
MultiAssayExperiment(preparedMAE$experiments, preparedMAE$colData,
preparedMAE$sampleMap)

## Alternatively, use the do.call function
do.call(MultiAssayExperiment, preparedMAE)
```

---

reexports   *Objects exported from other packages*

Description

These objects are imported from other packages. Click on the function name to see their documentation.

- S4Vectors: DataFrame

Examples

```
DataFrame()
```

---

saveHDF5MultiAssayExperiment

Save a MultiAssayExperiment class object to HDF5 and Rds files

---

Description

This function takes a MultiAssayExperiment object and uses the assays functionality to obtain data matrices out of the experiments. These are then saved into the .h5 file format. This function relies heavily on the HDF5Array package whose installation is required before use. saveHDF5MultiAssayExpeirment preserves the classes contained in the [ExperimentList](#) with the exception of matrix which is converted to HDF5Matrix. Internal SummarizedExperiment assays are converted to HDF5-backed assays as in HDF5Array::saveHDF5SummarizedExperiment. SummarizedExperiment objects with multiple i-th assays will have the first assay take precedence and others assays will be dropped with a warning. If the first assay in a SummarizedExperiment contains an array, the array is preserved in the process of saving and loading the HDF5-backed MultiAssayExperiment.

Usage

```
saveHDF5MultiAssayExperiment(
  x,
  dir = "h5_mae",
  prefix = NULL,
  replace = FALSE,
  chunkdim = NULL,
  level = NULL,
  as.sparse = NA,
  verbose = NA
)

loadHDF5MultiAssayExperiment(dir = "h5_mae", prefix = NULL)
```

Arguments

x	A [MultiAssayExperiment](#) object or derivative
dir	The path (as a single string) to the directory where to save the HDF5-based [MultiAssayExperiment](#) object or to load it from.
	When saving, the directory will be created if it doesn't already exist. If the directory already exists and no prefix is specified and replace is set to TRUE, then it's replaced with an empty directory.
prefix	An optional prefix to add to the names of the files created inside dir. This allows saving more than one object in the same directory. When the prefix is NULL, the name of the x input MultiAssayExperiment is used. To avoid the default

setting use an empty character string i.e., `""`. An underscore (`_`) is appended to the prefix when provided; therefore, typical inputs should be words, e.g., "test".

replace   When no prefix is specified, should a pre-existing directory be replaced with a new empty one? The content of the pre-existing directory will be lost!

chunkdim, level

The dimensions of the chunks and the compression level to use for writing the assay data to disk.

Passed to the internal calls to `writeHDF5Array`. See `?writeHDF5Array` for more information.

as.sparse   Whether the assay data should be flagged as sparse or not. If set to NA (the default), then the specific as.sparse value to use for each assay is determined by calling is_sparse() on them.

Passed to the internal calls to `writeHDF5Array`. See `?writeHDF5Array` for more information and an IMPORTANT NOTE.

verbose   Set to `TRUE` to make the function display progress.

In the case of `saveHDF5MultiAssayExperiment()`, verbose is set to NA by default, in which case verbosity is controlled by DelayedArray.verbose.block.processing option. Setting verbose to `TRUE` or `FALSE` overrides the option.

Examples

```
data("miniACC")

testDir <- file.path(tempdir(), "test_mae")

saveHDF5MultiAssayExperiment(
    miniACC, dir = testDir, verbose = TRUE, replace = TRUE
)

## inspect the files in the dir
list.files(testDir)

loadHDF5MultiAssayExperiment(
    dir = testDir
)

## remove example files
unlink(testDir, recursive = TRUE)
```

---

subsetBy   *Subsetting a MultiAssayExperiment object*

Description

A set of functions for extracting and dividing a `MultiAssayExperiment`

Usage

```
subsetByRow(x, y, ...)

subsetByColData(x, y)

subsetByColumn(x, y)

subsetByAssay(x, y)

## S4 method for signature 'ExperimentList,ANY'
subsetByRow(x, y, ...)

## S4 method for signature 'ExperimentList,list'
subsetByRow(x, y)

## S4 method for signature 'ExperimentList,List'
subsetByRow(x, y)

## S4 method for signature 'ExperimentList,logical'
subsetByRow(x, y)

## S4 method for signature 'ExperimentList,list'
subsetByColumn(x, y)

## S4 method for signature 'ExperimentList,List'
subsetByColumn(x, y)

## S4 method for signature 'ExperimentList,logical'
subsetByColumn(x, y)

## S4 method for signature 'ExperimentList'
subsetByAssay(x, y)

## S4 method for signature 'MultiAssayExperiment,ANY'
subsetByColData(x, y)

## S4 method for signature 'MultiAssayExperiment,character'
subsetByColData(x, y)

## S4 method for signature 'MultiAssayExperiment,ANY'
subsetByRow(x, y, ...)

## S4 method for signature 'MultiAssayExperiment,ANY'
subsetByColumn(x, y)

## S4 method for signature 'MultiAssayExperiment'
subsetByAssay(x, y)
```

```
## S4 method for signature 'MultiAssayExperiment,ANY,ANY,ANY'
x[i, j, k, ..., drop = FALSE]

## S4 method for signature 'MultiAssayExperiment,ANY,ANY'
x[[i, j, ...]]

## S4 replacement method for signature 'MultiAssayExperiment,ANY,ANY'
x[[i, j, ...]] <- value

## S4 replacement method for signature 'MultiAssayExperiment,ANY,ANY,ANY'
x[i, j, ...] <- value
```

Arguments

x	A `MultiAssayExperiment` or `ExperimentList`
y	Any argument used for subsetting, can be a `character`, `logical`, `integer`, `list` or `List` vector
...	Additional arguments passed on to lower level functions.
i	Either a `character`, `integer`, `logical` or `GRanges` object for subsetting by rows
j	Either a `character`, `logical`, or `numeric` vector for subsetting by `colData` rows. See details for more information.
k	Either a `character`, `logical`, or `numeric` vector for subsetting by assays
drop	logical (default FALSE) whether to drop all empty assay elements in the `ExperimentList`
value	An assay compatible with the MultiAssayExperiment API

Details

Subsetting a MultiAssayExperiment by the **j** index can yield a call to either `subsetByColData` or `subsetByColumn`. For vector inputs, the subset will be applied to the `colData` rows. For `List`-type inputs, the List will be applied to each of the elements in the `ExperimentList`. The order of the subsetting elements in the `List` must match that of the `ExperimentList` in the `MultiAssayExperiment`.

- subsetBycolData: Select biological units by vector input types
- subsetByColumn: Select observations by assay or for each assay
- subsetByRow: Select rows by assay or for each assay
- subsetByAssay: Select experiments

Value

`subsetBy*` operations are endomorphic and return either `MultiAssayExperiment` or `ExperimentList` depending on the input.

Examples

```
## Load the example MultiAssayExperiment
example("MultiAssayExperiment")

## Using experiment names
subsetByAssay(mae, "Affy")

## Using numeric indices
subsetByAssay(mae, 1:2)

## Using a logical vector
subsetByAssay(mae, c(TRUE, FALSE, TRUE))

## Subset by character vector (Jack)
subsetByColData(mae, "Jack")

## Subset by numeric index of colData rows (Jack and Bob)
subsetByColData(mae, c(1, 3))

## Subset by logical indicator of colData rows (Jack and Jill)
subsetByColData(mae, c(TRUE, TRUE, FALSE, FALSE))

subsetByColumn(mae, list(Affy = 1:2,
    Methyl450k = c(3,5,2), RNASeqGene = 2:4, GISTIC = 1))

subsetWith <- S4Vectors::mendoapply(`[`, colnames(mae),
    MoreArgs = list(1:2))
subsetByColumn(mae, subsetWith)

## Use a GRanges object to subset rows where ranged data present
egr <- GenomicRanges::GRanges(seqnames = "chr2",
    IRanges::IRanges(start = 11, end = 13), strand = "-")
subsetByRow(mae, egr)

## Use a logical vector (recycling used)
subsetByRow(mae, c(TRUE, FALSE))

## Use a character vector
subsetByRow(mae, "ENST00000355076")
```

---

upsetSamples	*Create a generalized Venn Diagram analog for sample membership in multiple assays, using the upset algorithm in* UpSetR

Description

Create a generalized Venn Diagram analog for sample membership in multiple assays, using the upset algorithm in UpSetR

Usage

```
upsetSamples(
  MultiAssayExperiment,
  nsets = NULL,
  sets = names(MultiAssayExperiment),
  nintersects = NA_integer_,
  order.by = "freq",
  check.names = FALSE,
  ...
)
```

Arguments

MultiAssayExperiment

                A `MultiAssayExperiment` object

nsets	numeric(1) The number of sets to analyze. If specified, `sets` will be ignored.
sets	character() A character vector of names in MultiAssayExperiment to use. If specified, `nsets` will be ignored.
nintersects	numeric() The number of intersections to plot. By default, all intersections will be plotted.
order.by	How the intersections in the matrix should be ordered by. Options include frequency (entered as "freq"), degree, or both in any order.
check.names	logical(1) Whether to munge names as in the `data.frame()` constructor (default FALSE).
...	parameters passed to upset

Value

Produces a visualization of set intersections using the UpSet matrix design

Note

This function is intended to provide convenient visualization of assay availability configurations in MultiAssayExperiment instances. The `UpSetR::upset` function requires `data.frame` input and has many parameters to tune appearance of the result. Assay name handling is important for interpretability.

Author(s)

Vincent J Carey

Examples

```
data(miniACC)
upsetSamples(miniACC)
upsetSamples(miniACC, nsets = 3, nintersects = 3)
```

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